

Redefining hygiene in practice: addressing emerging health risks in home microecologies

Rachael Wakefield-Rann

Institute for Sustainable Futures

University of Technology Sydney

Thesis Submitted for the Doctor of Philosophy in Sustainable Futures

2019

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Rachael Wakefield-Rann declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy in Sustainable Futures, in the Institute for Sustainable Futures at the University of Technology Sydney. This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

Signature: Production Note:
Signature removed
prior to publication.

Date: 11.4.2019

ACKNOWLEDGEMENTS

First, and most importantly, I would like to thank my two supervisors, Associate Professor Dena Fam and Dr Susan Stewart, for being such dedicated and supportive mentors throughout this project. In particular, I want to thank Dena for helping me find opportunities to connect my research with the world beyond academia, and for guidance through the messiness of transdisciplinary research. Susan, I would especially like to thank for never letting me leave a logical flaw uninterrogated, and a willingness to sit with me for hours to meticulously disentangle theoretical nuances. In addition to their insights, careful challenges, time and patience, Dena and Susan both role model thoughtful and practical scholars who care deeply about creating a better world.

I wholeheartedly thank my research participants for warmly welcoming me into their homes with cups of tea and tours of the most intimate and mundane details of their domestic lives. This research would not have been possible without their willingness, time, generosity and candidness. I hope that the outcomes of my research may someday feed back and help to ease the complex and often stressful dynamics involved in negotiating environmental health risks in the home.

Thank you to those who have reviewed my work and provided valuable feedback at crucial junctures, particularly Associate Professor Yolande Strengers, Dr Abby Mellick Lopes and Dr Irena Connon. I have also been lucky enough to have the articles in this thesis peer-reviewed by a number of generous and attentive scholars. The constructive feedback I received from these individuals challenged and transformed my thinking and greatly expanded the scope of ideas I engaged with.

A massive thank you to Dr Rob Dyball, Editor of the *Human Ecology Review*, for giving me the opportunity to very indulgently put together a special issue of the journal based around issues that emerged while researching this thesis. This special issue helped facilitate a

stimulating and generative conversation across disciplinary boundaries that greatly contributed to my thinking.

There are also a number of people involved in university administration who have gone beyond what is required. I would first like to acknowledge the stellar HDR program at the Institute for Sustainable Futures, run by Professor Chris Riedy and Professor Jason Prior, and my fellow HDR students. The retreats, dinners, learning modules and GAS groups all provided essential spaces for sharing, learning, empathising and having fun. The support of Suzanne Cronan within this program, and all the staff at the Graduate Research School and UTS Library, have also been extremely valuable. Thank you also to John Revington who provided copy-editing services for the final draft of this thesis.

I also received essential professional and financial support for this project. At both the Institute for Sustainable Futures and the Northern Beaches Council I benefited from understanding and encouraging work environments—I am especially grateful to Natasha Schultz, Henry Wong, Steve Clements, and the team in ‘Alcatraz’ in the case of the latter. Also, importantly, I thank the Australian Government Research Training Program for their scholarship.

I am fortunate to have many smart and supportive friends, who always know what to ask (and what not to) and when a yoga retreat is required. Special thanks to Alice Rumble and Tamryn Liddell, and Federico Davila for their many offers to read and talk through the always-exhilarating topic of hygiene practices.

Finally, thank you to my family for your constant support, interest and perspective. There is no better occasion than a family BBQ for a PhD candidate to test if they can explain what they are doing and why they are bothering. In particular, Tom Lee, I’m very fortuitous to have a partner that can offer support in the form of an in-depth writing critique, a sparring session, or handmade pasta, depending on the demands of the day. And mum, Corrine Stevens, who in

addition to constant and unconditional encouragement, provided invaluable copy-editing of the final manuscript.

In the spirit of this more-than-human research, I feel like I should acknowledge a number of the important non-humans that have contributed immeasurably to my journey over the past three and a half years, so a special shout out to the Bronte Bogey Hole, my boxing gloves, Pana chocolate, my potted veggie garden and my bath.

In line with the Institute for Sustainable Futures guidelines, this thesis is a Thesis by Compilation, comprised of both traditional chapters and published journal articles. A list of the articles included in this thesis are included below, followed by a list of other relevant journal publications, reports and conference presentations, and public media.

PUBLICATIONS INCLUDED IN THESIS BY COMPILATION

1. Wakefield-Rann, R., Fam, D., & Stewart, S. (2018). Routine exposure: social practices and environmental health risks in the home. *Social Theory & Health*, 1-18.
2. Wakefield-Rann, R., Fam, D., & Stewart, S. (in press) Microbes, chemicals and the health of homes: integrating theories to account for more-than-human entanglements, *BioSocieties*
3. Wakefield-Rann, R., Fam, D., & Stewart, S. (2018). "It's Just a Never-Ending Battle": The Role of Modern Hygiene Ideals and the Dynamics of Everyday Life in Constructing Indoor Ecologies. *Human Ecology Review*, 24(2), 61.
4. Wakefield-Rann, R. (2017). More Than Skin Deep: A Service Design Approach to Making the Luxury Personal Care Industry More Sustainable. In *Sustainable Management of Luxury* (pp. 211-231). Springer, Singapore.
5. Wakefield-Rann, R., Fam, D., & Stewart, S. (2018). "Initiating a Transdisciplinary Conversation to Improve Indoor Ecologies. *Human Ecology Review*, 24(2), 61.

OTHER RELEVANT PUBLICATIONS

Lee, T., & Wakefield-Rann, R. (2018). Design Philosophy and Poetic Thinking: Peter Sloterdijk's Metaphorical Explorations of the Interior. *Human Ecology Review*, 24(2), 153.

RELEVANT INDUSTRY REPORTS

Report: Mellick Lopes, A., Sofoulis, Z., **Wakefield-Rann, R.**, & Yu, Y. (2017). 'Exploring the Practices of Mandarin-speaking Water Drinkers: Research Conducted as Part of the Collaborative Research Project Understanding the Drivers of Public Trust in Sydney Water.'

Report: Dubash, J., **Wakefield-Rann, R.**, Prentice, E., Giurco, D., and Latimer, G. (2018): Chemical Management for Consumer Products – Company Evaluations for Stewart Investors. Institute for Sustainable Futures, UTS (publication awaiting outcome of final negotiations with companies assessed).

RELEVANT ONLINE PUBLICATIONS

Wakefield-Rann, R. (2018) 'Chemical Showers: How Daily Routines Structure Our Exposures to Toxicants.' *Toxic Bodies series*. Engagement: blog of the Anthropology and Environment Society, A Section of the American Anthropological Association:
<https://aesengagement.wordpress.com/2017/11/21/chemical-showers-how-daily-routines-structure-our-exposures-to-toxicants/>

RELEVANT MEDIA INTERVIEWS

TELEVISION

Television interview for The Project New Zealand, focused on chemicals in consumer products in the home, particularly toys, aired on 12/10/2018

PRINT MEDIA

Interviewed for story on the health and environmental sustainability challenges personal care companies are facing when designing their products. By Alejandra Borunda for National Geographic (awaiting publication).

'How environmentally friendly are 'eco' bath and cleaning products?' By [Jo Khan](#) for ABC Science: <https://www.abc.net.au/news/science/2018-08-08/how-environmentally-friendly-are-eco-household-products/10017734> 8/8/2018

'Smiggle, Kmart refuse to pull 'harmful' squishies toys from shelves despite cancer risk' By [Alana Mitchelson](#) for The New Daily:
<https://thenewdaily.com.au/money/consumer/2018/09/03/squishies-smiggle-kmart/> 3/9/2018

DECLARATION BY CO-AUTHORS

In the case of Paper 1, the undersigned agree that the nature and extent of the contributions to the work was as follows:

Co-author	Nature of contribution	Extent of contribution (%)	Signature	Date
Rachael Wakefield-Rann	Lead researcher and author	90	Production Note: Signature removed prior to publication.	11.4.19
Dena Fam	Reviewer	5	Production Note: Signature removed prior to publication.	11.4.19
Susan Stewart	Reviewer	5	Production Note: Signature removed prior to publication.	11.4.19

In the case of Paper 2, the undersigned agree that the nature and extent of the contributions to the work was as follows:

Co-author	Nature of contribution	Extent of contribution (%)	Signature	Date
Rachael Wakefield-Rann	Lead researcher and author	90	Production Note: Signature removed prior to publication.	11.4.19
Dena Fam	Reviewer	5	Production Note: Signature removed prior to publication.	11.4.19
Susan Stewart	Reviewer	5	Production Note: Signature removed prior to publication.	11.4.19

In the case of Paper 3, the undersigned agree that the nature and extent of the contributions to the work was as follows:

Co-author	Nature of contribution	Extent of contribution (%)	Signature	Date
Rachael Wakefield-Rann	Lead researcher and author	90	Production Note: Signature removed prior to publication.	11.4.19
Dena Fam	Reviewer	5	Production Note: Signature removed prior to publication.	11.4.19

Susan Stewart	Reviewer	5	Production Note: Signature removed prior to publication.	11.4.19
----------------------	----------	----------	--	----------------

In the case of Paper 5, the undersigned agree that the nature and extent of the contributions to the work was as follows:

Co-author	Nature of contribution	Extent of contribution (%)	Signature	Date
Rachael Wakefield-Rann	Lead researcher and author	93	Production Note: Signature removed prior to publication.	11.4.19
Dena Fam	Reviewer	7	Production Note: Signature removed prior to publication.	11.4.19

PREFACE

This thesis is written through a commitment to social and environmental justice and change. At the heart of my doctoral (and preceding) research has been a drive to understand the ways that the socio-material arrangements of everyday life produce different patterns of resource consumption and disposal, and their consequent social and ecological impacts. During my Honours research – examining how different epistemological approaches across the social sciences often lead to radically different propositions for interventions to address the problem of unsustainable clothing consumption rates—I became interested in Social Practice Theories and their capacity to shed light on ‘inconspicuous consumption’: the invisible acts of consumption embedded in everyday practices, associated with issues of infrastructure, interdependence and normal standards (Shove and Warde, 2002a).

My interest in inconspicuous consumption grew through my work outside of academia working in and with the waste industry, as a researcher, community educator, local government officer (devising waste policy and programs), and as a charity ‘food rescue’ driver. Throughout this period, I became increasingly interested in how communities are made responsible for making changes that are not well enabled, if at all, by the socio-material

conditions in which they are operating. The importance of how responsibility becomes individualised in the context of systems that deliberately work to make certain entities imperceptible, became a central concern for me. Paradoxically, it seemed, a successful waste management system is defined by the extent to which it is invisible to those using it, yet a successful citizen-consumer operating within this system is expected to maintain an active awareness of all the downstream impacts of their consumption choices as they are making them.

It is via this experiential and theoretical grounding that the trajectory of this doctoral thesis was formed. In particular, I perceived a need to further explore the ways that certain agents that are crucial to human and broader planetary health are made imperceptible by socio-material systems. On this basis, I originally proposed to conduct my doctoral research on the issue of plastic waste associated with the global food system. I also initially began this research in a School of Design. Although my background is broadly in Political Science, Geography and Human Ecology (BA/BSc), I chose design for two primary reasons. First, design plays a crucial role in populating the world with services and materials, which play a significant role in how resources are used and what practices are made possible. The second follows Latour's observation that the meaning of design has grown in comprehension and extension. To consider something in terms of design is to acknowledge that particular values and skills and technologies have gone into its creation, "The more objects are turned into things – that is, the more matters of facts[sic] are turned into matters of concern – the more they are rendered into objects of design through and through." (Latour, 2008: 2)

As I delved deeper into this subject, I became aware of a micro-scale of activity and interaction that is transforming ecosystems and bodies in unprecedented ways that belie extant definitions of toxicity and harm. The post-industrial chemicals that have come to populate the everyday lives of all living things, at pace since World War II, are participating in and transforming bodies in unprecedented ways: yet they have not been made broadly perceptible by our socio-material conditions. Simultaneously, I noticed parallels with the

ways that invisible microorganisms have been made perceptible via socio-material conditions that make certain types of pathogenic relations visible, while obscuring essential mutualistic relations between human, microbial and ecological systems. While these remain matters deeply embedded within an expanded conception of design, other epistemological traditions have also been crucial in determining the objects and boundaries of concern that have made some entities, risks and forms of relationality more perceptible than others.

My project was consequently reformulated to examine (in the broadest sense) how contending 'regimes of perceptibility' (Murphy, 2006) shape everyday socio-material conditions that come to shape human bodies, and the more-than-human ecologies we are embedded within. Specifically, I am interested in the socio-material dynamics that constitute indoor ecologies; the environments where most humans in industrialised nations now spend the majority of their lives. Questions of relations at the molecular scale go beyond what is required to adequately understand contemporary risks to human health. They reach back to broader questions of what we believe our world is made of and how our bodies relate to and are mutually constituted by the broader more-than-human ecologies we are part of.

The questions inherent to this project exceed and problematise the boundaries and domains of concern that demarcate traditional disciplinary boundaries. As a result, in the second year of my research I decided to move from the School of Design to the Institute for Sustainable Futures; an institute that specialises in transdisciplinary approaches to addressing complex socio-ecological issues. This thesis does not comfortably conform to the conventions of any single discipline but amalgamates conventions based on the different values they bring to the exploration of this complex cross-disciplinary topic. Moreover, in recognition of the need to make explicit and begin to bridge divergent disciplinary approaches, I also made the unconventional decision to consider the publications included in this thesis as an opportunity to target and connect different disciplinary audiences. Finding new ways to connect diverse knowledge traditions and approaches will continue to be my objective, building on the outcomes of this research into the future.

TABLE OF CONTENTS

TABLE OF CONTENTS.....	XI
FIGURES AND TABLES.....	XIII
GLOSSARY AND ABBREVIATIONS	XIII
ABSTRACT	XVI
1 INTRODUCTION	16
1.1 AN EMERGING INDOOR ECOLOGY.....	16
1.2 INDOOR MICROECOLOGIES AS A WICKED PROBLEM	19
1.3 RESEARCH FOCUS: HOME ECOLOGIES ANDHYGIENE PRACTICES	22
1.4 RESEARCH PURPOSE	25
1.5 RESEARCH QUESTIONS.....	28
1.6 RESEARCH SCOPE AND BOUNDARY CRITIQUE	29
1.7 THESIS OVERVIEW.....	39
2 HISTORICAL COEVOLUTION: HYGIENE AND INDOOR ECOLOGIES	47
2.1 CHANGING INDOOR ECOLOGIES AND MODERN HYGIENE	48
2.2 MICROBIAL ECOLOGIES AND HEALTH	50
2.3 CHEMICAL RISKS IN THE HOME.....	55
2.4 THE EVOLUTION OF HYGIENIC HOMES AND BODIES.....	59
2.5 HYGIENE AS A QUESTION OF BOUNDARIES	65
2.6 MICROBES BREACHING BOUNDARIES.....	65
2.7 TOXICANTS CHALLENGING BOUNDARIES.....	70
2.8 CONCLUSIONS.....	73
3 LITERATURE REVIEW: ACCOUNTING FOR EPISTEMIC DIVERSITY IN INDOOR ENVIRONMENTAL HEALTH RESEARCH	75
3.1 MICROBIOLOGY OF THE BUILT ENVIRONMENT	77
3.2 EXPOSURE SCIENCE.....	82
3.3 A SOCIAL SCIENTIFIC LENS ON EXPOSURE RESEARCH	87
3.4 SOCIAL PRACTICE RESEARCH IN DOMESTIC SUSTAINABILITY	90
3.5 MULTISPECIES ETHNOGRAPHY AND CHEMO-ETHNOGRAPHY.....	94
3.6 CONCLUSIONS.....	96
4 THEORETICAL FRAMEWORK: THEORISING MULTISPECIES INTERACTIONS WITHIN SOCIAL PRACTICES	99
4.1 THEORIES FOR MORE-THAN-HUMAN PRACTICES	99
4.2 SOCIAL PRACTICE THEORIES.....	102
4.3 MULTISPECIES ETHNOGRAPHY AND CHEMO-ETHNOGRAPHY.....	111
4.4 IMPLICATIONS FOR METHODOLOGY.....	115
4.5 CONCLUSIONS.....	117
5 METHODOLOGY: INVESTIGATING MORE-THAN-HUMAN HYGIENE PRACTICES.....	119
5.1 RESEARCH APPROACH	119
5.2 RESEARCH DESIGN	120
5.3 METHODS	121
5.4 DATA ANALYSIS.....	137
5.5 REFLECTION ON METHODOLOGICAL APPROACH.....	141
INTRODUCTION TO PAPERS	144
PAPER 1: ROUTINE EXPOSURE: SOCIAL PRACTICES AND ENVIRONMENTAL HEALTH.....	147
PAPER 2: MICROBES, CHEMICALS AND THE HEALTH OF HOMES: INTEGRATING THEORIES TO ACCOUNT FOR MORE-THAN-HUMAN ENTANGLEMENTS	177

PAPER 3: ‘IT’S JUST A NEVER-ENDING BATTLE’: THE ROLE OF MODERN HYGIENE IDEALS AND THE DYNAMICS OF EVERYDAY LIFE IN CONSTRUCTING INDOOR ECOLOGIES	217
PAPER 4: MORE THAN SKIN DEEP: A SERVICE DESIGN APPROACH TO CREATING MORE SUSTAINABLE PERSONAL CARE.....	245
6 TOWARDS HEALTHIER HOME ECOLOGIES: CONCLUSIONS AND FUTURE DIRECTIONS	280
6.1 KEY CONCLUSIONS.....	281
6.2 RECOMMENDATIONS	289
PAPER 5: INITIATING A TRANSDISCIPLINARY CONVERSATION TO IMPROVE INDOOR ECOLOGIES (EDITORIAL)	292
REFERENCES	334
APPENDIX A: PARTICIPANT INFORMATION SHEET.....	356
APPENDIX B: PARTICIPANT CONSENT FORM	358
APPENDIX C: RECRUITMENT FLYER.....	359
APPENDIX D: ACTIVITY DIARIES	360
APPENDIX E: DISAGGREGATED NVIVO CODES IN ALPHABETICAL ORDER.....	362

FIGURES AND TABLES

Figure 1: Greater Sydney	28
Figure 2: Boundaries of the research scope	32
Figure 3: ‘Hunting Microbes’ from Jean Marc Cote’s series (circa 1900)	49
Figure 4: 1968 Ad for Lysol Spray Disinfectant	60
Figure 5: Images of Villa Church, France (1928-1929) by Le Corbusier	61
Figure 6: Process of Endocrine Disrupting Chemical attaching	71
Figure 7: Examples of activity diary cover and ipage filled in by participant	123
Figure 8: Illustrative examples of photographs	131
Figure 9: Areas of sydney where participants reside	135
Table 1: Summary of included publications	42
Table 2: Participant characteristics	136

GLOSSARY AND ABBREVIATIONS

ABBREVIATIONS	
BPA	Bisphenol A
BPF	Bisphenol F
BPS	Bisphenol S
EDC	endocrine disrupting chemical
PFAS	Per- and poly-fluoroalkyl substances
PCP	personal care product
PVC	polyvinyl chloride

GLOSSARY	
Key Terms	Definition
cleaning practices	Cleaning practices include any act that involves the removal of unwanted substances, such as dirt, or other substances perceived to be unsafe. They also include preventative acts intended to mitigate against the development or spread of pathogens or other unwanted substances.
hygiene	Hygiene is defined in the Oxford English Dictionary (2016) as the ‘Conditions or practices conducive to maintaining health and preventing disease, especially through cleanliness’. However, a central argument and focus of this thesis is how hygiene comes to encompass different practices and entities at a given place and time based on cultural, environmental and historical contingencies. For the purposes of this thesis, hygiene and hygiene practices are consequently taken to mean the practices performed wholly, or in part, to maintain health and prevent disease in an environment. This definition encompasses practices such as cleaning a bathroom, but also aspects of meal preparation and personal care, such as bathing, which are based on certain ideas, standards and materials that guide normative conceptions of how cleanliness is supposed to be maintained. Hygiene considerations are also embedded in other practices, such as cooking, which is often accompanied by a series of actions, such as handwashing or wiping benches, that are intended explicitly or implicitly to prevent disease.
micro-species	Micro-species is a category developed for the purposes of this thesis to challenge existing species ontology and collectively theorise microorganisms and post-industrial chemicals. A complete description and justification for the use of this term is included in Paper 2.
microbiome	In the literature microbiome most commonly refers to the collective genetic material of microbiota, but has also commonly been used to refer to the ecology of the microbiota (Turnbaugh et al., 2007)
microbiota	The entire collection of microbes in a certain environment (Turnbaugh et al., 2007)
microecology	Within the field of microbiology, a microecology refers to the ecology of a micro-habitat. Microbial ecologists study the interactions of microorganisms with their environments, with each other, and with plant and animal species (O'Malley, 2016). For the purposes of this thesis, ‘microecology’ refers to both microbial and non-living entities, such as chemical pollutants, that make up a micro-habitat.

microorganism/ microbe	Microbes are single or multicellular microscopic organisms. They include viruses, bacteria, protists, archae, some fungi and algae (Crespi, 2001)
more-than-human	More-than-human refers to a mode of thinking and theorising about interactions between humans and non-humans that spans multiple disciplines, including human and cultural geography, science and technology studies (STS), environmental humanities, post-humanist sociology, anthropology and others (Maller, 2018). Although defined heterogeneously across these disciplines, more-than-human approaches generally serve to destabilise ways of theorising categories such as materiality, agency, relationality and causality. They do this by drawing focus away from the intentions and agency of humans, to examine the world through the dynamic relations that emerge through complex interactions between multiple human and non-human agents (Phillips, 2014, Whatmore, 2006). More context for these theories is provided in Chapter 4.
post-industrial chemicals	Post-industrial chemicals is a term used to refer to classes of human-synthesised chemicals that have primarily been developed and associated with industrial processes but are now used in a multitude of products and processes. These chemicals have unique properties that mean they have been designated as pollutants in most of the world's ecosystems and animal bodies. Examples of these chemical classes include highly fluorinated chemicals, antimicrobials, bisphenols and phthalates, some solvents, some metals and flame retardants (GSPI, 2016). 'Post-industrial chemicals' are also commonly referred to as anthropogenic or post-natural chemicals (Altman et al., 2008, Liboiron et al., 2018).
social practices	Drawing on social practice theories, 'social practice' is used here to refer to the repeated performance of certain groupings of the meanings, materials and bodily actions that comprise everyday life.
sub-optimal environment	A sub-optimal environment is defined here as an environment that affords sub-optimal conditions for human health based on the research cited into the types of environmental conditions that are supportive of human health. In particular, the health consequences of microbial and post-industrial chemical exposures are considered.

ABSTRACT

I argue in this thesis that dominant definitions and practices of hygiene in Australia must be updated to account for emerging indoor health risks at the micro-scale. Since World War II, new health risks have emerged in indoor environments that have both transformed and challenged notions of environmental health centred on pathogenic germs. The composition of home spaces, particularly in urban areas of developed nations, have been fundamentally altered by the introduction of post-industrial chemicals in everyday products and building materials. Further, the changing nature of building design, cleaning practices and urban life has altered the ‘microbiomes’ of homes, contributing to a rise in certain types of immune system conditions and resistance to antibiotics.

This thesis is concerned with if and how culturally contingent definitions of hygiene embedded in everyday practices contribute to these emerging health risks in the indoor ecologies of homes. This concern is based on the premise that underpinning operative definitions and practices of hygiene are particular conceptions of the human body and how it interacts with its environment.

I propose that to begin to address these health risks, the everyday practices that are based on limited notions of health and disease must be interrogated. To do this I develop and apply a qualitative research approach that integrates elements of multiple more-than-human research approaches – social practice theory, multispecies ethnography and chemo-ethnography – to investigate how microbes and post-industrial chemicals manifest physically and symbolically in everyday domestic hygiene practices. This approach informed fieldwork, conducted in Sydney, Australia, which examined the home hygiene practices of parents with children under five years old.

Findings from this research highlight some of the ways that chemicals and microbes are assumed to operate in everyday domestic practices. They also provide important insights into

the dynamics of everyday life that influence how hygiene is performed in the home and what risks may consequently manifest. In addition to providing insights into the dynamics of practice that may be contributing to maladaptive indoor home ecologies, this research also points to an urgent need for greater knowledge integration across disciplines concerned with different social and material aspects of indoor environmental health

1 INTRODUCTION

If we can abstract pathogenicity and hygiene from our notion of dirt, we are left with the old definition of dirt as matter out of place. This is a very suggestive approach. It implies two conditions: a set of ordered relations and a contravention of that order. Dirt then, is never a unique, isolated event. Where there is dirt there is a system. Dirt is the by-product of a systematic ordering and classification of matter, in so far as ordering involves rejecting inappropriate elements – Mary Douglas (1966: 35).

Human nature is an interspecies relationship – Anna Tsing (2012: 144).

1.1 AN EMERGING INDOOR ECOLOGY

Indoor environments represent the fastest growing biome¹ on earth. Residential and commercial buildings around the world are currently estimated to make up to 6% of global ice-free land area (Hooke et al., 2012). Moreover, while other biomes, such as grasslands and tropical coniferous forests, are shrinking, the indoor biome is expanding rapidly. Despite the burgeoning of new indoor habitats, relatively little is known about how conditions within indoor environments affect their primary occupants: humans and microorganisms (Dunn et al., 2013). This is concerning for at least four reasons. First, it is

¹ Biomes are distinct biological communities that have formed in response to a shared physical climate (National Geographic 2019).

often cited that members of wealthy industrialised nations spend up to 90% of their time indoors (National Academies of Sciences Engineering & Medicine, 2017). Second, increasingly since the 1950s, a range of post-industrial chemicals that interact with and cause harm to bodies in new ways have proliferated in the structures and products that make up indoor environments (Weschler, 2009). Third, the types of microbial communities that have been found to thrive in urban indoor environments lack components that are thought to be essential to human development. Fourth, estimates suggest that up to 70–90% of disease risk can be accounted for by environmental rather than genetic factors (Rappaport and Smith, 2010). Given these issues, this thesis is concerned with the set of risks to human health associated with indoor environments and their microscopic inhabitants.

More specifically, I focus here on interactive communities of microorganisms and post-industrial chemical classes that have proliferated in human-occupied indoor spaces in many wealthy industrialised regions in the post-World War II period (Weschler, 2009). The types of microbial communities found in indoor spaces in urbanised areas have been increasingly associated with a rapid rise in atopic (allergic) diseases, such as asthma, eczema, food intolerance, allergic rhinitis and other allergies, in addition to other conditions associated with how and when the immune system is activated in certain ways in childhood, such as leukemia (Greaves, 2018, Rook and Knight, 2015). The post-World War II chemical ‘boom’ saw particular classes of chemicals transition from industrial applications, to become central to the functionality of many products that now populate our daily lives (Weschler, 2009, Altman et al., 2008, MacKendrick, 2018). Many of these chemicals are known or suspected to be mutagenic, carcinogenic, neurotoxic and endocrine (hormone) disrupting (MacKendrick, 2018, Diamanti-Kandarakis et al., 2009). These chemicals, as explained in greater detail in later chapters, do not resemble any substances that we have cohabited with at any other point in history. Unlike poisons found more commonly in earlier indoor spaces, such as lead and arsenic, many of these post-

industrial chemicals have been found to ‘participate’ in human and other animal bodies in ways that are challenging traditional understandings of toxicity, dosage limits, and timescales of harm (Liboiron, 2015). Perhaps most importantly, the ways that these microbial and chemical entities, currently proliferating in indoor environments, act and cause harm are highly contingent. Rather than affecting bodies in consistent, predictable and linear ways, these micro-entities have different impacts depending on numerous factors such as how they interact in the environment and in the body, for how long, and the age of bodies exposed. These modes of interaction are challenging not only traditional conceptions of environmental health and hygiene that focus on the extermination of pathogenic ‘germs’, but also broader understandings of how human bodies relate to their environments and the relevance of assumed categories, such as species (Zoeller et al., 2012).

Late industrial indoor material ecologies have emerged due to a range of interconnected structural, technical, political and cultural influences – such as religion, ethnicity and cultural and intellectual zeitgeists – that have shaped how health risks are perceived, prioritised and mitigated in urban planning, building construction, and toxic substance regulation and control (Murphy, 2006, Shapiro and Kirksey, 2017). In addition to these influences on the materiality of buildings and urban areas, the everyday activities that make up collective everyday life significantly influence material flows within and through buildings. Normative ways of cooking, cleaning, working, and having fun all require specific artefacts and infrastructures with particular material affordances. These practices shape not only the types of materials that are brought indoors and used, but also our expectations and requirements of indoor spaces that ultimately shape how they are built.

1.2 INDOOR MICROECOLOGIES AS A WICKED PROBLEM

In writing about the intractable problems associated with urban planning in 1973, Rittel and Webber introduce the concept of ‘wicked’ problems: complex socio-environmental problems that cannot be solved through existing modes of inquiry and decision-making (Rittel and Webber, 1973). Wicked problems are characterised by their inability to be wholly defined and ‘solved’, and their resistance to all predictable attempts to address them. Because wicked problems are generated by the specific conditions of the society that generates them, a resolution must involve changes in that society itself, such as different forms of governance and ways of living. As claimed by Brown et al. (2010), resolving a wicked problem also requires a different type of research. If problems are identified based on individuated research traditions that conceptualise problems in the context of their own disciplinary interests and ontologies, then that research, and any resulting action, will be piecemeal, unable to capture the scope of variables involved, and it may even exacerbate aspects of the problem. Rittel and Webber (1973: 159) identify that:

one of the most intractable problems is that of defining problems (of knowing what distinguishes an observed condition from a desired condition) and of locating problems (finding where in the complex causal networks the trouble really lies). In turn, and equally intractable, is the problem of identifying the actions that might effectively narrow the gap between what-is and what-ought-to-be.

These issues characterise the problems of late industrial indoor microecologies. Despite the evident importance of understanding how indoor environments affect the bodies that dwell within them, very little is known about their overall constitution and effects (National Academies of Sciences Engineering & Medicine, 2017). Different disciplines have grappled with aspects of indoor ecologies and their effects on health, for example

microbiology, toxicology, exposure science, architecture, sociology and engineering. However, these investigations are generally bound by the questions, objects of concern and methodological approaches prescribed by the discipline to which they belong. There are examples emerging of collaborations between disciplines, such as microbiologists and architects (see Green, 2014), and a recognition that greater collaboration is required to address sub-optimal indoor environmental conditions (National Academies of Sciences Engineering & Medicine, 2017). However, the inability of any single discipline – or even of collaborations involving representatives from two or three academic disciplines – to adequately define the problem without excluding important perspectives, remains an issue. More detailed examples of current approaches to these problems within diverse disciplines are reviewed in Chapter 3.

Another issue that complicates the problems associated with sub-optimal indoor microecologies is the global geographic dispersal and ubiquity of concerning chemicals and microbial communities, and their constitutive roles in ‘normal’ ways of living. This issue presents a particularly daunting challenge. Unlike environmental health issues that are associated with: particular geographical locations; disastrous events (like oil spills); or particular instances of localised mismanagement (e.g. PFAS contamination on Defence sites in Australia (Aylward, 2018)), the increasing levels of post-industrial chemicals in indoor environments, and decreasing rates of important microbiota, are often the product of emergent conditions associated with achieving normative affluent or middle-class lifestyles and material conditions. The notion of emergence is important, not only for conceptualising how the environment has changed over time as a product of achieving a set of socio-material conditions, but also for understanding how these conditions are continually changing in response to effects over time. Legacy contaminants are distinct and characteristically different from immediate effects that may have been observed in the past (Campkin and Cox, 2012, Boudia and Jas, 2014). Issues of temporality and the ubiquity, insidiousness, invisibility, complexity and dispersal in sub-optimal indoor

environments also makes it challenging to develop a localised community of concern that can recognise these issues and mobilise against them.

To begin to work towards a new program of research and decision-making that is able to address sub-optimal indoor microecologies, it is important to understand how this problem has been defined, and what these definitions have excluded. To do this I propose that a transdisciplinary approach is required. Transdisciplinarity has been defined in many ways. Following Brown et al. (2010) transdisciplinary is taken here to mean the collective understanding of a problem or situation created through personal, local and specialised contributions to knowledge. Transdisciplinarity necessarily involves transgressing disciplinary boundaries and methodological constraints to develop problem-specific approaches based on shared definitions (Dyball, 2011, Brown et al., 2010, Mitchell et al., 2015). This is distinguished from multi-disciplinary inquiry, which involves a combination of specialised knowledge fields for a particular purpose, or an interdisciplinary inquiry, where common ground between disciplines may lead to the emergence of a new form of 'disciplined' inquiry with a set methodological prescriptions and hierarchies (Brown et al., 2010).

As it would not be possible to conduct a transdisciplinary inquiry into this problem within the constraints of a doctoral project, this thesis contributes to the progression of a transdisciplinary agenda for addressing sub-optimal indoor microecologies via an examination of a particular subset of issues related to social practices. This research does not aim to scientifically measure or quantify chemical or microbial molecular relations in indoor environments. Rather, it traces emergent forms of agency, interdependence and relationality associated with everyday life, particularly at the micro-scale, that have previously been obscured or misrepresented. In doing so, this thesis contributes a novel theoretical lens for understanding how micro-ecological relationships are curated through everyday practices in the indoors. My qualitative investigation of everyday domestic practices and my cross-disciplinary literature review also highlight some of the key areas

of ontological divergence and continuity across the fields of knowledge concerned. These areas of divergence and continuity provide the foundations upon which a new transdisciplinary program of research and intervention could be built. The following section provides greater detail on the specific focus and contributions of this thesis.

1.3 RESEARCH FOCUS: HOME ECOLOGIES AND HYGIENE PRACTICES

1.3.1 *HOME ECOLOGIES*

Many types of indoor environments, including schools, homes, hospitals and offices, have a significant influence on human health via their microecologies. This thesis is concerned specifically with the microecologies of homes and the practices that build them. The domestic environment is a key site where human immune systems are built and challenged. It is conventionally understood as a site of individual decision-making and control over what foreign organisms and matter are allowed in. In routine processes of accumulation, organisation and cleansing, people decide what matter is waste, what poses a health risk, how and when. The dynamics of these domestic practices of consumption and cleansing influence the flow and transformation of materials through the domestic environment, and consequently their microecologies.

The home is a particularly important site, because it reflects what we feel we require to be safe and comfortable in our most intimate habitat. In this way, homes are a kind of extended immune system. Bourdieu (1977) goes further to suggest the house is a microcosm of important cognitive categories in a culture, reflecting what is assumed to be moral, gendered, private and public, and that these cultural categories are materially embodied in the arrangement of walls, doors, rooms and objects. Social and cultural changes co-evolve with the materiality of the home, making it an important site to study in order to explore what societies value and what they think they need to live well (Quitau and Røpke, 2009).

The home is also a particularly important microecology for environmental health reasons, as children are generally more vulnerable than most adults to the risks associated with post-industrial chemical toxicants and impoverished microbial communities (Olsson, 2014, Rook and Knight, 2015, Alexandre-Silva et al., 2018).

The home, and parenting practices within the home, have also become important sites of social scientific research in recent years (Mackendrick, 2014). The effect of this has often been to produce moralising narratives about health and the consumption choices of parents (Kehily et al., 2014). This research seeks to situate the emerging environmental health issues in the home within the broader geographies and cultures that are producing them, rather than individual parental responsibility.

1.3.2 HYGIENE PRACTICES

Because understandings of what constitutes a healthy indoor environment, and how it should be constructed and maintained, are at the heart of this issue, this thesis will focus specifically on hygiene practices: the practices performed wholly, or in part, to maintain health and prevent disease in an environment. This definition encompasses practices such as cleaning a bathroom, but also aspects of meal preparation and personal care, such as bathing, which are based on certain ideas, standards and materials that guide normative conceptions of how cleanliness is supposed to be maintained. Hygiene considerations are also embedded in other practices, such as cooking, which is often accompanied by a series of actions, such as handwashing or wiping benches, that are intended explicitly or implicitly to prevent disease.

The term ‘practice’ is used here to refer to the repeated performance of certain groupings of the meanings, materials and bodily actions that comprise everyday life. This understanding of practice is grounded in social practice theories, the primary theoretical

lens guiding this research, which is elaborated in Chapter 4. From this perspective, practices are considered to be the site at which macro socio-material forces intersect with the micro-material and political encounters of everyday life to reproduce normative ways of living (Shove, 2007a, Hui et al., 2017).

All practices occurring within and around the home, such as cooking and gardening, influence the flow of materials and microorganisms through the home. However, common, contemporary hygiene practices play a particularly important role in adding or removing material entities that contribute to adverse health outcomes in homes (Fan et al., 2010, Rook and Brunet, 2005, Aiello and Larson, 2003). Certain chemicals, particularly antimicrobials used in cleaning and personal care products, have also been linked to reduced microbial diversity in the home, and to the proliferation of more resistant bacterial species, a state which is associated with increased rates of allergies in children (Dunn et al., 2013), leukemia (Greaves, 2018) and anti-biotic resistance (Hartmann et al., 2016).

More broadly, the things people do to create a 'hygienic' home environment are instrumental in guiding the flow of materials in and out of homes, and consequently the composition of home microecologies. The way that cleanliness has been defined and measured is not stable, and differs substantially across cultural and historical contexts (Smith, 2007). The hygiene practices performed at a given time and place are determined by how the body and cleanliness have come to be understood and represented, the evolution of cleaning product technologies and trends, the collective conventions governing how one should achieve cleanliness, and how one is able to meet these expected standards given the other competing pressures and constraints of daily life (Pink and Mackley, 2015, Smith, 2007, Campkin and Cox, 2012, Shove, 2003). Culturally dominant notions of hygiene at a given time and place play an important role in how cities, buildings and products are developed.

This thesis is premised on literature that suggests the dominant hygiene paradigm, or regime, that pervades domestic practices in a wealthy industrialised nation such as Australia, is focused on the extermination of pathogenic germs while largely disregarding emergent micro-scale health hazards associated with the chemical and other aspects of the microbial composition of indoor environments (Tomes, 1999, Smith, 2007, Quitzau and Røpke, 2009, Campkin and Cox, 2012, Murphy, 2008). Moreover, the literature also suggests that many attempts to mitigate culturally prominent health hazards, such as pathogenic germs, are exacerbating some of the risks posed by these emergent health hazards (Aiello and Larson, 2003, Hartmann et al., 2016).

My use of the term 'regime' is informed by Hand and Shove (2004) who define a regime as 'an orchestrating concept, that is, as a kind of "force field" that repels and holds particular sets of images, materials, and forms of competence together and that is sustained by them' (Hand and Shove, 2004: 239). Based on this conception, practices can be understood as intertwined with dominant regimes. In relation to hygiene regimes, Quitzau and Røpke (2009: 224) suggest that 'the *regime* of the hygienic bathroom was constituted by morally and scientifically motivated cleansing practices and the need to eliminate biological waste.' In this example, the orchestrating concept of hygiene has brought together and sustained a particular set of materials, actions and competencies over time. By making elements of hygiene regimes explicit, the ways in which it may be detrimental, and to whom, may become apparent. It may also become clear how the regime could be reworked.

1.4 RESEARCH PURPOSE

The primary purpose of this thesis is to contribute knowledge that may help improve indoor home environments so that they are more supportive of human health, and of the health of the broader more-than-human ecosystems in which we are embedded. To do

this, I propose that dominant notions of hygiene rooted not only in culturally explicit narratives, but also in infrastructures and everyday practices, must be interrogated and critically revised. In particular, I suggest that we need a more accurate and encompassing definition of hygiene that is able to account for the emergent chemical and biological risks in homes, and indoor spaces more broadly.

To begin to expand definitions of hygiene to encompass the emerging risks associated with the microecologies of homes, the way that current definitions of hygiene are embedded in existing practices and materials must first be investigated. As a result, this research is designed to analyse how certain assumptions about the agency of entities at the micro-scale are operative in practices. These assumptions are functional at the level of meaning and narrative, non-conscious material engagements, and habitual bodily movements that are constitutive of daily life. However, despite their pervasive and shaping role within our practices, they do not attract high levels of critical reflection. Of particular interest are: how microbial communities and post-industrial chemical classes physically and symbolically come to exercise agency within hygiene practices; whether some of these communities and chemicals are more perceptible than others, and if so, how; and the assumptions we make about how these micro-agents interact with one another and with human bodies within indoor environments.

Given that I have characterised emerging issues within sub-optimal indoor microecologies as unable to be resolved within current disciplinary modes of inquiry, I have endeavoured to begin to bridge disciplinary divides in this thesis. I have done this in two ways. First, I have targeted each of the five publications included in this thesis to multiple disciplinary audiences considered to be important to future change creation. As a result, the terminology, framing and key points emphasised in the included papers are designed to communicate effectively to the disciplinary audiences targeted, while also contributing to the development of the narrative and argument of the thesis. Second, I initiated a special issue in the journal *Human Ecology Review* with the objective of beginning a

transdisciplinary conversation on issues affecting indoor ecologies. This involved devising a process and criteria for enabling scholars from diverse disciplines to not only comprehend one another's work, but to actively review and critique it. The outcomes of this process and the recommendations for future research are included in Paper 5.

Linked to this transdisciplinary line of inquiry are larger questions about how different disciplinary cultures perceive the relationship between human health and planetary health. If one is to take the position that ecological and human health are inextricably linked, one must consider human health as a product of more-than-human practices and environments. The ways in which human health is affected by more-than-human environments and practices are positioned in numerous ways; for example Ingold (2000) proposes humans are shaped directly through human/environment entanglements, while Gell (1995) examines the ways we are affected by how we conceptualise and frame our environments. In my inquiry into domestic hygiene practices, these different perspectives are aligned in their objective of prioritising care, not only for humans, but for the multitude of non-humans that co-constitute all the biomes (indoor and outdoor) of the planet. In adopting this approach my intention is not to advocate for the rights of microbes. Rather, it is adopted to assist in reorienting my gaze, as a researcher, to how ways of living influence the broader ecosystems of which we are a part.

1.4.1 RESEARCH SETTING AND PARTICIPANTS

My research focuses on the domestic hygiene practices of parents with young children in Sydney, Australia. Young children (I focus on children under five years of age) as noted above, are more vulnerable to the health risks associated with home microecologies. By

focusing on the practices of parents it is not my intention to further burden them with the responsibility of protecting their families from health risks. It is not possible, practical or reasonable to expect parents to be responsible for protecting their children from toxic and microbially impoverished material ecologies.

Rather, my investigation of parental practices is an investigation of: how



FIGURE 1: GREATER SYDNEY
 USER:(WT-SHARED) LTURNER, OPENSTREETMAP [CC BY-SA 3.0
 ([HTTPS://CREATIVECOMMONS.ORG/LICENSES/BY-SA/3.0/](https://creativecommons.org/licenses/by-sa/3.0/))]

particular hygiene regimes are manifested and reproduced in everyday lives; the extent to which emerging risks are acknowledged, comprehended, and accommodated; and the interdependencies and dynamics of everyday life that make some avenues for change more acceptable and probable than others. Further information about the characteristics of participants and their homes is included in Chapter 5.

1.5 RESEARCH QUESTIONS

Based on the conception of practices and hygiene regimes outlined in Section 1.4, the research questions below were developed to interrogate how the dynamic interactions between practices in the home, and their constituent elements, influence the micro-ecologies of homes.

- 1. What are the dynamics between practices of hygiene and other domestic practices carried out by parents in homes?*
- 2. How do the relationships between materials within practices influence how hygiene is maintained in homes?"*

3. How does micro-species agency emerge within practices enacted to create a hygienic home?

1.6 RESEARCH SCOPE AND BOUNDARY CRITIQUE

Given the inherent limitations of a doctoral thesis, a number of relevant factors that contribute to indoor environmental health have been marginalised in this research. Three important limitations are acknowledged here before I present a more comprehensive critique and justification of the boundaries drawn around this research.

First, many of the toxicants commonly found in homes originate from sources not directly related to hygiene practices, such as carpets treated with flame retardants, paints, pesticides in foods and air pollution that has accumulated indoors (Weschler, 2009, La Guardia et al., 2017). To understand the composition of an indoor environment over time, how it fluctuates, and how it will affect occupants, the multitude of interacting entities in the indoors must be considered. However, the objective of this study is not to map all potential interactions in home environments. Nor is it to measure the molecular interactions that take place in these spaces. Rather, it aims to trace the material and cultural factors that shape practices enacted to maintain healthy and hygienic home environments.

Second, microbial communities and post-industrial chemicals introduced and fostered through everyday domestic practices are by no means the only contributors to human health risks associated with time spent in indoor environments. Significant factors that are outside of the scope of this thesis include variables such as climate change, which will influence indoor environmental health in manifold known and unknown ways, for example, by increasing heat stress and disturbances due to extreme weather events (Wakefield-Rann and Fam, 2018). In addition, increasingly digitised indoor work and leisure practices that contribute to sedentary lifestyles are a risk factor for a number of

diseases, from obesity to heart disease (Stokols, 2018). It must also be noted that although deaths from communicable, pathogen-borne diseases have decreased in wealthy nations, pathogens still pose a significant disease risk in indoor environments. This is particularly challenging for countries that are rapidly industrialising while simultaneously having to contend with deadly communicable diseases, such as tuberculosis and cholera, in addition to emerging indoor health risks including post-industrial chemicals and non-diverse microbial ecologies (Atiim and Elliott, 2016, Rook and Brunet, 2005). Although many of these factors are interwoven at various points in this thesis, they do not constitute its primary focus.

Third, attending to context-specific cultural, geographic and political differences is evidently important in determining the types of health risks present in indoor spaces. For example, indoor air pollution from traffic is particularly problematic in parts of London (Taylor et al., 2016), while historical industrial regulations governing matters such as toxic waste dumping and development on contaminated land disproportionately affect residential areas in a number of places (Strom, 2018, Birch, 2011). However, some general claims can be made about rapidly urbanising industrialised nations and the increase in indoor health risks associated with impoverished microbial communities and post-industrial chemicals, and the interactions between these micro-systems (National Academies of Sciences Engineering & Medicine, 2017, Murphy, 2006, Rook and Knight, 2015). As noted above, increases in allergic disease linked to decreased exposures to environmental microbial diversity are observed across urban industrialised geographies, in which proximity to a range of non-human organisms has declined (Rook and Knight, 2015, Rook and Brunet, 2005, Green, 2014). The internationalisation of trade in particular industries, such as food and personal care, has contributed to a degree of standardisation in certain product categories around the world. This standardisation has resulted in the emergence of common chemical classes and interactions in indoor spaces (Weschler, 2009, MacKendrick, 2018). The ways in which these trends manifest and intersect are

deeply situated and will differ substantially between local contexts. It is consequently important to begin to trace these many intersections within diverse contexts.

1.6.1 BOUNDARY CRITIQUE

Following Midgley et al. (1998) a boundary critique is a method of making explicit what is included and excluded within an inquiry. Boundaries are social or personal constructs that define the limits of the knowledge that is to be taken as pertinent in an analysis. Drawing boundaries around a problem system directly determines how the problem is defined, and consequently the variables that are included and excluded from the analyses of the responsible and implicated actors. Moreover, this exclusion of actors and variables influences the types of improvement or 'solutions' that are deemed desirable, possible or probable. The objective of the boundary critique is to make explicit the assumptions and value judgements that inform what is considered central to the problem definition, and what issues are marginalised. I use this method here in order to make explicit what is included, excluded and marginalised in my research; to justify these inclusions and exclusions; and to enable the reader to critique this reflexive process and the values and premises that have informed it.

Figure 2 indicates the primary and secondary boundaries that demarcate what has been included and marginalised in this inquiry respectively. Those issues within the primary boundary have been included within the analysis. Those represented on the primary boundary are considered important to the topic under investigation, but have only been briefly included in the analysis, while those in between the primary and secondary boundaries are considered important issues, but are outside the scope of this research.

BOUNDARIES OF THE RESEARCH SCOPE

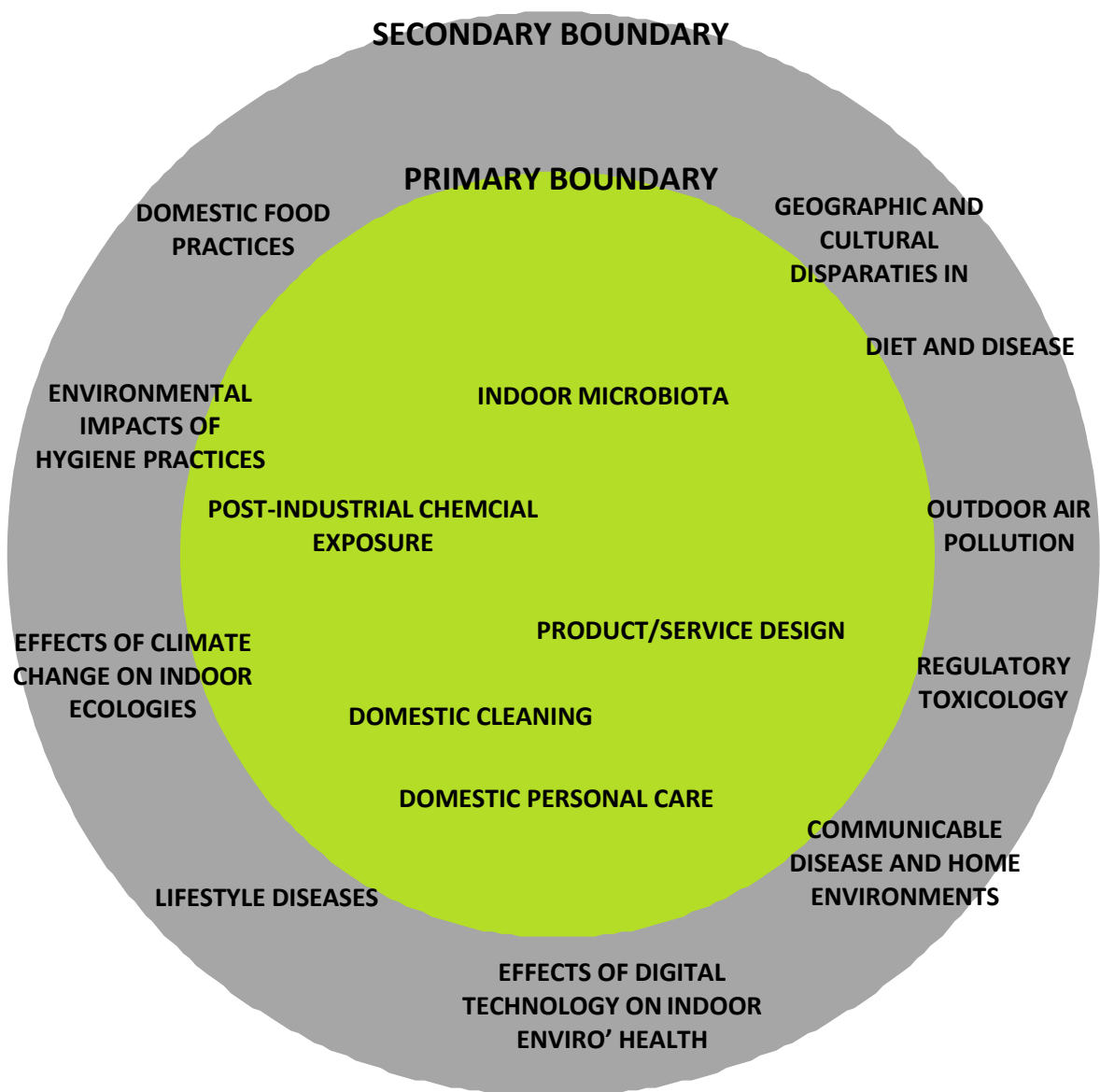


FIGURE 2: BOUNDARIES OF THE RESEARCH SCOPE. ISSUES APPEAR IN THE SECONDARY BOUNDARY OR MARGIN BECAUSE THEY ARE ADDRESSED IN RESEARCH ELSEWHERE.
SOURCE: ADAPTED FROM MIDGLEY (1998) AND CORDELL (2010)

1.6.2 EXPLANATION OF RELEVANT SUBJECTS INCLUDED IN THE ANALYSIS OF DOMESTIC HYGIENE PRACTICES

INDOOR MICROBIOTA: The behaviour of microorganisms is considered to be central to modern understandings and practices of hygiene. Their inclusion in this analysis is therefore considered central to the objectives of this research in terms of both the ways they are culturally represented and perceived, and the ways in which modern hygiene practices are influencing the composition of indoor microbial communities that affect human health.

POST-INDUSTRIAL CHEMICALS: The chemical classes that have proliferated in consumer products and building materials in homes since the 1950s pose some of the most significant contemporary indoor environmental health risks. The relationship between these health risks and hygiene practices intended to mitigate disease form a core consideration of this thesis.

THE HOME ENVIRONMENT: The home was included as the focal indoor ecology for research because it is the environment in which children, who are the people who are most vulnerable to the microbial and chemical exposures of concern, spend the majority of their time. It is also the site at which one can study how personal practices and beliefs coincide with public norms, expectations and rules around hygiene.

DOMESTIC PERSONAL CARE PRACTICES: Personal care practices, including bathing, teeth brushing, hand washing and other forms of grooming which occur within the house, are included in this analysis. These practices which involve measures taken to protect one's own body and one's children's bodies from disease, play a significant role in structuring exposures to micro-organisms and toxicants, through both direct exposure and by introducing particular materials into the home environment. The materials, embodied knowledge, aesthetic indications and values that inform operative notions of hygiene embedded within domestic personal care practices are closely intertwined with those that

govern how the home is cleaned. It has consequently been deemed beneficial to analyse these linked practices collectively.

DOMESTIC CLEANING PRACTICES: The terms ‘hygiene’ and ‘cleaning practices’ are used interchangeably here, although a primary contention of this thesis is that there is a need for a more expansive definition of hygiene that addresses additional, emerging types of disease risk that cannot be addressed through cleaning. Cleaning practices include any act that involves the removal of unwanted substances, such as dirt, or other substances perceived to be unsafe. They also include preventative acts intended to mitigate against the development or spread of pathogens or other unwanted substances. These practices play a significant role in structuring the microecologies of homes, and through this, the health of occupants.

PRODUCT/SERVICE DESIGN: The design of products and services has been included as a point of analytical focus, as design plays a significant role in determining how objects orient actions, and what chemicals and microorganisms populate homes. Design is not only the purview of designers, as they sit within political, social and institutional cultures which they help materialise and reproduce. Also, regulations determine to some degree what can and cannot be included in products. However, by focusing on the role of design in orienting current practices and microecologies, the structural relationships that orient design practices can also be examined.

PARENTS OF YOUNG CHILDREN: Young children have been deemed one of the age groups most vulnerable to both toxicant and certain types of microbial exposure. Their domestic exposures are therefore an important analytical focus area. More broadly, when individuals become parents, hygiene practices often take on additional importance, as they are taking care of infants that are more vulnerable than themselves. This increased importance placed on considering and enacting hygiene may therefore allow for greater insight into operative notions of hygiene and assumptions about disease risks.

1.6.3 REASONS FOR EXCLUDING OR MARGINALISING RELEVANT ISSUES

OTHER INDOOR ENVIRONMENTS: Schools, offices, hospitals and other indoor spaces are all sites at which important research could be conducted into the role of practices in constructing microecologies. However, due to the particular importance of home microecologies in the health of children noted above, and the scope and depth of my research approach, I decided to focus exclusively on the home.

DOMESTIC FOOD PRACTICES: Meal preparation, clean up and food consumption are intimately intertwined with hygiene practices. Conventions around the consumption of food are also a significant determinant of how individuals and families structure their days and their homes, and there has been a significant amount of research that examines domestic food practices (Watson and Meah, 2012, Delormier et al., 2009). Food-related practices are examined herein when they explicitly involve attempts to create a hygienic environment – for example wiping benches after meal preparation and eating. However, their broader role in determining the microorganisms and chemicals that enter the home are not examined. The intersections between cleaning, food and other domestic practices would be a valuable focus for larger research projects in the future.

CULTURAL AND GEOGRAPHIC COMPARISONS: This research provides insights from an in-depth exploration of the hygiene practices of a limited group of participants, and it does not attempt to be representative of any population. Due to the limited participant sample size, an extensive examination of cultural and geographic factors is outside of the scope of this thesis. Further studies that build on this research to explore related questions, with a focus on comparisons between a range of cultural and geographic practice influences, would be valuable.

DIET: Diet is a significant variable in the development of atopic disease and the constitution of the gut microbiome (Zeng et al., 2016). It is also a significant source of

environmental toxicant exposure due to the ingestion of pesticides. These would be essential variables to consider in any study seeking to examine the total exposure profile of an individual. As this study focuses on how healthy home environments are conceived of and created, diet has been excluded from the analysis.

PHARMACEUTICALS: In addition to the chemicals in hygiene products, pharmaceuticals are also a significant environmental source of endocrine disruptors. However, as this study focuses on impacts on the home microecology, rather than broader interconnected ecological impacts, they have been excluded from this study.

ENVIRONMENTAL IMPACTS OF HYGIENE PRACTICES: Scientific studies have indicated that domestic hygiene practices have various and significant impacts on ecosystems beyond the home, due to the chemical emissions of everyday products and the pollutants that exit the home through water pipes (Vos et al., 2000). There are also impacts associated with the production of chemicals and other products involved in hygiene practices. These are alluded to briefly in Paper 4, however a comprehensive analysis of these impacts on all affected organisms and systems is beyond the scope of this study.

REGULATORY TOXICOLOGY: The present and historical influence of regulatory toxicology on the composition of indoor environments and disease burdens associated with post-industrial chemicals is substantial. I highlight in this thesis the basic tenets of traditional toxicology upon which current regulations in Australia are based, and their limitations. However, the full impacts of regulatory institutions and laws, and their effects on indoor environments, is beyond the scope of this research. Also, analyses of regulatory practices and regimes and environmental health have already been the subject of much critical inquiry (Comiskey et al., 2017, Silbergeld et al., 2015, MacKendrick, 2018, Boudia and Jas, 2016)

OUTDOOR AIR POLLUTION: The air outside of the home and its proximity to traffic, industry and green spaces, also have a substantial influence on the composition of air

inside the home, and consequently its microecology. Factors associated with outdoor air were examined in this thesis when they became integral to cleaning practices inside the home, but were not considered more broadly. Future research linking outdoor environmental conditions with indoor practices would be valuable.

COMMUNICABLE DISEASES: Common infections remain an issue in domestic environments, particularly where inhabitants are immune-compromised. However, in wealthy industrialised nations such as Australia, the incidence of serious and fatal infectious diseases has substantially decreased. Moreover, a key contention of this thesis is that normative hygiene practices often respond disproportionately to the risk of communicable pathogens and exacerbate other disease risks. The factors that contribute to the spread of infectious diseases in home environments are therefore not a key focus of this thesis.

LIFESTYLE DISEASES: Diseases significantly associated with a sedentary lifestyle, smoking, drug use and diet were not considered within the scope of this research. These diseases, such as Type 2 diabetes, obesity and atherosclerosis, are associated with the chemical and microbial exposures that are the primary focus of this thesis, and they may act as compounding or confounding factors to one another. These considerations will be important in any research aimed at determining the exact disease burdens associated with sub-optimal indoor environments, but are beyond the aims and scope of this thesis.

EFFECTS OF CLIMATE CHANGE ON HOME ENVIRONMENTS: Climate change will have many impacts on indoor environments, many of which are still unknown. These may include the proliferation of different types of airborne biological and other allergens, tighter sealed buildings to improve climate control, and more time spent in sedentary behaviour indoors. These factors are noted in Paper 5. However, as the manifestations of climate change indoors are still largely speculative, they have not been included as a key focal area.

EFFECTS OF DIGITAL TECHNOLOGIES ON HOME ENVIRONMENTS: Digital technologies have been implicated in increasingly sedentary lifestyles, new forms of knowledge sharing about risk, changes to work and leisure practices, and altered domestic material landscapes (the amount of digital technology in the home). Electronic goods contain a number of chemicals that have been listed as concerning, and they are increasingly a category of material with which we are constantly intimately exposed. These factors are noted in Paper 5, however an analysis of the full scope of material changes in domestic material culture is beyond the scope of this thesis

1.7 THESIS OVERVIEW

The five papers included in this thesis build its central argument: that dominant definitions and practices of hygiene must be updated to account for emerging indoor health risks at the micro-scale, necessitating new forms of situated, transdisciplinary research and intervention. While Paper 1 lays the groundwork through a cross-disciplinary analysis, Papers 2 and 3 present the core findings and theoretical contributions from my qualitative research. Paper 4 then provides an example of the application of the type of approach advocated in the preceding papers to a ‘real-world’ challenge: how to develop sustainable, non-toxic product-service systems for domestic personal hygiene. Paper 5 then draws together the findings of my research and situates it within a transdisciplinary conversation about how to improve indoor ecologies, emphasising recommendations for future research. Chapters 2, 3, 4 and 5 support the development of this argument by providing a theoretical and methodological basis for the investigation. The final chapter provides recommendations for future research.

There is some necessary repetition across the papers in the presentation of the central concerns that this thesis addresses, and in the explanation and justification of the theoretical position adopted. However, the contributions of each article are distinct. An overview of the contributions of each chapter are summarised below. The contributions of each peer-reviewed paper are then presented in Table 1.

1.7.1 OVERVIEW OF CHAPTERS AND TABLE OF PUBLICATIONS

Chapter 2 presents the historical context that situates modern hygiene practices and their effects in homes, particularly in Western industrialised nations, but increasingly across industrialised nations around the world. This history covers important aspects of the evolution of ideas about the body, its boundaries, and distinctions between humans and

non-humans, particularly disease-causing entities relevant to this thesis. This background knowledge not only locates the research presented in this thesis, but also presents essential considerations that must be accounted for in any intervention which aims to change hygiene practices or the composition of home microecologies.

Chapter 3 examines the fields of literature considered most relevant to this thesis. Given the complex, cross-disciplinary territory which this thesis inhabits, there is not a single ‘gap’ in one field that this thesis fills. Rather, this research responds to research gaps that have primarily emerged due to a lack of knowledge integration and divergent ontological and epistemological approaches to understanding health and hygiene in the home across different fields. The literature review in this chapter identifies some of the foundational contributions from diverse fields to our knowledge of sub-optimal indoor environments, their points of departure from one another and their points of convergence upon which new research collaborations could be built. The primary fields examined include microbiology of the built environment, exposure science, and the literature underpinning my theoretical framework including social practice research and multispecies ethnography.

Chapters 4 and 5 present my theoretical framework and my methodological approach respectively. I have devised and employed a hybrid theoretical framework that combines social practice theory with multispecies ethnography and chemo-ethnography as the basis for investigation in this thesis. This theoretical lens sensitised me to particular objects of inquiry and key variables that I considered relevant to addressing sub-optimal indoor home ecologies, and informed the methodological approach explained in the Chapter 4. This methodological approach included: activity diaries and semi-structured interviews in participants’ homes with integrated practice enactments.

Chapter 6 then draws together the key conclusions of this thesis and makes recommendations for future research. Incorporated within this chapter is **Paper 5**, which

links the research findings presented in this thesis with emergent themes across various disciplinary inquiries into indoor environments and their implications for future research. The recommendations emphasise the need for cross-disciplinary research with communities to collectively and iteratively re-examine how health and hygiene are defined and measured in relation to indoor environments, particularly in the context of emerging trends associated with climate change and the increasing digitisation of work and leisure.

TABLE 1: SUMMARY OF INCLUDED PUBLICATIONS

NO.	PUBLICATION TITLE	JOURNAL	RESEARCH APPROACH	TARGET AUDIENCES	KEY CONTRIBUTIONS	RESEARCH QUESTION
1	Routine exposure: How social practices structure environmental health risks in the home	<i>Social Theory and Health</i>	Analyses of literature across environmental health, consumption studies, exposure science, and social practice-based research.	Sociology of health; public health experts interested in toxic exposures and human-microbial interactions; consumption studies.	1. Using endocrine disrupting chemicals as an example, this paper demonstrates why adverse effects of home microecologies cannot be resolved by replacing individual ingredients or products. 2. Using this example, the paper demonstrates why social practices are a more appropriate unit of investigation and intervention, and it lays the groundwork for the development of this approach in subsequent papers. 3. It establishes the macro-political and regulatory issues that have enabled potentially harmful chemicals to persist in products, and the micro-political dynamics which have resulted in women and children being disproportionately vulnerable to indoor environmental hazards. 4. It provides evidence for why interventions in the domestic space that exclude micro-ecological interactions can maintain or even exacerbate potentially harmful conditions.	2

2	Microbes, chemicals and the health of homes: integrating theories to account for more-than-human entanglements	<i>BioSocieties</i>	An integration of social practice theory and multispecies ethnography and chemo ethnography applied to qualitative research into the hygiene practices of parents.	Science and technology studies; life sciences; researchers working with multispecies ethnography and social practice theories.	1. Building on Paper 1, this paper narrows the scope of research to present findings specifically on domestic hygiene practices. 2. Based on qualitative investigation, it identifies key assumptions operative within practices that may be contributing to sub-optimal home microecologies, including: a. Harmful micro-species behaviours accompany particular material arrangements in the home. b. 'Sensory proxies' can reliably be used to detect harmful micro-species activity. c. The micro-species in the home act in consistent predictable ways. d. Children's vulnerability to potentially harmful micro-species decreases as they learn to walk and become capable of ingesting food. 3. It also introduces and demonstrates the value of a theoretical approach that combines multispecies ethnography and social practice theory to elucidate how micro-species culturally and physically participate in and reinforce everyday practices.	3
---	---	---------------------	--	--	---	---

3	'It's just a never-ending battle': the role of modern hygiene ideals and the dynamics of everyday life in constructing indoor ecologies	<i>Human Ecology Review</i>	Analysis of findings from qualitative research into the hygiene practices of parents. The guiding theoretical framework is social practice theory.	Human ecologists; exposure scientists; social scientists broadly interested in social practices, hygiene and environmental health.	1. Also drawing on my qualitative research, this paper extends the analysis of practices in Paper 2 to examine how conceptions and performances of hygiene are influenced by the broader dynamics of practice in the home. 2. It details how in homes where numerous practices are competing for time and resources, parents often do not feel they can meet normative expectations of a clean home. 3. It shows how the definitions of hygiene, and notions of 'cleaning well' embedded within cleaning practices often require significant amounts of time, vigilance and labour. 4. It shows how many of the product attributes that create an aesthetic 'sense' of cleanliness, are either ineffective or contain potentially harmful chemicals, and how potential 'germs' are more perceptible in domestic cleaning practices than other micro-species that may present a health risk. 5. It also reports on how the health experiences of parents and children can sensitise parents to new potentially harmful and beneficial micro-species in ways that disrupt or reorient practices.	1
---	--	-----------------------------	--	--	--	---

4	More than skin deep: a service design approach to creating more sustainable personal care (book chapter)	Book chapter – ‘Sustainable Luxury’	Analysis of literature from exposure science, design and social practice theories to present a case study of a product/service model that could enable more healthy and sustainable personal care practices.	Sustainable business scholars and practitioners; product and service designers.	1. Having established the significance of the aesthetic aspects of hygiene and the dynamics of practice in determining how hygiene is performed, this paper presents a case study of a type of intervention that could be implemented in product/service industries to address potentially harmful exposures to post-industrial chemicals in the home. 2. It proposes a model of provisioning domestic personal care based on the retailer LUSH, that has potential global reach, and does not necessitate the use of harmful chemicals. 3. This case study grounds the arguments developed in this thesis in a ‘messy’ real-world context – acknowledging the competing pressures that businesses must accommodate if they are to participate in positive change. 4. It also demonstrates why overcoming the ‘regrettable substitution’ of chemicals in products will require a re-examination of practices, and of the ‘needs’ and expectations they generate.	2
5	Initiating a transdisciplinary conversation to improve indoor	<i>Human Ecology Review</i>	A synthesis of research presented in this special issue, including findings from my qualitative data, to articulate key	Ecologists; human and social ecologists; microbiologists; environmental philosophers;	1. This paper identifies synergies between the findings of my qualitative research and broader issues affecting indoor environments identified different across disciplines.	1

	ecologies (Editorial)		emerging themes relevant to the study of indoor ecologies.	toxicologists; designers; geographers; transdisciplinary scholars.	2. It highlights some of the crucial agencies at play in other practices, such as digital working and socialising, and adapting to urban heat stress, that influence how practice dynamics in the home impact on the ways parents try to create hygienic homes for their children. 3. By initiating a transdisciplinary conversation, this paper indicates crucial gaps, contradictions and points of commonality between different disciplinary approaches and research subjects on indoor environments.	
--	----------------------------------	--	--	--	--	--

2 HISTORICAL COEVOLUTION: HYGIENE AND INDOOR ECOLOGIES

Parents, teachers, health care professionals, and advertisers all continually reinforce the association between practices such as hand washing or refrigerating food and the preservation of health. The rituals of germ avoidance are so many and so axiomatic that one scarcely can remember when or where we first learned them – Nancy Tomes (1999: 2)

The evolution of the way hygiene is defined and practised is central to the evolution of home microecologies. This chapter provides historical context that situates modern hygiene practices and their effects in homes across Western industrialised nations, including Australia, and increasingly industrialised nations around the world. This history is not exhaustive, but encompasses aspects of the evolution of ideas about the body, its boundaries, and distinctions between humans and non-humans, particularly disease-causing entities relevant to this thesis. These ideas not only provide important background knowledge to situate the research presented in this thesis, but also represent essential considerations that must be contended with in any intervention which attempts to change hygiene practices or the composition of home microecologies.

This chapter is divided into three sections: the first section examines current research into the emerging forms of disease associated with the home environment and their causes, with a particular focus on microbial communities and post-industrial chemicals use; the second section reflects on these changes in relation to changing historical notions of hygiene and the factors that influence how it is practised in the home, including its

persistent aesthetic influence on modern home design and architecture; the final section examines hygiene in relation to questions of boundaries, species, and how particular ontological positions on the 'self' and the 'other' have influenced the way humans have attempted to keep themselves 'clean'. The chapter concludes with a discussion of the 'politics of evidence' that may be inhibiting the popular recognition of a number of health risks in the home.

2.1 CHANGING INDOOR ECOLOGIES AND MODERN HYGIENE

In this first section I provide background on two of the key emerging issues affecting indoor environments across the industrialised West: changing indoor microbial ecologies, and post-industrial chemicals in the home. Historians of science have now abundantly catalogued and theorised the processes by which the molecular scale of life has become perceptible, and the scientific tools and practices that have shaped our understanding of these processes (Rose, 2007, Braun, 2007, Myers, 2015, Roberts et al., 2008). The way in which this micro-scale of life has been culturally imagined and embedded within institutions has influenced not only the development of industries, regulatory practices and public health initiatives, but also infrastructures and materials that populate our world, including urban sanitation schemes and home design (Lupton and Miller, 1996, Fam et al., 2009). Some have traced what Rose (2007) has termed the *molecularisation of life* back to the realisation that pathogenic microbes cause infectious disease, inserting this invisible scale of life into the public imagination (Figure 3 shows early examples in visual culture). Since then, the molecular realm has been extended to include genes, allergens, hormones, viruses and a multitude of other interacting entities (Braun, 2007, Murphy, 2008). According to Rose, a new style of thought has emerged to accompany the molecularisation of life, characterised by a focus on individualised risk and variations (Rose, 1990). Braun (2007) adds that a greater understanding of entities such as viruses at the molecular scale has brought new levels of comprehension around the extent to which

the world is precariously interconnected and able to be collectively affected by events such as pandemics. The tensions identified by Rose and Braun between a tendency towards the individualisation of medical diagnosis and treatment, and the systemic, interconnected causes of disease at the molecular scale, are central to the ideas of risk and perception discussed in this thesis.



FIGURE 3: 'HUNTING MICROBES' FROM JEAN MARC COTE'S SERIES (CIRCA 1900) IMAGINING FRANCE IN THE YEAR 2000; HIGHLIGHTS THE EMERGING AWARENESS OF LIFE AT THE MOLECULAR SCALE [PUBLIC DOMAIN VIA WIKIMEDIA COMMONS]

Murphy (2008) builds on theorisations of the molecularisation of life in the biosciences, and applies them to the growing understanding of the ways that post-industrial chemicals travel between, participate in, and transform bodies. Many of these chemicals have entered the world and our bodies through developments in modern chemistry associated with improved understandings of molecular interactions and entities. The emergence of practices such as toxicology and gas spectrometry have further enabled chemical molecular relations to be traced beyond the lab (Darling et al., 2016, Myers, 2015, Roberts et al., 2008). Murphy uses the term 'chemical regime of living' to describe modern, global conditions 'in which molecular relations extend outside the organic realm and create interconnections with landscapes, production and consumption, requiring us to tie the history of technoscience with political economy' (Murphy, 2008: 697).

The emergence of microbial and chemical risks in homes, and the practices that have been developed to make them perceptible or to obscure them, are considered in this section in the context of this broader process of the molecularisation of life.

2.2 MICROBIAL ECOLOGIES AND HEALTH

Homes create a unique habitat for microorganisms, many of which can only thrive in the ecological niches created by modern indoor environments. A survey of homes across the United States revealed on average approximately 7000 different types (operationally defined as operational taxonomic units) of bacteria and 2000 types of fungi per house in the dust on the upper trim of an inside door (Steinemann et al., 2017). Recent research into the microbial life of extreme environments in homes—including extreme temperature, pH and chemical conditions—found microbial genera living in homes that were normally only found in places such as Antarctic sea ice (Savage et al., 2016). This section provides background information on some of the ways that microbiota are coming to thrive in homes within late industrial material ecologies, and how they are affecting human health.

2.2.1 *EVOLVING CONCEPTIONS OF INDOOR MICROBIAL EXPOSURES AND HEALTH: FROM THE HYGIENE HYPOTHESIS TO ‘OLD FRIENDS’*

The health risks linked to home life in industrialised nations, including Australia, have undergone a significant shift from those associated with fatal communicable diseases, to atopic (allergic) and other auto-immune conditions (Bloomfield et al., 2016, Okada et al., 2010). Although communicable illnesses have certainly not been eradicated, there has been a significant decline in their incidence, and associated mortality rates in the industrialised West (Maizels, 2005, Rook, 2012, Bloomfield et al., 2006). Changing living conditions, including the amount of time spent indoors, diet, companion animals, the

material composition of indoor environments, how they are cleaned and the composition of air in urban settings, have been identified as potentially important variables in this transition (Isolauri et al., 2004, Fujimura et al., 2010, Fotopoulou et al., 2018, Penders et al., 2013).

The rapid rise in many atopic conditions such as asthma in Australia beginning between 1960 and 1970, with advances during the 1980s and 1990s, is found across the industrialised world (James et al., 2010). Some researchers, such as Isolauri (2004), suggest that there has been a steady increase in sensitivity to airborne allergens since the 1920s. However, the prevalence of conditions such as allergenic asthma did not start increasing rapidly until around 1980, when it began increasing by about 1% a year (Warner, 1999).

In 1989, the 'hygiene hypothesis' was proposed by Strachan to explain the rise in atopic disease (Strachan, 1989). He theorised that the development of infections during the first period of childhood decreases when there is non-hygienic contact (spreading of infections) with older siblings from the same family (Alexandre-Silva et al., 2018).

However, this theory has attracted controversy and there have since been several studies in which the validity of the hygiene hypothesis has been inconsistently supported (see Ercolini and Miller, 2009, Oliveira et al., 2017, Yazdanbakhsh et al., 2002). Its key issue lies in the assumption that multiple older siblings provide protection from allergic disorders because they transmit common childhood infections. Evidence is now suggesting that the exchange of particular types of microbiota, rather than the transmission of 'true' infections such as tuberculosis or childhood virus infections, is likely to be creating protection from atopic disorders (Penders et al., 2013). Indeed, several studies have now indicated that these infections do not protect from allergies at all (Benn et al., 2004, Bloomfield et al., 2006).

The evolution of research into associations between childhood microbial exposures and immune responses has now expanded to include many more possible variables, such as parasitic infections, immunisations, changes to the home environment such as heating and ventilation, cleaning practices, dust mite exposure, duration of breastfeeding, diet and age certain foods are introduced, parental smoking, pollution, child care exposure, and exposure to pets and farm animals (Gupta et al., 2016, Fujimura et al., 2010, Maizels, 2005, Okada et al., 2010). Studies have also moved beyond the scope of atopic disease, as recent research has also linked lack of exposure to common infections in early childhood to the development of childhood acute lymphoblastic leukaemia (ALL) (Greaves, 2018).

Although the hygiene hypothesis cannot serve as a generic explanation for allergic disease, research has consistently demonstrated more nuanced associations between microbiota alteration and allergies. As a result, researchers such as Rook and Brunet (2005) have proposed a shift from the hygiene hypothesis to the 'old friends' hypothesis, which theorises that certain microorganisms that are part of our evolutionary history are recognised as 'old friends' by the innate immune system. This recognition drives mechanisms that help to control inappropriate inflammation, rather than priming aggressive immune responses. Rook identified three key groups of organisms (lactobacilli, saprophytic environmental mycobacteria and some helminths) as 'old friends', but emphasises that according to this logic, there would be many more yet to be discovered (Rook et al., 2004).

The immunological reasoning that underpins the 'old friends' hypothesis is shared by proponents of a broader 'biodiversity hypothesis' (Haahtela et al., 2013), and the 'biome depletion hypothesis' (Parker, 2014), which focus on the role of the exchange between microbial communities in the environment and the body's microbiota, particularly in the gut, in the modulation of the immune system (Haahtela et al., 2013). The proponents of these theories agree that instead of limiting infection, the absence of many crucial microbes in the lifestyles and environments of industrialised nations limits microbial

exposures necessary for immune system development. They suggest that this limiting modifies, and decreases the diversity of, the microbial colonisation of children's gastrointestinal tracts, thus increasing the probability of allergic and autoimmune disease development (Azad et al., 2013)

Despite persistent uncertainty surrounding the exact types of microbial exposures that are protective of children's immune systems, and the difficulty in establishing causation mechanisms in such complex systems, a number of findings related to microbial exposure are important for determining how household environments may be affecting health. The first is that, although the precise processes are unclear, the gut microbiota is crucial to the way the immune system is sensitised to antigens (foreign substances that induce an immune response) (Peterson et al., 2015, Zeng et al., 2016). The gut microbiota composition is determined by a number of factors, including the indoor environment, diet, family members and the microbes on and in one's mother while in utero. A key review of the microbiome of the built environment states that a primary concern related to the development of undesirable microbial communities has been exposure to cleaning chemicals, as they are common sources of Volatile Organic Compounds (VOC) in indoor air (National Academies of Sciences Engineering & Medicine, 2017: 209). They report that both 'green' and conventional cleaning products emit primary chemical aerosols and may react to produce other substances (Nazaroff and Weschler, 2004). This claim is supported by other studies that provide evidence that chemicals used in hygiene practices directly destroy some crucial microbes (Brooks et al., 2013, Fotopoulou et al., 2018). Even where hygiene practices do not directly impact microbes, they still play a significant role in determining what communities of microbes become dominant in particular spaces, and which are outcompeted. A second concern they report is the presence of antibiotics or antimicrobial chemicals in many consumer cleaning and personal care products that increase the risk of producing resistant bacterial strains (Aiello and Larson, 2003).

Research suggests that the use of many of these products containing antimicrobial agents

promotes the recolonisation of cleaned surfaces with particularly resistant species of bacteria and lower levels of microbial diversity (Aiello and Larson, 2003). This is important, as a number of studies have strongly correlated exposure to microbial diversity with the development of a normal immune system, although it remains unknown whether it is diversity itself that is protective, or a particular group of microbes within the diverse microbial community (Rook and Knight, 2015, Cavaleiro Rufo et al., 2017, Haahtela et al., 2013).

The design of the home itself also has been shown to significantly influence microbial diversity and the exposures of individuals. A number of studies have found that the way a building is ventilated plays a significant role in shaping its microbiome (Meadow et al., 2014, Martin et al., 2015). In their study of healthcare facilities, Kembel et al. (2012) found that mechanical versus window ventilation resulted in significantly different airborne bacterial communities in patient rooms: mechanically ventilated rooms had lower bacterial diversity and more human-associated bacteria (for example from the skin and mouth) than window-ventilated rooms. Moreover, they found that concentrations of bacteria closely related to human pathogens were higher indoors than outdoors, and higher in rooms with lower airflow rates and lower relative humidity. Ventilation experiments in a university classroom have demonstrated that ventilation strategies directly impact the composition of indoor air microbiota (Meadow et al., 2014). The levels of sunlight and humidity indoors have also been shown to significantly alter microbial communities (Kembel et al., 2012).

Research also shows that choices about indoor surfaces can make a significant difference to the types of microbes that thrive indoors. Green (2014) notes that for any given indoor surface, microbial community composition will vary due to a combination of environmental conditions (type of material, temperature, and humidity), dispersal conditions (the relative magnitude of human, pet, plant, and bioaerosol sources), and biological interactions (interactions within and among members of colonising and

resident microbial communities). Regardless of the mechanisms involved, multiple studies have shown that the composition of microbial communities on indoor surfaces vary (Dunn et al., 2013, Adams et al., 2013, Kelley and Gilbert, 2013). For example, in their investigation of shower head microbiomes, Gebert et al. (2018) found that microbial communities differ significantly based not only on geographic factors, such as municipal water sources, but also on whether the shower head was made from plastic or metal. These studies and others suggest that the type, spatial covering, and location of indoor surfaces will influence microbial diversity both on surfaces and in indoor air.

In addition to the design of the home, the use of antimicrobial cleaning and personal care products not only potentially reduces microbial diversity, but can also promote the colonisation of the indoors by microbes that are resistant to antimicrobials (Hartmann et al., 2016). A number of significant studies have measured the relationship between antimicrobial chemicals and antibiotic-resistant genes in indoor spaces (Fan et al., 2010, Lu et al., 2013, Geens et al., 2009). One study (Hartmann et al., 2016) which measured the relationship between antibiotic-resistant genes and the common antimicrobial chemicals triclosan, triclocarban, and methyl-, ethyl-, propyl-, and butylparaben in the dust microbiome across a number of indoor building types found antibiotic-resistant genes in these environments that cover a wide spectrum of antibiotics. They ultimately suggest that the use of these antimicrobials may have a strong influence on the promotion and retention of antibiotic resistance genes in indoor microbial communities. In addition to affecting microbial genes, these common household chemicals, and a number of others that have entered homes in industrialised countries since World War II, have a number of direct health impacts on human occupants.

2.3 CHEMICAL RISKS IN THE HOME

Since industrialisation, and in some cases prior to it, homes have contained a range of toxicants that endanger human health. However, the types of chemical classes that have become ubiquitous in household consumer products since World War II act in characteristically different ways to the ‘poisons’ that previously pervaded homes (Weschler, 2009). Due to substantial investments in chemical research during World War II, the production of synthetic chemicals increased threefold after the war to become a trillion-dollar industry (MacKendrick, 2018). At present, it is estimated that there are 85,000 chemicals registered for use in consumer products around the world, and just over 2000 are added to the market each year (Ha et al., 2016, MacKendrick, 2018). Despite their ubiquity, only a very small proportion of these chemicals have ever been tested for their long-term effects on humans and the environment, and an even smaller number have been banned. This is because under current regulatory systems across the majority of the world, including Australia, a product is allowed onto the market until sufficient research has been conducted to demonstrate it is harmful, based on current regulatory criteria (MacKendrick, 2018, Scruggs et al., 2014, Altman et al., 2008, Schug et al., 2013). This regulatory model is problematic, as a number of these new classes of chemicals act in complex ways that challenge traditional regulatory toxicology, and are not associated with observable health conditions until years after exposure (Bergman et al., 2013).

Many post-industrial chemicals that have entered the market in this post-war chemical production ‘boom’ have been classified as carcinogens, mutagens, endocrine disruptors, neurotoxins and allergens, most of which take a long time to cause harm in the body (Boudia and Jas, 2016). Endocrine disrupting chemicals (EDCs), for example, interfere with the development and normal functioning of the endocrine (hormonal) system (Bergman et al., 2013). There is strong epidemiological and laboratory evidence to suggest that EDCs are involved in a number of health conditions connected to the endocrine system, including some types of cancer, feminisation of male foetuses, early-onset puberty and menopause and senility, obesity, diabetes, stunted brain development and

miscarriages, among others (Grün and Blumberg, 2009: 20, Reuben, 2010: 40, Bergman et al., 2013, Di Renzo et al., 2015). In Nordic countries, research suggests that the adverse effects on male reproductive systems from regular exposure to EDCs, including the use of PCPs, could be costing up to €36 million for each year of exposure (Olsson, 2014: 55).

The mechanisms through which EDCs cause harm are complex and contingent on the environment in which they are acting, and the body that is exposed. This way of acting challenges traditional regulatory toxicology, which has largely adhered to the truism that 'the danger is in the dose' – that is, small doses will be less harmful than large doses, and safe low doses can be calculated through animal tests in laboratories. However, a number of these new chemicals participate in the internal processes of bodies in ways that cause more harm at low doses (low dose effects), and act in different ways according to how much has accumulated in the body (cumulative exposure), or what chemicals are simultaneously present and interacting in the body (cocktail effects) (Vandenberg et al., 2012, Meeker et al., 2009, Liboiron, 2015). As a result, the true effects of these chemicals cannot be understood unless the temporal patterns of exposure and combination are measured. The chemicals a body accumulates during a lifetime of exposure are referred to as a chemical 'body burden' (MacKendrick, 2018). At present, all human bodies that have been tested since this chemical proliferation contain a body burden of hundreds of these synthetic chemicals (Bushnik et al., 2010, Meeker et al., 2009). However, measuring human body burdens and the effects of chemical combinations in daily life are not yet part of regulatory toxicological methods.

The frequency of exposure, and the ways in which people are exposed to these chemicals, are also important. For example, some of them, like bisphenols (used to line food cans and in some plastics), are excreted from the body, so they act over a short period, while others, like some flame retardants and pesticides, are lipophilic, meaning they accumulate in tissues and fat (MacKendrick, 2018). The way these chemicals act on the body is also affected by a number of variables, such as pregnancy and breastfeeding, where the

mother's fat stores are mobilised to feed the baby (LaKind et al., 2004). Chemicals also enter a baby's body in utero through the placenta (Adibi et al., 2008)

In the context of the home, these chemicals have become central to the aesthetic and functionality of many home furnishings and products that are now considered essential. Since the 1950s, some of these products have included: composite-wood, polyvinyl chloride (PVC) pipes and PVC wire/cable insulation, synthetic carpeting, linoleum flooring, latex paints, furnishings such as treated fibreboard, and foam bedding and sofas treated with flame retardants, appliances and electronic equipment, and a multitude of specialised cleaning and personal care products, to name a few (Weschler, 2009). All of these products 'off-gas' silent and invisible micro-emissions of chemicals at different rates into the indoor environment.

The concentrations of chemicals in the indoors depend not only on the emission rates of products, but also the rate at which emissions are transported from outdoors to indoors, and the rates at which they are absorbed or refracted by indoor surfaces, or consumed and transformed by indoor chemistry or microbes, or removed or recycled by ventilation or filtration (Weschler, 2009). This variability highlights the importance of measuring emissions in situ to understand their effects. In studies that have measured cumulative indoor pollutant emissions of personal care products in cities in the United States, parts of Europe and China, it has been found that they are comparable to, and in some areas worse than, traffic emissions (McDonald et al., 2018, Yang et al., 2018).

This section has shown that the types of risks posed to individuals in the home environment have changed significantly since the 1950s. However, popular understandings and practices of hygiene have not necessarily adapted to respond to these new risks. There is research suggesting that awareness of the role of microorganisms in supporting health has increased in some places (Paxson, 2014). However, much of the publicly disseminated information is not necessarily supported by evidence (O'Malley and

Skillings, 2018), and it is not known if and how this knowledge is being translated into practice. Indeed, research is showing that sales of antimicrobial products for domestic and personal use are at their peak internationally (Weatherly and Gosse, 2017), microbiologists of the built environment contend that houses are still not designed to foster healthy microbial ecologies (Green, 2014), and thousands of untested new chemicals enter consumer products intended for home use each year. One reason for this lack of adaptation may be a paucity of research into everyday practices, and people's reasons for preferencing certain home designs and products.

Before interventions can begin to be designed to enable the development of hygiene practices that respond to the contemporary risks described, it is important to understand the evolution of current home hygiene practices, and the cultural and material forces that may be causing aspects of them to persist. The following section provides a brief overview of some of the key developments in the ways that disease and human bodies have been understood across the industrialised West, including Australia, and how these have shaped hygiene practices.

2.4 THE EVOLUTION OF HYGIENIC HOMES AND BODIES

The way hygiene is practised is informed by ideas about how disease enters the body and the materialisation of these ideas over time. For example, Barnett (2014) notes that in the sixteenth century, illness was thought to be caused by imbalances in bodily 'humours' caused by impure substances entering the skin via heat and water. This resulted in a concept of good hygiene based around protecting the body from penetration by these substances, and infrequent washing. Similarly Corbin (1986) notes that the miasma (or 'foul air') theory of disease understood illness to be caused by odorous air. This resulted in hygiene practices in which the deodorisation of the body and environment were paramount (Classen et al., 1994, Shove, 2003: 81). There is broad agreement in the

literature that the emergence and popularisation of the ‘germ theory’ of disease in the late nineteenth century represents the beginning of modern hygiene practices, based on the notion that the key risk to bodily health is pathogenic microorganisms (Tomes, 1999, Barnett, 2014). Latour (1988) and subsequently others (Paxson, 2008, Tomes, 1999) argue that the revelation of microbial relations via institutional arrangements that sought to control them subsequently framed the role of hygienists, government officials and economists as agents responsible for predicting, rationally ordering and maintaining ‘pure’ social relations through the absolute control of microbial encounters. The hygiene trajectory spurred by an understanding of molecular life centred on germ theory is maintained through persistent cultural beliefs, and remains a force that structures public health and its associated institutions. Early examples of this in advertising can be seen in Figure 4. A number of scholars have also suggested that hygiene and cleaning practices based on the framing of microorganisms as agents that must be controlled have escalated and become standardised across numerous cultural contexts since the beginning of the twentieth century (Gram-Hanssen, 2007, Quitzau, 2004, Shove, 2003).



FIGURE 4: 1968 AD FOR LYSOL SPRAY DISINFECTANT; ILLUSTRATES THE TWENTIETH CENTURY CULTURAL DEVELOPMENT OF THE ASSOCIATION BETWEEN INVISIBLE MICROBES AND HARM. PUBLISHED IN REDBOOK MAGAZINE, NOVEMBER 1968, VOL. 132, NO. 1

It is documented that in Australia, hygienic reforms were adopted with a particular gusto (Bashford, 2003, Davison, 2008, McCalman and Spadinger, 1984). This is likely due to a combination of forces such as climate, and as Bashford (2003) details in great depth it is

impossible to separate hygiene as a moral imperative from everyday practices of cleanliness in a colonial context in which boundaries that demarcate purity and whiteness are considered to be under threat. This imperative manifested in individuals from Aboriginal, Chinese or Islander backgrounds being quarantined forcibly during outbreaks of diseases such as leprosy, while white settlers were able to reside in their homes, or voluntarily attend sanatoriums in the case of tuberculous outbreaks, for instance (Bashford, 2003). The genealogy of public health in Australia has been usefully conceived of in terms of 'governmentality', in which self-administered practices and the objectives of



FIGURE 5: IMAGES OF VILLA CHURCH, FRANCE (1928-1929) BY LE CORBUSIER: TYPIFIES THE 'CLEAN', WHITE, MODERN HYGIENE AESTHETIC.
[HTTPS://LANTERNSLIDE.WIKISPACES.COM/FRANCE](https://lanternslide.wikispaces.com/France) [CC BY-SA 3.0
 (HTTPS://CREATIVECOMMONS.ORG/LICENSES/BY-SA/3.0)]

state agencies come into alignment (Rose, 1990).

Bashford notes that Victorian culture made personal 'cleanliness' into a subjectivity, 'a practice which shaped one's soul' (Bashford, 2003: 5). Over the past 50 years much of the

moral hubris around hygiene has retreated, however there remain latent examples of Australians' commitment to cleanliness. For example, by the end of the twentieth century, Australian households were using on average about twice as much

water for bathing as the members of English households in the early 2000s (Pullinger et

al., 2013, Davison, 2008). This remains a source of contention in Australian–English rivalries. Davidson (2008) astutely points to Barry Humphries’ caricature of Australian Barry Mackenzie, once exclaiming on entering a London pub that he was ‘as dry as a Pommy’s towel’.

In addition to the cultural trends and institutions that shaped hygiene practices, designers adopted hygiene principles as a key aesthetic category that informed domestic architecture and interiors from around the 1930s. Cowan (1983) and Forty (1995) show how the development and introduction of new technologies have changed what it means to clean and imposed their own classifications of dirt. Drawing on examples such as minimalist, wipeable railway compartment upholstery, inbuilt hard-surfaced bathroom fixtures, vacuum cleaners and Le Corbusier’s buildings (pictured in Figure 5), Forty (1995) examines how a germ-based conception of hygiene shaped mid-twentieth century design. The objects that embodied this modern hygienic aesthetic also prompted people to see and understand dirt in new ways. For example, the introduction of the vacuum cleaner forced the user to see an accumulation of dirt in a way that made it more tangible and quantifiable, and advertising accompanying the newly expanding range of chemical cleaning products encouraged people to ‘see’ dirt where it was previously absent. Lupton and Miller (1996) have also made an important contribution through their research into modern domestic interiors by tracing how the modern bathroom emerged at the turn of the century as an overtly industrial construction with porcelain-enamelled features and light, washable surfaces that reflected a contemporary aesthetic of ‘obsessive cleanliness’; these trends were adopted with particular enthusiasm in Australia (Davison, 2008).

A number of researchers have also examined the interplay between design and hygiene at a larger urban scale (Campkin and Cox, 2012, Ogle, 1996, Melosi, 2008). For instance Melosi (2008) shows how large urban infrastructure and services such as electricity, water and sewage play a significant role in shaping the meaning and practice of cleaning, and consequently the expectations surrounding normal practices. Melosi (2008) and

Tomes (1999), identify that the forms public infrastructure and services take strongly reflect dominant theories of public health. The ideas of hygiene underpinning these infrastructures, such as modern plumbing and sewage, determined to a large degree how cleaning, waste removal and other practices take place in the home. For example, the Victorian-era sanitation system constructed in Sydney, Australia was a response to emerging knowledge and concerns about water-borne pathogens, prompting the use of water pipes flowing away from the city (Fam et al., 2009).

The hygiene infrastructures established throughout the twentieth century, and the domestic products designed to work within them, have enabled certain forms of 'dirt' and potential agents of disease to become more perceptible than others in the home. By sensitising people to the presence of potential germs through surfaces and appliances, certain disease-causing agents become more physically and culturally salient. This may engender what Murphy has termed a 'regime of perceptibility'. With reference to the values embedded in the development of ventilation engineering in buildings, Murphy states that:

Produced by assemblages that are anchored in material culture, regimes of perceptibility establish what phenomena become perceptible, and thus what phenomena come into being for us ... regimes of perceptibility populate our world with some objects and not others, and they allow certain actions to be performed on those objects. (Murphy, 2006: 24)

The exclusion of certain agents of disease, such as toxic chemicals, from common definitions, measurements and performances of hygiene can be understood as a regime that is excessively focused on eradicating germs.

The claim that dominant hygiene regimes and practices are characterised by a form of 'germaphobia', does not suggest that other conceptions of germs are not operative (Paxson, 2014). Indeed, growing research into, and popular media engagement with, the

significance of the human and built environment microbiomes in numerous aspects of human health are presenting a strong counter narrative (Lorimer et al., 2019). Research in countries across North America, Europe, Australia and others has documented various actions by communities and individuals that aim to cultivate mutually beneficial relations with microorganisms. These include practices such as fermentation (Dolejsova and Kera, 2017), the use of probiotic dietary supplements and cleaning products (Greenhough et al., 2018), and the use of faecal microbial transplants (Mackowiak, 2013). Many of these interventions that are designed to cultivate microbial ecologies that will be conducive to human health have little, if any, evidence to support them at this stage. Much of the current scientific knowledge is based on correlative studies between particular microbial ecologies and health conditions, while causative mechanisms remain elusive (O'Malley, 2016). Scientific uncertainty notwithstanding, little is also known about the degree to which 'probiotic' practices are altering mainstream hygiene practices, or the ways in which they are doing so. For now, research still suggests that a 'hygiene regime' persists in modern homes characterised by the perceived need to reveal and exterminate germs (Smith, 2007, Quitzau and Røpke, 2009, Campkin and Cox, 2012, Hand and Shove, 2004). Importantly, the presence of a hygiene regime in conceptions of how a room *should* look and feel guides domestic practices as much as, if not more than, fear of disease. As Mary Douglas states, 'In chasing dirt, in papering, decorating, tidying we are not governed by anxiety to escape disease, but are positively re-ordering our environment, making it conform to an idea' (Douglas, 1966: 2). More than this, she and many others have detailed the intricate association between hygiene and morality, and their shifting, but co-dependent parameters across cultures. Although the moral underpinnings of hygiene are less explicit in secular cultures, the imperative to maintain a clean home is still linked to being a good citizen, and particularly a good parent (Fasulo et al., 2007, Douglas, 1966, Lupton and Miller, 1996, Campkin and Cox, 2012, Martens and Scott, 2005). The aesthetic influence of hygiene on modernist design, and its role in defining acceptable aesthetic

standards for home and good housekeeping, can therefore be understood as an equally important driver of cleaning practices in the home as the actual fear of germs.

The following section examines implications of the conceptualisations of self and other, and the assumed boundaries between them, for the formation of hygiene practices, and ideas of hygienic dwellings.

2.5 HYGIENE AS A QUESTION OF BOUNDARIES

The preceding sections in this chapter have provided some history on the contingency of cultural understandings of hygiene, and the materials and practices that co-create them. This section addresses a question that logically follows from this problematisation of a stable notion of hygiene: What is a hygienic home environment? This is a substantial and metaphysical question that exceeds the scope of this thesis. I do, however, aim to edge closer to an answer, and disentangle some of the ontological disputes across disciplines that are currently determining how this question is being asked and answered. Achieving some clarity around definitions and measurements of hygiene will be crucial to understanding how human dwellings support or inhibit human health into the future.

Central to questions of hygiene are assumptions about the boundaries of different agents and the systems that make sense of them. This section will address how assumed boundaries between entities play a role in the systems that define toxicity and pathogenicity, and how they are being challenged by emerging research.

2.6 MICROBES BREACHING BOUNDARIES

Anthropologist Mary Douglas influentially proclaimed in 1966 that 'dirt is matter out of place', and that dirt requires 'two conditions: a set of ordered relations and a contravention of that order' (1966: 35). She proposes that cleanliness and contamination

are part of a classification system, used by all cultures, to manage boundaries. From this perspective, the ultimate purpose of beliefs about dirt and pollution are 'to force one another into good citizenship. Thus we find that certain moral values are upheld, and certain social rules defined by beliefs in dangerous contagion, as when the glance or touch of an adulterer is held to bring illness to his neighbours or his children' (1966: 3). Even in societies which respect and employ science to understand the world, dirt and pollution still reflect symbolic systems and visions of 'the good society'. Contests over definitions of dirt and pollution that employ science in different ways can therefore be understood as contests about what a good society means, and the form of proper relationships between industry, government and citizens. Although Douglas has been criticised for framing dirt simply as a social construction, thus ignoring 'natural' biological aversions to some materials (Dant and Bowles, 2003) others have argued that 'natural' and 'social' accounts can be easily merged, as certain biological predispositions lend themselves to particular ways of experiencing the world and creating categories to understand it (Campkin and Cox, 2012: 17).

It can be said that the hygiene regime that has dominated in the cultural West since the early twentieth century is based around a classification system which associates microorganisms with 'dirtiness', and thus something that is unwanted in human bodies and homes. This framing of microorganisms as 'other' and 'out of place' is associated with a history of biological thought which categorises all animals, including humans, as individual, functionally independent organisms within distinct species (Kirksey, 2015). From the time of their discovery, microorganisms were consequently perceived of as threats that would breach human defences and inhibit the normal functioning of the body (Smith, 2007, Latour, 1988). Despite a history of utilising microbes for purposes such as antibiotics and the degradation of explosives, a more nuanced understanding of their value and role in human biology has only recently begun to be part of dominant cultural understandings (O'Malley and Dupré, 2007).

Recent research at the intersection of microbiology and genomics has brought into question not only the assumed boundaries that had been drawn between human bodies and microorganisms, but the extent to which these supposedly independent types of species co-constitute one another (Paxson and Helmreich, 2014, Hird, 2010, O'Malley, 2016). This is important because the ways in which a culture conceives of human/microbial relations evidently plays a significant role in how humans attempt to control those relations through hygiene practices. The perception that it is better to exterminate as many bacteria as possible in the home to mitigate the risk of encountering a pathogen has been repeatedly demonstrated to be misguided and potentially harmful (Hartmann et al., 2016). As noted above, probiotic trends are emerging in response to increasing public knowledge of the microbiome, but their efficacy, penetration and forms remain largely obscured. Paxson (2008) also notes that an extreme 'post-Pasteurian' culture has formed in some places that advocates for unmitigated microbial freedom and the disabling of all microbial control. To investigate how human/microbial relations can be more usefully conceptualised in order to foster relations that are conducive to building healthy habitats for humans, we require an account of the key ways in which culturally dominant conceptions of species boundaries are being challenged.

Key challenges to the notion of species have occurred in what has been termed a 'microbial turn' in biology, and an 'environmental turn' in microbiology. O'Malley and Dupre (2007) note that decades of heated philosophical discussion about systematics and concepts of species within biology have either failed to notice the microbial world or deliberately dismissed it. However, they continue, this is now changing, and the assumptions which have determined how species have been defined and categorised are being challenged. A key reason for this was the discovery in the field of microbial ecology that microbes within a community can transfer genes between them, in a process known as horizontal or lateral gene transfer (Greenhough et al., 2018, von Wintersdorff et al., 2016). Microbes do this to enable a coordinated division of labour between differentiated

cell types that allow them access to more types of energy sources, habitats, protection and other group survival strategies (Shapiro and Dworkin, 1997, Crespi, 2001, Webb et al., 2003). This capacity for lateral gene transfer in communities undermines the assumption that a single organism has a single genome traditionally used to describe the genetic constitution of microbial communities and species.

Up until this 'environmental turn', microbiology was practised based on the model pioneered by Koch, whose 'postulates' for experimentally isolating a disease-causing process by removing organisms from their complex communities dominated microbiology for more than a century (O'Malley and Dupré, 2007). According to O'Malley and Dupre (2007), these postulates stressed two things: first, microbes are static single-celled individuals from which pure cultures can be developed, and second, tightly controlled uniform environments are necessary despite them being artificial constructions. Both of these assumptions, they argue, skewed microbiology until work on bacteria as dynamically interacting components of multicellular systems in a variety of non-laboratory environments began to gain traction in the last couple of decades. The body of evidence now supporting lateral gene transfer not only challenges traditional microbiology, but has raised important questions for the philosophy of biology, especially in relation to how biological individuality, evolution and the concept of species are understood.

The traditional philosophy of biology is based on the central ontological categories of the individual organism and lineage, while populations are understood as being constructed out of individuals (Kirksey, 2015). The developments in microbial ecology outlined above have prompted philosophers to ask questions about the ontological status of microbial communities, and whether the community organism is more fundamental than the individual organism. Although communities may not possess the level of physiological integrity and boundaries that individual organisms do, the recent research cited above clearly suggests microbial communities are more than simply co-located individuals.

Rather, it has been proposed that it is more appropriate to conceptualise microbial communities as individuals with partially indeterminate boundaries and some properties that are 'un-organism-like', although they still possess many organismal characteristics (Webb et al., 2003). If one positions a microbial system as more ontologically fundamental than its individual components, then its causal properties must be conceived of differently in relation to its influence on the micro- and macro-organisms involved (O'Malley and Dupré, 2007).

The cultural dissemination and materialisation of knowledge related the role of 'the microbiome' in human health has implications for hygiene practices. Individuals and organisations that have positioned human microbiota as 'another organ' (O'Hara and Shanahan, 2006), or as a supportive unified community of microbes that can be 'healthy' or 'unhealthy' in their own right, are misguided (Hooks and O'Malley, 2017). Philosophers of microbial ecology contend that this framing of human/microbial interactions risks reinvigorating the 'us and them' dichotomy that germ theory promoted (Skillings, 2016). A more compelling proposition is emerging that positions the human body and its microbiota as a single ecosystem, full of competition and functional cooperation for survival (Amedei and Boem, 2018). From this perspective, the microbiome does not act as a unified entity there to 'serve' humans (Hooks and O'Malley, 2017). The implication of this ecological perspective for human habitats and hygiene is that different types of interactions and interventions must be considered when determining the 'health' of different parts of the human/microbial system and how this system changes with different inputs (other microbes, food, environmental conditions) over time. A crucial outcome of this is that one cannot generally designate 'good' or 'bad' microbes, as their functions change along with environmental conditions.

The implications of the ‘microbial turn’ have begun to be recognised by social scientists interested in how it may shift understandings of the human ‘self’ and the ecologies it relies on. Paxson and Helmreich (2014: 166) claim that:

The microbial turn in recent biology, we suggest, marks the advent of a newly ascendant model of ‘nature’, one swarming with organismic operations unfolding at scales below everyday human perception, simultaneously independent of, entangled with, enabling of, and sometimes unwinding of human, animal, plant, and fungal biological identity and community.

The way that these new interactions continue to be defined, and the ways these definitions are materialised in culture, will continue to shape how we design the spaces and objects we live with, and their impacts on our bodies.

2.7 TOXICANTS CHALLENGING BOUNDARIES

Similarly, in discussing toxicity, Liboiron (2015) has indicated the importance of ‘techniques of definition’: the epistemological practices and tools that produce the boundaries and properties of novel entities. Following Douglas (1966), she contends that it is now science rather than religion that is the contemporary arbiter of ‘matter out of place’ (Liboiron, 2015). The way that science therefore defines pollution, and toxicity more specifically, is based on currently dominant epistemological traditions. A number of scholars in fields such as social studies of science (Liboiron, 2015, Bohme, 2014, MacKendrick, 2018, Murphy, 2006), endocrinology (Diamanti-Kandarakis et al., 2009) and exposure science (Ott et al., 2006) argue that the cultural and scientific boundaries that denote pollution and toxicity are currently being challenged by classes of post-industrial chemicals that are endocrine disrupting, bio-accumulative and persistent, among other novel ways of participating in biological systems. As noted above, traditional regulatory

toxicology is based on the principle that ‘the danger is in the dose’. Boudia and Jas, (2014) explain that from the 1920s and '30s, beginning in the United States, the notion that the human body and the environment could absorb a certain amount of a pollutant before causing harm became standardised and obscured other ideas of environmental and bodily pollution. Moreover, under this conceptualisation, for a toxic substance to be considered harmful it has to be both observable and quantifiable, and it must act in a consistent, linear, universal fashion. Much like the status quo in microbiology until recently, toxicology is based on testing substances in controlled laboratory settings removed from the interactions and contingencies that influence the behaviour of chemicals in the environment, and in bodies.

Understanding the ways in which new classes of ubiquitous chemicals are participating in human bodies will be crucial to developing a notion of hygiene that can account for some of the most pernicious emerging disease risks this century. EDCs pose a particular challenge to the idea of how chemicals are expected to interact with and

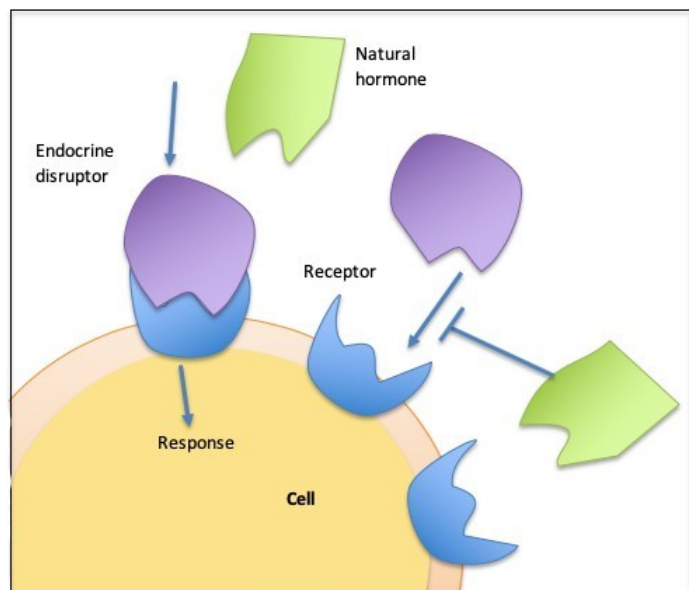


FIGURE 6: PROCESS OF ENDOCRINE DISRUPTING CHEMICAL ATTACHING TO A HORMONE RECEPTOR ON A CELL – ADAPTED FROM STAMATIAN AND GOIDESCU (2016)

cause harm in bodies under traditional toxicological models. Rather than acting like foreign trespassers or things that are ‘out of place’, EDCs imitate parts of and act within the body’s hormonal system. Normally, a hormone will travel through the body until it meets a receptor with a shape that fits its own, at which point they lock together (see Figure 6). Through this binding, the receptor communicates to DNA that it should start

performing a specific activity, such as building tissue or expressing genes. Endocrine disruptors have an effect because they mimic the shape of hormones, thus signalling DNA to perform particular tasks or prevent other hormones from binding to the right receptors. This process may not produce an evident or significant effect; however, it may produce the range of health conditions listed above that can significantly impact on quality of life, reproduction and mortality (Liboiron, 2015, Ott et al., 2006). Not only do EDCs produce inconsistent effects, people's vulnerability to them varies. As bodies develop, the endocrine system performs different functions, creating 'critical windows' in which EDCs can have more severe effects (Diamanti-Kandarakis et al., 2009). This type of non-linear, complex and contingent form of harm is not able to be accounted for by traditional toxicology, which requires the identification of a foreign substance that is 'out of place'.

Given the implications of toxic exposures for the health of individuals and communities, a new 'politics of evidence' has emerged in response to the contestation of the science currently employed to define harm (Liboiron et al., 2018). Toxic pollution of environments and bodies often cannot be demonstrated within the timeframe required to have it recognised and remediated, or removed from circulation, if it meets the regulators' criteria at all. Due to the inability of scientists to establish sufficiently conclusive results in the time limits required by regulators, other actors have begun to gather data and establish new modes of knowledge production and evidence by gathering data on exposed individuals to demonstrate associations between local exposures and increases in irregular health conditions. This gave rise in the 1980s to what Phil Brown calls 'popular epidemiology' (Brown, 1997). Increasingly since then, community groups around the world have mobilised to gather evidence that challenges those who are unwilling to recognise the harm being done to communities through toxic pollutants. Gabrys et al. (2016: 1) have proposed the concept of 'just good enough data': data that is not good enough to be deemed valid by regulators, but is good enough to demonstrate patterns that

could lead to conversations with regulators, to make claims about polluting processes, or to argue for more resources to be invested in altering regulatory standards.

The new politics of evidence that underpins non-government, or citizen-led monitoring practices not only contests the types of evidence considered valid, but in some cases highlights and challenges the social constructions of concepts of toxicity and harm. These practices do this by addressing the power dynamics inherent in processes which determine who gets to define what a risk is. Risk theorists such as Wynne (2006), Irwin (2014) have found that that community concerns are often labelled as incorrect risk perceptions, as though decision-makers have greater access to relevant information, and more ability to define what a risk is. However, decisions about what constitutes a risk often depend on what is scientifically measurable at the molecular scale, overlooking community concerns about the driving forces and interests that are determining how their land and bodies can be managed. As Zahara (2018) astutely puts it: 'Risk perception models are part of contaminant fetishization, where an object (e.g. dioxins) is mistaken for the thing it stands for (e.g. longstanding social inequities).' Alternative approaches have drawn attention to types of molecular interactions that are different to those heeded by regulators, and they have also challenged claims that symptoms of harm can only be validated when quantifiable changes in cells, molecules, or populations, discovered via laboratory research, are presented (Davis, 2014). An understanding of the contingency and complexity of harm from toxicant exposures will consequently be required to perform genuinely protective hygiene practices.

This chapter has presented an overview of some of the ways in which microbes and post-industrial chemicals are challenging the bodily and species boundaries that current hygiene practices, and assumptions about healthy dwellings, are premised on.

2.8 CONCLUSIONS

The background context presented in this chapter has aimed to demonstrate the inadequacy of a domestic hygiene regime centred on the extermination of germs in the face of emerging health risks in the home. It has provided examples of some of the ways that microbes and toxicants materialise in and shape cultural, design and scientific practices. It has also argued, through examples of emerging and still-contested scientific understandings of disease and the body, that the assumed agency and modes of behaviour of invisible entities embedded in contemporary hygiene regimes are unstable and in need of revision.

Perhaps the most important point addressed in this chapter for the argument developed in the remainder of this thesis is the contingency of harm associated with the emerging household risks. When hazards are inconsistent and dependent on complex situated interactions, modes of assessing risk based on laboratory experiments examining single microbes or chemical compounds on a single test subject are insufficient. Rather, an understanding of how the movements and material engagements that comprise everyday life structure the microecology of the home, and the types of beneficial and potentially harmful interactions it generates, is required.

The following chapter presents a review of the literature across fields that are currently interested in defining and intervening in environmental health and hygiene in the home.

3 LITERATURE REVIEW: ACCOUNTING FOR EPISTEMIC DIVERSITY IN INDOOR ENVIRONMENTAL HEALTH RESEARCH

In this thesis I have defined the problem of creating a genuinely hygienic home as a 'wicked', inherently transdisciplinary problem. Given that the territory this thesis inhabits crosses disciplinary boundaries, there is not a single 'gap' in one field that I am seeking to address. Rather, my research purpose and design emerged in response to a broad review of the literature, a review which indicated a lack of knowledge integration and the existence of divergent ontological and epistemological approaches to understanding health and hygiene in the home. The focused literature review presented in this chapter identifies some of the crucial contributions from diverse fields to knowledge related to microecologies of indoor environments and their effects. The review presented here does not aim to be comprehensive, as each publication that is included in this thesis contains a review of the literature relevant to the questions it addresses.

The first section of this chapter focuses on the ways in which key relevant fields have addressed the issue of microbial and chemical interactions in indoor environments and their effects on health that are not addressed within the publications. The second section then provides a short review of the literature related to the more-than-human theoretical approaches adopted to develop the theoretical framework for this thesis. This framework is a hybrid of social practice theories and multispecies ethnography. As this thesis develops, and applies, a novel combination and application of these theories, it is important to clarify the subjects to which they are generally applied and have developed in response to. A full articulation of the genealogies of these theories is provided in Chapter 4 and Paper 2.

To situate this thesis in the context of the diverse literature it is contributing to, it is first necessary to elucidate the ways in which the problem of sub-optimal indoor environments

is being conceived of and analysed across relevant fields. The way that 'problems' associated with indoor home environments are framed informs the types of interventions that are perceived as possible, and obscures others. Framing is the 'signification work' that focuses attention on an issue by prioritising one set of meanings over another, and by configuring the ways in which some objects or actors are seen or associated (Snow et al., 2013). When actors with divergent frames converge around a shared interpretation, framing can have a 'transformative function' in shifting collective understandings, and in enabling the emergence of those solutions that are more likely to succeed (Snow et al., 2013). Reinecke and Ansari (2016) argue that adequately framing a problem so that all relevant variables can be included in a proposed solution is particularly challenging in the case of 'wicked' problems that require multiple knowledge perspectives to come together. This is because there is ambiguity or disagreement over: (1) the root cause of the problem and the central actors responsible; (2) the proposed solutions, given the problem's ambiguity; and (3) how to mobilise support given the ambiguity around a problem's definition, root cause and solutions targeting relevant actors (Reinecke and Ansari, 2016). This review attempts to highlight some of the framing techniques that underpin research across a number of relevant fields, including: microbiology of the built environment, exposure science, social scientific research into environmental exposures, social practice research in domestic sustainability, and multispecies ethnography.

In restricting this review to these fields, I acknowledge the potential for my own biases and framing techniques to exclude some relevant perspectives. To limit the exclusion of important perspectives I have endeavoured to be as critically reflective as possible in this process. To do this, I conducted the 'boundary critique' presented in Chapter 1, which involved iteratively reviewing literature outside of the assumed boundaries of the thesis, or as new data emerged. The fields included are the ones deemed most important to both contextualise my research, and demonstrate how it may contribute to addressing sub-optimal home environments in the future.

3.1 MICROBIOLOGY OF THE BUILT ENVIRONMENT

Microbiology of the built environment has recently emerged as a field in response to evident links between building design and materials, and various pathologies associated with certain microbes. The approach to research within this field is based on scientific field sampling and lab testing, led by research centres such as the Fierer Lab Group at the University of Colorado (Fierer Fierer-Lab, 2019) who are studying the microbial composition of indoor spaces and how they interact with the humans that inhabit them. Similarly, the Rob Dunn Lab at North Carolina State University (Rob Dunn Lab, 2019) has been examining the unique microbial communities which have come to thrive in different indoor niches, such as shower heads and air conditioning units. The Biology and the Built Environment Centre at the University of Oregon (Biology and the Built Environment, 2019) have gone one step further and begun to design buildings that are intended to foster microbial communities that are supportive of human health. Last year (2017) a seminal Consensus Study Report was published by the United States National Academies of Sciences, Engineering, and Medicine titled 'Microbiomes of the Built Environment: A Research Agenda for Indoor Microbiology, Human Health and Buildings'. The report synthesises research to date and proposes a research agenda for the future. This report, and a number of other seminal papers examining the microbiomes of schools (Cavaleiro Rufo et al., 2017), hospitals (Smith et al., 2013, Holst et al., 2016), university buildings (Haleem et al., 2013, Meadow et al., 2014) and homes (Fall et al., 2015, Stein et al., 2016) have determined that architectural design significantly influences the diversity and structure of the built environment's microbiome.

The types of variables measured within this field include materials that are used to construct buildings, how buildings are ventilated, environmental factors such as temperature and humidity, and the concentration and diversity of microbes that exist under different building conditions. Research in this field has been able to demonstrate

how the construction of modern buildings out of synthetic materials, plastics, concrete, timber and cardboard treated with adhesives and biocides, and ventilated by air conditioning systems, have contributed to a significant shift in the types of microbial communities that thrive in different ‘niches’ within indoor spaces (Fahimipour et al., 2018, Green, 2014, Weschler, 2009). Rook and Knight (2015) found that when these modern structures degrade, become damp, or accumulate moisture in wall cavities, they do not become colonised with types of microorganisms that we have co-evolved with. This is important, given the hypothesised symbiotic relationship between bacteria classified as ‘old friends’ and humans discussed in the previous chapter (Rook and Brunet, 2005). The literature also emphasises that these types of modern buildings promote low microbial biodiversity, and often become habitats for uncommon bacterial strains, some of which synthesise toxic molecules (Sahlberg et al., 2010, Rook and Knight, 2015)

The literature suggests several interventions that may have some success at reducing exposures to harmful pathogens indoors and at increasing exposures to beneficial microbes. These include increasing outdoor ventilation rates; altering the type and efficiency of air filtration; employing more targeted air, water and surface disinfection strategies; and promoting indoor exposures to beneficial microorganisms (a strategy known as ‘environmental probiotics’) (Wang et al., 2013, Meadow et al., 2014, Caselli et al., 2016). The latter concept has been explored in the context of the proposed use of probiotics in cleaning agents in hospital environments, (Caselli et al., 2016) in pathogen control in plumbing systems (Wang et al., 2013), and in the microbial rewilding of urban areas (Mills et al., 2017). However, given the complexity and contingency of microbial ecologies, tailoring the right microbial interventions to specific urban and indoor contexts requires more research.

Although this field is primarily concerned with interactions between environmental variables (‘natural’ and human-made) and the microbiome, they recognise that occupant behaviour, health impacts, and potential trade-offs with energy consumption and

economic factors must be considered in research design (National Academies of Sciences Engineering & Medicine, 2017). The need to consider social variables, and to engage social scientists, is indicated across this research. However, it is rarely noted that social scientists could add value in terms of research design, or in determining what types of social factors should be studied.

For example, the 'Microbiomes of the Built Environment' (2017) report acknowledges the need for greater cross-disciplinary collaboration, including with social scientists, in their proposed 12 priority research areas, especially in areas 1, 2, 3 and 12:

Priority Research Areas

1. Improve understanding of the relationships among building site selection, design, construction, commissioning, operation, and maintenance; building occupants; and the microbial communities found in built environments. Areas for further inquiry include fuller characterization of interactions among indoor microbial communities and materials and chemicals in built environment air, water, and surfaces, along with further studies to elucidate microbial sources, reservoirs, and transport processes.
2. Incorporate the social and behavioral sciences to analyze the roles of the people who occupy and operate buildings, including their critical roles in building and system maintenance.
3. Recognize that human exposures in built environments are complex and encompass microbial agents, chemicals, and physical materials. Develop exposure assessment approaches to address how combinations of exposures influence functional responses in different human compartments (e.g., the lungs, the brain, the peripheral nervous system, and the gut) and downstream health outcomes at different stages of life.

12. Support the development of effective communication and engagement materials to convey microbiome–built environment information to diverse audiences, including guidance for professional building design, operation, and maintenance communities; guidance for clinical practitioners; and information for building occupants and homeowners. Social and behavioural scientists should be involved in creating and communicating these materials.

It is acknowledged in these priority research areas that humans will always influence the indoor environment through their presence as ‘important sources of indoor microorganisms and through their behaviors’ (National Academies of Sciences Engineering & Medicine, 2017: 225). The report also lists occupant comfort and perception as critical factors in building design and operation that will need to be incorporated into effective research on built environment microbiomes into the future.

Similarly, a recent study (Fahimipour et al., 2018) which examined the dust collected from athletic facilities to characterise relationships between indoor antimicrobial chemicals and microbial communities found that the use of antimicrobial products in these facilities was more strongly associated with antibiotic-resistant microbes than any other feature of the building. The authors acknowledge that:

Antimicrobials are typically deposited and transported by humans through use of toothpastes, antiperspirants, detergents, and cosmetics; they are also formulated into cleaning products, paints, flooring, furniture, kitchenware, toys, and appliances to reduce microbial loads in indoor environments (Fahimipour et al., 2018: 2).

Despite the evident importance of lifestyle practices in determining how and when these products are used, the need engage social scientists to investigate these factors is not discussed.

Aside from these specific instances, the broader literature in the microbiology of the built environment acknowledges several trends that are likely to continue to impact on building design and operation, including increasing urbanisation and densification; climate change; aging and adaptive reuse of buildings; and the use of chemicals indoors, including antimicrobials. However, there is an assumption embedded in a number of the texts reviewed (National Academies of Sciences, 2017, Smith et al., 2013, Kembel et al., 2012), and particularly evidenced in Priority Research Area 12 above, that the role of social scientists will be to communicate research findings and enable the smooth operation of any interventions that are designed, rather than contributing to the research design itself.

This limited understanding of the role of social science overlooks the benefits of research designed to investigate shifts in microbial composition based on different cultural practices that inform how buildings are designed and lived in, and that influence the use of products such as synthetic fragrances and antimicrobials. Social research could provide valuable insights into the drivers and types of interventions that may prove effective in different contexts, in addition to the identification of which microbial communities thrive under different building conditions and maintenance practices.

In addition to social research, the literature reviewed in this field also acknowledges, but does not yet fully integrate, ways of understanding environmental health that focus on how multiple interacting entities are transformed by how they interact at the site of exposure. Priority Research Area 1 of *The Microbiomes of the Built Environment* report states that 'Areas for further inquiry include fuller characterization of interactions among indoor microbial communities and materials and chemicals in built environment air, water, and surfaces' (2017a: 225). Studies in the field of exposure science contend that in order to glean meaningful insights into the effects of interacting entities, it is important, to study not only the sources of potential exposure, but also how they interact at the receptor on the 'target' (e.g. a human) exposed (Senier et al., 2017). To do this, it is necessary to understand how targets move through the world and become exposed. The following

section reviews the approach to reviewing indoor environmental research in exposure science, and its synergies with the other research fields examined.

3.2 EXPOSURE SCIENCE

Exposure science is a recent field to emerge within the environmental health sciences alongside the older disciplines of epidemiology and toxicology (Lioy, 2010, Lippmann, 2013). Approaches to environmental health assessments grounded in traditional toxicology are based on a method that begins by examining a source of pollution, such as a smoke stack or contaminant leak into a water source, and then tries to establish who may be affected (Ott et al., 2006). This source-based approach presents challenges for assessing the exact impacts the pollutants are having and on whom. Exposure science emerged as a field largely in response to this limitation. Exposure scientists focus their investigations on a target and measure what pollutants actually reach them, and how they interact within them, and they then work backwards to find the source (Lioy, 2010). Crucially, this was made possible by technological developments that enabled interactions at the receptor to be accurately measured for the first time. This approach has been central to the discovery of many previously unknown indoor sources of indoor pollution, such as consumer products and building materials, that are now emerging as key contributors to human exposure and environment-related illness (Wild, 2012).

The term 'exposome' has been coined to refer to the total cumulative exposures of an individual in a lifetime and how those exposures relate to health (Wild, 2012). The primary methods employed within exposure science are a combination of personal monitoring and probability sampling across a population. Significant contributions have also been made through 'activity mapping', which involves fitting people with personal exposure monitors to detect particular pollutant/s of interest and then tracking increases in exposure based on the amount of time spent in different locations at different times of

the day, such as the home, the workplace, in vehicles or outdoors (Rappaport and Smith, 2010, Ott et al., 2006). Modes of sampling can also include blood, urine, hair and breast milk, and umbilical cord testing to determine the initial presence and levels of pollutants (Ott et al., 2006). The growth of this field and technological innovations have led to the emergence of a number of projects that are attempting to map the human exposome, some of which are HELIX: The Human Early-Life Exposome (HELIX: Building the Early-Life Exposome, 2019) *ECPOsOMICS* (ISGlobal: Barcelona Institute for Global Health, 2019), and HEALS: Health and Environment-wide Association (HEALS, 2019) based on Large population Surveys. The Human Exposome Project (The Human Exposome Project, 2019), much like the Human Genome Project, has also been proposed and is likely to commence in the near future.

It is claimed across the literature that the emergence of exposure science research represents a shift away from the individualised paradigm of disease causation that dominated epidemiological research throughout the twentieth century (Senier et al., 2017, EWG, 2003, Brody et al., 2009, Zota et al., 2008). Traditional epidemiology in this period framed disease as a product of individuals' innate susceptibilities and lifestyle decisions, rather than as a product of macro social or environmental conditions. This reflection is also captured in Rose's theorisation of the 'mode of thought' that emerged with the 'molecularisation of life', that focused on individual practices and risk, as discussed in the preceding chapter (Rose, 2007). Senier et al. (2017) detail the ways that exposure science moves away from this individualised paradigm in conceptualising and addressing environmental health in four important ways: first, it acknowledges that timing and other factors are as important as, if not more important than, the dose of a substance one is exposed to; second, it recognises that there are crucial 'windows of development' in which humans are more vulnerable; third, researchers, advocacy groups, citizens and public health agencies have developed monitoring tools and initiatives to begin to gather evidence of the accumulation of environmental toxicants in people by sampling things

such as blood, urine, hair and breast milk (LaKind et al., 2004, Adibi et al., 2008, Ott et al., 2006); fourth, exposure science is advancing to account for chemical interaction, and the effects of cumulative and low dose exposures.

While this target- or receptor-oriented approach is accepted and encouraged within some fields, such as public health (Ott et al., 2006), the majority of environmental regulators around the world still employ a source-oriented approach to studying health issues that fits with an individualised model of disease causation. The persistence of a source-oriented approach is problematic for the four reasons outlined above, but also because of the importance of what scholars in both the microbiology of the built environment and exposure science have termed a 'personal cloud': the unique communities of micro-entities and interactions that directly surround the human body (Bachmann et al., 1996, Meadow et al., 2015). Although no evidence of cross-referencing of this concept between these two fields could be found, they have significant implications for one another. In exposure science the personal cloud refers to personal exposure to a pollutant in concentrations that are higher than concentrations measured simultaneously indoors. This 'cloud' results from the activities of individuals, such as walking on a carpet, generating particles that only affect the individual or a small localised area surrounding the person (Bachmann et al., 1996). Similarly, a 2015 study (Meadow et al.) found that humans carry personalised 'microbial clouds' that have a distinct community structure. In both cases studies suggest that human action re-suspends material, which carries pollutants and airborne bacteria and fungi into one's 'personal cloud', to structure exposures, particularly in low-ventilation, densely occupied settings (Hospodsky et al., 2012, Qian et al., 2012).

I could not find any research that links the analysis of chemical and microbial 'personal clouds' through an examination of the daily activities that determine cloud composition, and hence exposure. Moreover, no research could be found that assesses the cumulative effects on these clouds of successively and routinely performed activities, to provide a

sense of the temporality of shifts in composition. Although exposure science has contributed significantly to knowledge of exposures linked to specific types of locations (e.g. home vs. vehicle) there is limited evidence of research into the effects of different practices and interactions between types of product use within those locations. A number of studies have examined products such as flame retardants (La Guardia et al., 2017) and 'air-fresheners', and their molecular transformation under differing indoor conditions (Steinemann et al., 2017, Mitro et al., 2016). One study was also found that included research into habits and practices in relation to exposure models for soaps, cosmetics and air care products using an existing aggregate exposure model (Comiskey et al., 2017). However, it only employed surveys rather than an in-depth exploration of practices. To begin to understand how normative lifestyle preferences may be contributing to exposures, and the probability of interventions being able to disrupt aspects of these lifestyles, such as air-fresheners, these practices must be investigated.

The progress made in exposure science and the microbiology of the built environment is essential to answering the broad questions at the core of this thesis about how the materials that populate our domestic practices influence the hygiene of home environments. However, alone, these fields cannot account for the cultural, political, corporeal and material interactions that generate exposures to harmful pollutants and pathogens. A number of scholars working in environmental and health justice caution that approaches to personal and environmental monitoring that only measure changes at the molecular level risk further entrenching definitions of harm embedded in the threshold theory of pollution that underpins the maxim 'the danger is in the dose' in traditional toxicology (discussed the previous chapter)(Boudia and Jas, 2014, Murphy, 2008). Liboiron (2015) argues that the threshold model of pollution is based on three premises: first, that some level of a pollutant is allowed and accepted as normal; second, perceptible pollution marks the moment that harm occurs; third, that harm is able to be observed, measured and traced in a laboratory, rather than traced via medical methods which attend

to the experience of the person. In this model, harm is only said to have occurred when the third condition is met. The literature suggests that the harm-as-molecules perspective has been pursued since the early twentieth century, when a shift occurred in the way that harm was conceptualised, away from a notion based on experiences of suffering to an idea grounded in observable changes in cells (Shapiro and Kirksey, 2017, Murphy, 2008). This perspective became institutionalised and normalised post-World War II when ‘acceptable levels’ of many pollutants were written into key environmental laws across the United States and Europe (Boudia and Jas, 2014, Davis, 2014, MacKendrick, 2018). Harm has since primarily been taken to mean a quantifiable biochemical alteration in cells, molecules, or populations measured in a laboratory rather than pain or suffering experienced by an individual or community (Davis, 2014, Shapiro, 2015, Murphy, 2006).

Although recognising and measuring changes at the molecular level is evidently crucial to understanding how non-human micro-entities are acting and interacting with human bodies and in the environment, these molecular changes should not be the only measure of harm. As can be seen in studies such as Cannon et al. (2018) into the profound effects of worry associated with not feeling safe and protected from contamination, and studies of the experiences of First Nations communities whose land or food resources have been placed at risk, suffering is not only associated with changes at a cellular level (see contributions in Sarathy et al., 2018). The experience of hazard, or potential hazard, in the home has been found to affect not only people’s sense of existential security, but also the ways in which people attempt to create a healthy, safe (hygienic) home environment. There is now an emerging body of social scientific literature that is paying greater attention to the socio-cultural dynamics involved in how exposures are generated and measured, and how their effects are felt. Some of the contributions of this research are discussed below.

3.3 A SOCIAL SCIENTIFIC LENS ON EXPOSURE RESEARCH

In response to the limitations of measuring and sequencing molecular interactions as a way of determining environmental health and harm, social scientists are increasingly making the case for their inclusion in the future development of this field. Wild (2012) argues that the term exposome was originally coined with the intention of cataloguing and quantifying environmental exposures as accurately as genes have been measured. Rappaport and Smith (2010) and Senier et al. (2017) claim that approaches to examining the exposome to date, including the projects listed above, have primarily focused on individual-level exposures rather than the social determinants of health: the conditions in which people are born, raised, live, work and grow old.

Marmot et al. (2008), Senier et al. (2017), Hoover et al. (2015) argue that these approaches have begun to resemble other recent life science projects (such as epigenetics) that, while acknowledging the importance of measuring complex socio-environmental effects on human health, often fail to adequately recognise the social scientific expertise and empirical work already being done (Landecker, 2011, Darling et al., 2016, Niewöhner, 2011). Key issues with failing to engage social scientists include the aforementioned risk of reducing complex social phenomena to molecular changes, and the pursuit of particular research questions and agendas that only serve the interests of a limited group. The neglect of the social determinants of exposure that condition population-level variations and the focus on individualised molecular-scale differences in research could therefore inhibit the potential to improve environmental conditions for all (Marmot et al., 2008, Sarathy et al., 2018).

Some researchers (Senier et al., 2017, Juarez et al., 2014) have positioned current exposome research at a 'fork in the road', as research could go down one of two paths from here: first, it could follow the path of genome research and take an individually-

oriented turn which is primarily expressed in personalised medicine initiatives, or second, it could follow a path that seeks to link environmental exposures to disease outcomes in ways that account not only for biological processes but the social, political, and economic factors that create vulnerabilities to particular types of exposures (Senier et al., 2017, Juarez et al., 2014). The risks of pursuing the first path are that 1) personalised medicine is generally only available to those who can afford it, further exacerbating existing inequalities in access to health care, and 2) by turning away from the structural causes of diseases to focus on personalised treatments, these causes remain unaddressed and may be amplified (Juarez, 2019). To link environmental exposures to their social origins, it is acknowledged in the literature that a transdisciplinary approach is required. Senier et al. (2017: 107) claim that: 'Understanding the exposome is a prototypical transdisciplinary problem, one that provocatively illustrates both the rewards and risks inherent in contemporary bioscience'. Transdisciplinarity is important here, rather than multi-disciplinarity or interdisciplinarity, as the social, material, ecological and health aspects of the problem are so deeply entwined that it does not make sense to conceive of them in a disaggregated way. Hoover et al. (2015: 1104) illustrate some of the ways that transdisciplinary research into environmental health is already contributing:

Transdisciplinary environmental health research has increased awareness of effects beyond the physical and health consequences of environmental disaster and contamination to include community empowerment, ethical practices of sharing data, and policy implications.

An example of transdisciplinary collaboration cited by Hoover et al. is the Household Exposure Study, a United States National Institute of Environmental Health Sciences' community-based participatory research project that evaluated exposures to pollutants from legacy contaminants, consumer products and local emissions (Brody et al., 2009).

These types of transdisciplinary exposure research projects have emerged out of a broader field of social studies of environmental health, particularly within sociology and anthropology. They have been evolving since the 1980s, and they have made significant contributions to knowledge of experiences of contamination and debates about responsibility and action (Crichton et al., 2013, Altman et al., 2008, Brown, 1997). Diverse, often cross-disciplinary, social scientific studies have informed environmental health science through ethnographic studies of contaminated communities (Sarathy et al., 2018), geographical distributions of environmental injustice (Maantay, 2002), psychological and affective experiences of contamination (Connon et al., 2018), cultural and community impacts of environmental violence and disasters (Nixon, 2011) and the social construction of risk frameworks and perceptions (Crichton et al., 2013, Zahara, 2018). Research in this area has not only shed light on the causes of pollution and environmental injustice, but has helped equip and empower communities with the organisational skills, and often the scientific hardware, they need in order to speak out. This literature is reviewed more extensively throughout the papers in this thesis, particularly in Papers 1, 2 and 5, so I will avoid repetition here. However, it bears noting that despite significant advances in collaborative social and scientific environmental health research, the role of everyday practices in structuring the complex interactions that determine pollutant exposures has not been analysed in any of the literature examined.

This section has established the value of current approaches to assessing exposures to chemicals and microorganisms in the domestic environment, and the limitations of the existing research parameters of the microbiology of the built environment and exposure science. It has also provided an overview of some of the reasons why a deeper analysis of the social determinants of health is required, and has outlined how social scientists are beginning to add value to the design and analysis of scientific research into indoor environmental health. The following section reviews some of the social scientific literature

that I propose may be usefully applied to progressing our understanding of the practices that reflect and help construct the social determinants of health in home environments.

3.4 SOCIAL PRACTICE RESEARCH IN DOMESTIC SUSTAINABILITY

This section provides an overview of how social practice theories have been used to address other research questions, and why I argue they provide the most suitable approach for my investigation. A more complete account of the ontological positioning and practical orientation of social practice theories is provided in the following chapter.

Social practice theory refers to the heterogeneous body of thought that takes the concept of ‘practices’ as central to social life. Emerging since the 1970s against the background of the philosophical work of Wittgenstein and Heidegger (Hui et al., 2017), social theorists such as Giddens (1984), Bourdieu (1977) and Pickering (1993) established the theoretical grounding for what is today most commonly referred to as social practice theory. Maller (2018) notes that in the 2000s a more cohesive group of practice theorists emerged, including Schatzki et al. (2001), Shove et al. (2012), Reckwitz (2002a), who outlined what a social practice ontology is and its potential utility for research and policy.

Social practice theories have been developed and utilised by social theorists in response to the perceived limitations of individualised behaviour change strategies that do not adequately account for the reasons why people use resources, what constitutes their ‘needs’ and ‘wants’, and how they are changing within the broader context of everyday life (Hui et al., 2017, Shove, 2017b). Much of this work has been oriented to the examination of everyday practices, such as bathing, cooking, laundering and house cleaning, which continue to shift in a direction that requires ever more resources. The premise of this research is that to change practices to reduce resource consumption, the composition of practices, and how they evolve, persist and fade in everyday life must first be understood.

Since the late 1990s, social practice theories have informed the study of numerous phenomena, including consumption, teaching, nursing, migration, organisational studies, environmental sustainability and energy use (Pullinger et al., 2013, Reckwitz, 2002a, Ryghaug and Toftaker, 2014, Sahakian and Wilhite, 2014, Scott et al., 2009, Strengers and Maller, 2014, Watson and Meah, 2012). In the context of environmental sustainability research, a social practice approach is distinguished by its focus on how assumed needs are constructed and embedded through practices, rather than seeking more environmentally sustainable ways of meeting existing perceived needs. Central to this questioning, is an interrogation of how particular conventions become normal while others fade, and the consequences of this process for the way we use resources (Sahakian and Wilhite, 2014, Strengers, 2011a, Strengers and Maller, 2014).

As noted above, social practice theories have an extended and heterogenous lineage, but their application to questions of sustainability in the context of everyday domestic life are often traced to Shove's (2003) text *Comfort, Cleanliness and Convenience: The Social Organization of Normality*, although a few other papers on domestic provisioning, social practices and sustainability preceded this text (Shove and Southerton, 2000, Harvey et al., 2001). The research agenda that was articulated within this text is based on three premises outlined within it: first, that domestic consumption and domestic practices are inextricably linked in the reproduction of what people consider to be normal ways of living; second, that much of the resource consumption that takes place throughout the course of everyday life is 'invisible' or 'inconspicuous' and bound up with routines – particularly in relation to energy and water; third, changing routines, and expectations of how they should be performed, has significant consequences for the resources required to sustain everyday domestic life. An important implication of this perspective is that targeting individuals to make more sustainable consumption choices, based on the needs and preferences they consciously consider, may not precipitate the change required if those choices are not enabled by broader socio-material conditions and perceptions of

what certain routines *should* look like (Hui et al., 2017, Shove, 2003). Rather, research that fits within this broad agenda attempts to examine the constitution of this socio-material landscape, and the collective practices it supports (Hui et al., 2017, Shove, 2003, Strengers and Maller, 2014, Schatzki, 2016).

I propose that a social practice orientation may afford unique insights into the investigation of how regimes of hygiene and chemical living are materialised, performed and reproduced in daily life. Through sensitising the researcher to the dynamic interplay of material, emotional, cognitive and bodily elements at play within and between practices, the many modes of engaging – in body and mind – with micro-species can be traced. Unlike studies that exclusively focus on a research participants' phenomenological accounts of the world, a social practice orientation is also attentive to the structural forces that guide the construction of infrastructures or social institutions (Hui et al., 2017). Actor Network Theory may also be an instructive theoretical frame through which to understand relations between human and non-human actors in the home. However it lacks the focus on repetition and reproduction embedded within practice-oriented approaches (Maller, 2018). I propose this attentiveness to repeated sequences of action is vital to understanding the material flows that cumulatively and interactively structure and transform the ecologies of homes and their human occupants *over time*. In particular, a focus on the routinised and habituated aspects of social practices, and the way they are distributed, made and performed across different communities, is essential for understanding the dynamics of contamination, toxicity and microbial interaction that is to be analysed in this thesis.

To my knowledge, social practice theories have not yet been applied to the study of living and non-living entities within a microecology. Sustainability-oriented research conducted from a social practice perspective has overwhelmingly focused on the water and energy consumption associated with collective conventions. This research has produced valuable insights into bathing practices (Pickerill, 2015, Pink and Mackley, 2015) laundering (Jack,

2013b, Kaye-Smith, 2017) and food preparation (Delormier et al., 2009, Watson and Meah, 2012) or combinations and intersections of these practices in relation to overall resource demand in different social contexts (Strengers, 2011b, Maller, 2011, Sahakian and Wilhite, 2014, Gram-Hanssen, 2014) among other energy and water consuming practices. While social practice theories are increasingly interconnected with theorisations of more than human worlds (for example, Maller, 2018, see Chapter 4 for further elaboration), these literatures tend to focus on interactions with larger species, such as birds and dogs, and other dynamic non-humans, such as autonomous vacuum cleaners (Strengers and Maller, 2019). The agency of micro-scale materials and organisms in the constitution of practices has not been broadly considered.

Importantly, Shove et al. (2007a) highlight the need for greater attentiveness to the material culture of substances and micro-materials. The authors argue that in only attending to the symbolic qualities of objects in analyses of their significance, the co-evolution of materials and objects has largely been neglected in the social sciences. They note that changing materials are central to changing concepts of performance, and that concepts of performance that new materials introduce have significant consequences for the material world as a whole. Through examples of the replacement of conventional materials in certain domestic objects in the mid-twentieth century, such as ceramic for plastic, they show how the relational fabric of material interactions can be reconfigured. These insights have made a constructive contribution to thinking about the importance of materiality beyond the symbolic character of objects. However, none of the social practice literature reviewed for this thesis has examined the role of micro-materials such as post-industrial chemicals and microorganisms in orienting and enabling collective domestic practices. This thesis aims to begin to link the insights gleaned through research into hygiene practices with insights into their implications for the micro-configuration of domestic ecologies.

3.5 MULTISPECIES ETHNOGRAPHY AND CHEMO-ETHNOGRAPHY

To begin to address questions of the emergent agency of living and non-living micro-species within social practices, I have drawn on the theory and literature relating to multispecies ethnography and chemo-ethnography. There are a number of potential assemblage (Strengers et al., 2016) or non-representational (Thrift, 2008) theories that have been used by other researchers to delve more deeply into particular elements of practice in response to different questions. For the purposes of this thesis, multispecies ethnographic and chemo-ethnographic approaches emerged as the most appropriate. This is because they attend to the nature of living and non-living non-human encounters, as they relate to and problematise our standard categories for understanding these relations, such as “species” and “life”.

Multispecies ethnography can be understood as the product of a turn in anthropology towards animals. Beginning primarily with studies of animal pastoral relations, the growth in this field saw anthropological publications emerge such as *The Animal Estate* (Rittvo, 1989) and *Creatures of Empire: How Domestic Animals Transformed Early America* (Anderson, 2006). In a review essay in 2002, Mullin notes that anthropologists must now not only begin to revisit old interests in evolution and domestication; they must also develop a means of understanding phenomena such as genetically modified organisms. At this time, the material entanglements between humans and other organisms increasingly demanded anthropologists attend to interventions in biological processes in the laboratory, and to the effects of these interventions in the world (Benson, 2010). Donna Haraway's (2008) *When Species Meet* captures this momentum as a seminal text of this turn. At this time the particular ways that even invisible species exert agency became a point of focus. This is highlighted in Schrader's (2010) examination of *Pfiesteria piscicida*, a 'phantom dinoflagellate' whose agency is only exposed via the fish kills it leaves behind. Ethnographers also began to conceive of microbes as social agents in diverse settings such

as the ocean (Helmreich, 2009), and in food practices such as cheese making (Paxson, 2008). As this field emerged in earnest as multispecies ethnography in the late 2000s, the discussion of human/animal relations began to centre on questions of relationality, governmentality and care (Kirksey and Helmreich, 2010). Multispecies ethnographers now investigate the numerous ways the livelihoods of human and non-human organisms shape and are shaped by political, economic, and cultural forces, generating mutual ecologies.

Like multispecies ethnography, chemo-ethnography emerged within anthropology in response to the perceived need to account for the role of emergent forms of non-human agency that were beginning to transform social and biological lives. Chemo-ethnographers have been particularly interested in exploring the role of many post-industrial chemicals in shaping social and cultural phenomena, from rave culture, to chemotherapy, to communities living with legacy contaminants (Shapiro and Kirksey, 2017, Langlitz, 2013, Jain, 2013). In some cases, researchers have come to chemo-ethnography via multispecies ethnography. However, it also has other branches, including environmental justice circles that preceded the emergence of multispecies ethnography, and medical anthropology, with a focus on the relationship between bodies and markets associated with pharmaceuticals and processed foods (personal communication Shapiro 2019, Shapiro and Kirksey, 2017). The value of adding this perspective, in addition to the multispecies perspective, is that it attends to the transformative capacity and modes of agency and interaction at the molecular scale, and that it is attuned to the unique ways in which post-industrial chemicals are participating in bodies and ecosystems. The novel ways in which these chemicals participate cannot be predicted in the laboratory. In addition, chemo-ethnographers do not exclusively analyse phenomena based on the assumed significance of categories of life and non-life. The importance of this binary division to the way practices interact with microecologies is discussed in greater depth in Paper 2.

The theoretical lenses guiding multispecies- and chemo-ethnographic approaches sensitise the researcher to the agency of micro-entities that are having a profound effect on, and are being affected by, everyday social practices and material arrangements. The exact epistemological contributions of social practice and multispecies ethnographic and chemo-ethnographic approaches are discussed in the following chapter.

3.6 CONCLUSIONS

This chapter has examined the ways in which research related to domestic hygiene has been framed, bounded and advanced across disparate fields. The developing field of the microbiology of the built environment has contributed significantly to our understanding of how different materials, products and spaces within homes encourage different microbial species to flourish. Indoor environmental health has in this context predominantly been defined in relation to both pathogenic and commensurate microorganisms that occupy the environments we build and dwell in. Although there is an acknowledgement of the role of household chemicals, and the perceptions that may drive their use, no significant engagement with researchers examining complex interactions between post-industrial chemicals and microbial communities in home environments could be found. The important exception to this is the research on the role of antimicrobial chemicals in promoting antibiotic-resistant species of microorganisms in indoor spaces (Geens et al., 2009). However, the social elements of exposure are still largely excluded from these studies.

The limited acknowledgement in the literature of the potential value of social research in determining how and why the conditions for particular microbial communities and toxicant exposures have been established potentially obscures important causative mechanisms and future research avenues. This thesis proposes that engagement with social scientists in the framing and design, as well as dissemination and evaluation, of

research could help transform research agendas within both the microbiology of the build environment and exposure science. Although it must be recognised that the degree to which researchers within these disciplines have engaged with social science may not be made transparent in published research, based on disciplinary conventions for designing and reporting scientific research, no evidence could be found of research collaborations in which researchers from microbiology, architecture, exposure science and the social sciences have designed and examined the nature and drivers of sub-optimal indoor environments together.

The emergence of social scientific research into exposome science potentially represents a 'bridge' which may build networks and facilitate greater engagement between these disciplines (Senier et al., 2017). This field has brought together engineers and exposure scientists with activists and social scientists to develop ways of using sensing devices and mapping techniques to further social and environmental goals (see LaKind et al., 2004, Adibi et al., 2008, Ott et al., 2006). Through attempting to shape the emerging exposome research agenda, social scientists are hoping to bring to the fore the cultural and material forces this research agenda will deem relevant. This thesis fits within and contributes to this emerging socio-exposome field. It endeavours to add to existing socio-exposome research within sociology and anthropology by examining some of the ways in which everyday practices structure and entrench particular interactions between microbes, post-industrial chemicals and humans.

Based on the state of knowledge, and the collaboration and gaps identified in the literature reviewed in this chapter, I propose in this thesis that research into social practices may help to identify the drivers of current conditions and improve insights into the practices that have led to some microbial communities and chemical toxicants flourishing in the material ecologies of modern homes in much of the world. Although research into domestic practices related to cleaning have focused almost entirely on understanding and reducing the use of energy and water, the insights and approaches provided in these

studies represent a valuable tool, not only to complement and guide research into microbial communities and toxicant exposures, but also to redesign practices, and the 'needs' and systems of material provisioning that enable them. Moreover, the combination of multispecies ethnography and chemo-ethnography with a social practice perspective can sensitise the researcher to additional forms of emergent agency at the micro-scale, that influence and are influenced by social practices. Although the integration of multiple theoretical perspectives carries inevitable challenges associated with attending to sometimes conflicting theoretical and methodological commitments (Shove, 2011), it is proposed that the integration of knowledge and perspectives across these fields could lead to the required redefinition of hygiene discussed in Chapter 6, not only in narrative, but also in the embodiment and materiality of practice.

The following chapter describes the theoretical lens that guided this research based on theories of social practice, and elements of multispecies ethnography.

4 THEORETICAL FRAMEWORK: THEORISING MULTISPECIES INTERACTIONS WITHIN SOCIAL PRACTICES

This chapter presents the theoretical orientation and assumptions that underpin the research approach of this thesis. It details how the guiding theoretical lens adopted led to the specification of the key variables that are considered in relation to domestic hygiene practices and the microecologies they produce. The theoretical framework developed in this chapter is a hybrid of two approaches to understanding more-than-human practices: social practice theory and the approach that underpins multispecies ethnography and chemo-ethnography.² After briefly outlining some of the shared ontological foundations for the more-than-human approaches used, I examine how social practice epistemology sensitises the researcher to a particular set of research objects and interactions. I then briefly state why this epistemological approach can help elucidate the relationships crucial to understanding the performance and consequences of hygiene practices in modern home environments. Taking social practice theory as the 'lead' theory for my investigations, I draw on approaches grounded in multispecies ethnography to orient my research of micro-species interactions within the performance of hygiene practices. Finally, I detail how this hybrid theoretical approach informed my research design and the methods selected.

4.1 THEORIES FOR MORE-THAN-HUMAN PRACTICES

In line with Maller (2018) and Phillips (2014) I categorise social practice and multispecies approaches as broadly more-than-human. More-than-human thinking and theories span

² When referring to multispecies ethnography and chemo-ethnography collectively I will just use the term multispecies ethnography from this point forward.

multiple disciplines, including human and cultural geography, science and technology studies (STS), environmental humanities, post-humanist sociology and anthropology, among others. I will not cover the extent of its genealogy here, but it is important to note a few crucial elements of its emergence, and uniting characteristics.

Across these disciplines, more-than-human approaches have served to destabilise ways of theorising categories such as materiality, agency, relationality and causality. They do this by drawing focus away from the intentions and agency of humans, to understand the world through the dynamic relations that emerge through complex interactions between multiple human and non-human agents (Phillips, 2014, Whatmore, 2006). The development of more-than-human theories has been charted in different disciplines (see Whatmore, 2006), and Maller (2018) has traced their development across multiple disciplines according to three 'turns' crudely summarised here as: the Affective Turn, the New Materialist Turn, and the Practice Turn. The Affective Turn charts a move away from the representational and linguistic focus in social science, particularly in human geography and linguistics, to bring in a greater attention to how emotions, feelings and other experiential and pre-cognitive states influence modes of being in the world (Thrift, 2008). It shares with other more-than-human approaches a focus on emergence over representation and quantifications.

The New Materialist Turn, principally experienced in STS, geography and political science, engages with how matter comes to have agency in the world, with a particular focus on its performativity and 'vibrancy'. The 'New' serves to mark a difference in these theories from Marxist materialist conceptions to varying degrees. They often draw on pre-Marxist conceptions of materialism (Coole and Frost, 2010). These heterogeneous perspectives emphasise emergent entanglements and the consequent uncertainty of all outcomes. Maller (2018) proposes that the Practice Turn, concretised in social practice theories since the early 2000s, has a more dispersed history than the other turns. Its theoretical evolution is briefly catalogued in the preceding chapter, but it is worth adding here that

these theories share with other more-than-human theories the decentring of human cognition, and that they emphasise the interplay of agencies that emerge through acts of 'doing' and their constituent bodily competencies and knowledge, meanings and beliefs and materials (Phillips, 2014). Despite practice-based accounts often relying on humans as 'carriers' of practices – although this position is increasingly being questioned (see Strengers and Maller, 2019) – it can be considered more-than-human through its commitment to agency as relational and emergent in practice.

For the purposes of positioning this theoretical framework, the key shared commitments of more-than-human approaches include:

1. the rejection of human exceptionalism and acknowledging the relational agency of multiple 'materials' such as microbes, animals, plants, artefacts and technologies in social life
2. an emphasis on the dynamism of form, agency, time and space, and the identification of patterns through relations that link past and present, and geographically dispersed points
3. the collapsing of common boundaries such as agency and structure, macro and micro (advocating for flat ontologies)
4. an emphasis on ongoing processes, doing and performance through the enactment of everyday mundane activities and practices
5. the privileging of embodied knowledges, affect and experience over cognitive modes of knowing the world (Maller, 2018, Phillips, 2014, Whatmore, 2006).

Despite these points of commonality, the different emphases brought by each ontological stance influence the types of futures that are imagined and actioned. For example, in social practice theories, the key units of analysis, practices, are necessarily repeated over time.

An investigation of this repetition over time is considered crucial to understanding phenomena such as how many and what type of resources are used up in the course of

everyday life. Conversely, other more-than-human approaches, such as multispecies approaches, do not necessarily consider encounters or emergent phenomena in terms of their repetition. The different values and limitations of these perspectives are considered in the following sections.

4.2 SOCIAL PRACTICE THEORIES

Within the diverse range of scholarship under the banner of social practice theories, practices are most commonly conceived of as organised sets of connected actions performed across space and time (Reckwitz, 2002a, Schatzki et al., 2001, Hui et al., 2017). Further definitions and different concepts of relevance are provided in Papers 1, 2 and 3. However, it is useful to note here that social practice theorists generally hold the following propositions in common: (1) that practices consist in organised sets of actions, (2) that practices link to form wider bundles, complexes and constellations – a nexus – and (3) that this nexus forms the ‘basic domain of study of the social sciences’ (Hui et al., 2017: 1, Giddens, 1984: 2). Practices are also necessarily recognisable entities that are routinely carried out by multiple practitioners. These might include things like cooking, bathing and commuting – practices that are consistently and routinely performed by multiple members of society. For practices to persist ‘as entities’, they must continue to be performed and ‘recruit’ enough carriers. ‘Recruitment’ often happens at a young age or when an individual’s socio-material conditions change (e.g. migration to a new country) (Maller and Strengers, 2013).

As noted above, social practice theories decentre the central objects of study in traditional social theories based on the analyses of symbols, texts and cognitive thought. Instead, they elevate dynamic relations between bodily movements, objects, practical knowledge and routine to the centre of analysis. This focus is based on an epistemology that does not preference the agency of the individual or macro-structural forces as the key drivers of

social life. Rather, these forces are considered to come together in the dynamic unit of practice. Despite acknowledging material agency, they often reject the idea proposed by Latour and others that materials have as much, and sometimes greater agency, in configuring emergent entanglements and practices than humans do. For example, Schatzki (2002: 71) directly contests the extension of the categories of actor and action to encapsulate all entities and he is critical of propositions within Actor Network Theory which 'contend that practices comprise the actions of various entities and not those of people alone'.

Recently, debate has increased among practice theorists around whether non-humans can indeed carry practices in the absence of humans. A recent volume edited by Strengers and Maller (2019) employs the term dynamic non-humans to refer to devices, bodies and phenomena that act autonomously and take independent actions within practices. Examples include automated devices, robots, heatwaves, animals and plants. They are dynamic in the sense that they are constantly changing, transforming and often 'acting up' without direct human intervention. Strengers and Maller point out that materiality has been conceptualised across the majority of practice theories as:

relatively static, bounded, and easily identifiable material objects and technologies, such as showers, air-conditioners, freezers and buildings have been the dominant focus, rather than ecological systems, heat, air, animals, plants and artificial intelligence (Strengers and Maller, 2019: 5).

To begin to make sense of dynamic non-human agency within practices, researchers have drawn social practice theory together with other theoretical frames that often come under New Materialist or Affective perspectives (see Pink, 2015). These theoretical hybrids, in Hui et al.'s (2017: 3) words 'develop and extend practice theoretical concepts alongside and in dialogue with other forms of social theory.' Continuing in this vein, and contributing to this theoretical development of social practice theories, the latter part of this chapter

proposes an augmented view of how agency emerges within social practices. This view integrates concepts from multispecies ethnography to account for the relational agency of micro-species in domestic hygiene practices.

Prior to explaining why I propose to integrate aspects of multispecies ethnography with social practice theories, and how I do so, it is important to explain some of the ways that practices are thought to relate to one another to create the observable social world. It is commonly held that no practice can exist in isolation, but must be dynamically and interdependently related in a 'nexus' (Hui et al., 2017), or a plenum (Schatzki, 2002). To understand the composition, persistence or disappearance of a practice, it is therefore important to understand the 'nexus' of which it is part. To examine how practices interact in more detail, concepts of 'bundles' (loose-knit groupings of practices based on co-location and coexistence) and 'complexes' (more integrated arrangements of practice, including co-dependent sequencing), are also employed to describe the ways that practices accompany and relate to one another with different degrees of interdependence and synchronicity (Shove et al., 2012).

Another set of related concepts that is instructive in understanding how practices interact in different contexts are 'dispersal' and 'integration'. According to Schatzki (1996 91-92), a 'dispersed' practice is found in numerous settings, and across multiple domains of life. The materials and knowledge involved in dispersed practices are applicable to all these different settings. 'Integrated' practices (Schatzki, 1996) are more complex collections of practices that, when realised in a particular context, will result in an emergent entity. Gardening, cooking and cleaning practices are all examples of integrated practices that need a certain arrangement of 'sub-practices' for their existence. The distinction between integrated and dispersed practice is often unclear. This is the case for cleaning or hygiene practices, as hygiene is sometimes the explicit purpose of a practice (e.g. disinfecting floors), but is also sometimes a latent value embedded in material arrangements (e.g.

cleaning white tiles to make them shine and look nice), or one of many outcomes of a practice (e.g. wiping the bench and washing hands during food preparation).

Many researchers who use social practice theories are broadly interested in accounting for change. Central epistemological questions underpinning the use of social practice theories consequently address how practices evolve and persist, how they spread and disappear, or how they connect or move away from each other (Shove et al., 2012, Schatzki, 2016). Practices remain as recognisable entities only through repeat performances; however, these performances are not identical and are responsive to shifts in context, whether physical, cultural or temporal (Strengers and Maller, 2014). In moments of performance, the 'elements' of practice can be reconfigured in ways that can change all subsequent formulations. From this perspective, when attempting to identify paths to more healthy or sustainable ways of living, investigating this indeterminacy by tracing relations within and between practices can highlight options for change and strategic points of intervention (Shove et al., 2012).

Although the investigation of practices that occur at the meso-scale of social life, such as households and workplaces, may seem to disregard the larger political, institutional and cultural forces at play, it is proposed that practices are the sites at which the macro, meso – and in this case micro – forces of social life meet and are reproduced. Patterns of stability and change in social life are not produced or controlled by any one actor alone, but are understood as emerging from the convergence of socio-material interactions. Nicolini (2016) contends that temporally situated investigations of connections between practices resolves this issue, as relatively large and small phenomena intersect in these connections and can be observed. It is proposed that investigating practices, their dynamics, and the forms of agency that emerge within them, may enable avenues to destabilise dominant forces or power relations from the meso (e.g. domestic) to the macro (e.g. national) scales. Examples of these forces could include infrastructures, belief systems and regulators, among others. Similarly, Shove (2017a) notes that by tracking the roles of different

materials as they move between practices and across supply chains can help to explain how large technical systems and infrastructures are sustained and become embedded across different areas of daily life, such as in the home.

In addition to providing insights into how daily movements continuously influence the types of objects, substances and organisms that populate homes, social practice theories can help one to understand why houses have been built in particular ways over time. The standards and expectations that influence how a practice is conducted also influence how rooms are designed (Quitau and Røpke, 2009). For example, since domestic labour such as cooking became a more social activity, and family time became centred around meal preparation, houses have increasingly been built with open-plan kitchens and living areas (Lupton and Miller, 1996). Houses, and their rooms, can therefore be understood as materials that serve particular collective practices at a given point in time. This is important, as the ways in which home spaces are designed, the degree of indoor/outdoor fusion, and the materials used, are crucial determinants of the indoor microecology (La Guardia et al., 2017, Green, 2014).

It is therefore taken in this thesis that practices and the microecologies of homes co-structure one another through the ongoing curation and structuring of material arrangements in the home, and through the ways the material structure of the house itself comes to be designed around the needs determined by practices. Importantly, the interaction between these ongoing and embedded practices is not always determined by the home occupants. Many people live in homes that they have not designed, or do not own, or that may embody the practices of previous eras. This leads to renovation and retrofitting to meet existing practice needs, but also practice adaptations that do not require material infrastructure to be altered. This framing sensitised me to the ways in which people's hygiene practices reflected adaptations to aspects of their homes that did not fit their preferred practices.

4.2.1 *THE ELEMENTS OF PRACTICE*

In social practice theories, there are a number of ways of distinguishing and conceptualising the constituent elements of practices, although they all share crucial points of similarity. Perhaps most influentially, Shove et al. (2012) proposed three types of elements: competence, meaning, and material. Shove and Pantzar (2005) earlier formulation of practices included images, skills and stuff. Prior to this, Reckwitz (2002a) proposed practice elements including body, mind, things, knowledge, discourse, structure/process, and agent. Strengers (2010b) proposes a different arrangement which includes: material infrastructures, practical knowledge, common social understandings and rules.³ Importantly, these elements are not understood as pre-existing isolated entities that remain autonomous when they come together in practice. Rather, they are considered to be fundamentally co-constituted and co-dependent, and often adopt different roles in response to the requirements and dynamics of practice.

The terms 'meaning' and 'social understandings' refer to the collectively agreed-upon 'why' of doing something within practices (Strengers, 2010b, Shove et al., 2012). They also include the stories and beliefs that ground meanings and influence their persistence. As meanings shift across time and space, practices come to reflect different justifications and values. In this thesis, 'meaning' is used to refer to the values, narratives and beliefs that structure the expectations for how a practice should be performed in a given place and time.

³ Note that Strengers subsequently moved away from conceptualising the elements of practice this way in subsequent publications (see Strengers et al, 2016; Strengers and Maller 2014)

The element variously referred to as ‘competence’, ‘practical knowledge’, ‘corporeal knowledge’ ‘practical consciousness’ and ‘embodied skill’ encapsulates the often non-conscious skills that individuals employ to carry out practices (Shove et al., 2012). This element represents experiential, procedural knowledge which is enacted through the body in practice performances. For example, when washing the dishes, one is often skilfully performing a set of bodily movements with a set of materials without consciously thinking about every action. Generally, it is accepted that this type of knowledge is less likely to be questioned by actors, as it is not a result of reasoning and cognition.

Finally, ‘materials’, ‘things’, ‘infrastructures’, ‘devices’ and ‘resources’ all refer to the range of physical artefacts integral to everyday practices (Shove, 2017a, Strengers, 2010b). As I contend that the conception of materiality within social practice theories is in part challenged by the questions that guide this thesis, I will focus on materiality in greater detail than the other elements. Schatzki (2010: 140) has proposed that materials prefigure practices. From his perspective, prefiguration is ‘a qualification of possible paths of action’ and this means that ‘the particulars of material arrangements prefigure the course of practices in indefinitely complex ways’. Prefiguration is related to the proposition within Actor Network Theory that designed objects and infrastructures ‘script’ programs of action to make them easier or more difficult to follow in different ways (Latour, 1992). However, these notions of ‘scripting’ are less attentive to the ways in which scripts are created and transform through unfolding and cumulative material relations over time.

In an attempt to make sense of the ‘indefinitely complex ways’ that materials prefigure practice, and to respond to criticisms that social practice accounts of the ‘material’ lack nuance, Shove (2017) has recently proposed that the ‘material’ element of practices might be usefully differentiated into (1) things that have an ‘infrastructural’ relation to practice, or a necessary background, but are not directly engaged in the performance of a practice,

(2) 'devices' that are directly mobilised and actively manipulated in practice, and (3) 'resources' which are radically transformed or used up in the course of practice. These infrastructures, devices and resources add valuable nuance to the illustrative case study of energy consumption Shove has employed to articulate them, and to many other comparable practices relating to the consumption of resources. In more general terms, this process of distinguishing between different yet connected material relations is important, as certain material prefigurations may create positive, or reinforcing, feedbacks along a particular course of action which may be harder to disrupt than other material configurations. The degree to which different material arrangements prefigure practice is important for this thesis; however, there remains no specific version of materiality in the social practice literature reviewed that can account for the type of agency that emerges via material interactions involving the types of transformative properties of microorganisms and post-industrial chemicals.

Although the types of material categories proposed by Shove only partially account for the types of emergent material agency investigated in this thesis, the act of categorising and defining materials in terms of their roles in a practice provides a useful means of thinking, not only about sequences of production and consumption, but also about the sequences of development of interacting systems of things within a given environment. Understanding material roles as relational connects well to current thinking in microbial ecology, particularly in relation to human microbiome research, which proposes that focusing on individual microbes and their functions is not going to be useful for understanding their roles in human bodies and health (Bloomfield et al., 2016). Rather, microbes take on roles depending on the functional 'niches' that need to be filled within particular microbial ecologies in the body (Sharma and Gilbert, 2018). In other words, the roles played by different microbes change based on the roles being played by other microbes in the system, and the types of inputs (e.g. food) that are being received (O'Malley, 2016). This

relational understanding of material and micro-material agency within practice is a central guiding concept of this thesis.

As noted above, within social practice theories the agency of materials is recognised, but materials are not thought to have the same degree of agency or capacity to configure practices as humans (Maller, 2018). However, micro-species such as microbes and post-industrial chemicals have innate modes of behaviour which transform the environments and bodies they interact with in a range of contingent yet specific ways. For example, given the right indoor conditions in a home, a fungal biofilm will form on a surface, which may trigger an allergic reaction such as sneezing in an individual dwelling there, and this may then trigger that individual to purchase antihistamine medication and a chemical cleaning product to stop the agent reacting with their body and to inhibit its future agency (O'Malley and Dupré, 2007). However, the interaction between fungal and chemical entities may not reconfigure the human/fungal relations as one might expect. For instance, bleach is commonly used to treat fungus, but in many cases it changes the colour of the fungus without inhibiting its proliferation or reproduction (Rogawansamy et al., 2015). Consequently, the fungus may continue to exert influence in invisible ways while the affected individual continues to apply ineffective chemicals, which then transform the composition of the indoor environment. In this example both the chemicals and the fungus as 'materials' are exerting influence on the practice beyond the meaning and utility ascribed to them by the human performing the practice.

To become sensitive to the types of emergent micro-species agency in the practices studied in my qualitative research, I integrated concepts from multispecies ethnography into the theoretical lens that informed the selection of objects to study and modes of inquiry.

4.3 MULTISPECIES ETHNOGRAPHY AND CHEMO-ETHNOGRAPHY

As detailed in the preceding chapter, multispecies ethnography attends to the ways in which non-human organisms and chemicals interact within and produce forms of modern sociality. They are thoroughly more-than-human in their attention, not only to non-humans, but also to how agency emerges through interactions over time and space. The scope and contributions to research being made within multispecies ethnography are detailed more comprehensively in Paper 2. This section focuses on how this theoretical lens sensitised me to the particular objects and subjects that make up my research design.

The reason for selecting multispecies ethnographic approaches above other more-than-human theories is their attentiveness to the distinctiveness of different forms of living and non-living agency in emergent entanglements. Some perspectives are less focused on these distinctions. For example, Bennett (2009) has influentially made a case for the 'vitality' or 'liveliness' of all matter, a proposition which flattens distinctions between living and non-living things, like a bacteria, a shower head or an EDC. However, if one extends the qualities and dynamics of life to apply to all forms of non-living being, one may risk obscuring the nuances associated with the unique and different types of agency enacted by the materials under investigation. Abrahamsson et al. (2015), recommend that ethnographers should move beyond an interest in 'the liveliness of "matter itself"' and rather attend to 'the complexities, frictions, intractabilities, and conundrums of "matter in relation"' (Abrahamsson et al. (2015: 13). More broadly, Ingold (2007) proposes that there is an epistemological hazard in making general claims about 'material' things without acknowledging their variety (e.g. chemical or biological) or how they have come to be realised as part of historical cultural and physical processes.

My research is based on the premise that understanding the relationality of agency that emerges in practice due to the particular characteristics of micro-species when they

interact is vital for understanding the ongoing constitution of home microecologies. This understanding of agency as relational means that it is not seen as inherent to and divided among actors, but rather as emerging from interactions. This understanding is common to more-than-human theories. Barad (2003: 826) has influentially framed emergent agency as a product of 'intra-action'. She states, 'Agency is a matter of intra-acting; it is an enactment, not something that someone or something has'. If one accepts this perspective, it means that one's task in exploring the agency of non-humans is not simply to track the connections that link human and non-humans in the world; it also involves analysing the emergence of their inter-, or intra-actions, and as Ingram (2011) emphasises, it involves considering the ethical and political implications of different emergent agencies in practice and the technologies that enable those connections.

I propose that the mode of attending to particular types of emergent material agency within multispecies ethnography can provide a lens for studying the modes of interaction and social consequences of microorganisms and post-industrial chemicals. Khon, Kirskey and Helmrich (2010: 562) position multispecies ethnography in the following way:

The goal in multi-species ethnography should not just be to give voice, agency or subjectivity to the nonhuman—to recognize them as others, visible in their difference—but to force us to radically rethink these categories of our analysis as they pertain to all beings [Eduardo Khon personal communication with authors, March 29, 2010].

In this way, multispecies ethnography directs the researcher's gaze not only towards studying emergent and unique forms of non-human agency, but also towards problematising and challenging the categories which have guided us thus far to interpret them. A large part of this challenge is directed at the ontology of 'species' (Kirksey and Helmreich, 2010, Kirksey, 2015). In grappling with species, and the other taxonomic classifications that make sense of them, these authors examine and rethink assumed

natural-cultural categories. Central to this questioning is the assumption that 'species' should be the key concept used to ground biological similarity, difference, roles, and therefore agency. By challenging this assumption, this type of ethnography can provide insight into how living and non-living things develop agency in relation to one another in different contexts. Given the emergent and fluid forms of agency now being discovered as fundamental to the behaviour of microorganisms and post-industrial chemicals, as discussed in Chapter 2, this type of investigative lens may be instructive in making sense of emergent species agency in practices.

Within multispecies ethnography, the methodological requirements of investigating micro-and macro organisms are distinct in many ways. Engagements with invisible organisms are intrinsically different to engagements with visible ones, which we can interact with and observe in an immediately tangible and often an affective register. As noted in the preceding literature review chapter, an increasing number of multispecies ethnographers are focusing on microorganisms. Some of these studies involve investigating microorganisms in labs, where they acquire an extra dimension of visibility (Hayward, 2010). However, they also involve analyses of how human social relations, cultures and institutions can be structured around assumed modes of microbial action. For example, Paxson (2008) examines the microbial ecosystems and cultivation practices that enable artisanal cheeses to exist, and how the people involved in these practices are engaged in debates surrounding food regulation standards, biohazards and international borders. In this type of multispecies study, the investigation is primarily focused on how the microbes come to be represented and exert agency in culture and institutions, rather than laboratory-based studies.

Similarly, chemo-ethnographic studies involve investigations of laboratory practices and socio-political transformations precipitated by certain forms of chemical agency (Tousignant, 2013, Shapiro and Kirksey, 2017). An account of the emergence of chemo-ethnography is provided in Paper 2. To situate my theoretical approach, I will briefly note

here some of the key methodological strategies utilised within the field, and how they relate to my research. Chemo-ethnographers have employed subjective or auto-ethnographic research, such as recreational drug use experiences, or the use of chemicals to alter sexual characteristics and identity in queer communities (Chen, 2012). They have also explored the emergence of *chemosocial* communities around these experiences, and others, such as those that form around the shared experiences of cancer sufferers going through chemotherapy. Shapiro proposes that ‘chemosociality involves novel, altered, attenuated, or augmented relationships that emerge from shared and shifting chemical ecologies’ (Shapiro, 2015: 483). Finally, chemo-ethnographers also explore the influence of chemical infrastructures. For example, they study the socio-political conditions that result in populations in distributed locations being exposed to polluted water, air or products, and that do not necessarily result in the emergence cohesive social movements (Shapiro, 2015). This latter approach most closely resembles that taken in this thesis. The types of exposures that are common in households emerge through the intersection of industrial, infrastructural and regulatory powers and interests that foreground (through products actively used) and background (through infrastructures) practices. By investigating how microbes and chemicals have agency—based on the ways that they are imagined and materialised in everyday domestic practices—the actors that have the power within, and the power to shift, practices that contribute to sub-optimal home environments can be made explicit.

As a theoretical lens that guides the objects, subjects and relationships that a researcher traces, I propose that the theoretical positions presented here are complementary for the purposes of this thesis. This is because it is assumed that if one is to understand how microbial and chemical agency emerges in a given situation, one must examine the practices in which they are participating. As Woolgar and Lezaun (2013) note, ‘materiality’ must be understood as the contingent product of practices, rather than a foundational reality to be shown via an ontological investigation. Pickering’s (1993) proposition about

the significance of the movement of entities between socially constructed things and real objects in the 'mangle' of social practices, is instructive in the merging of the two theoretical positions outlined above. He states that 'things' constantly transition between being socially constructed via discourse and existing as real, material entities. He proposes that the human and non-human elements of the 'mangle' have performative attributes that keep them from being confined to realist representations (Pickering, 1993). Crucially, the existence of an entity as a real or imagined presence is understood as determined by all the agents involved in each particular performance of a practice. For example, imagined potential germs might exert agency in a practice in which a child comes into contact with a cat's bowl, prompting sterilisation, even if there are no pathogenic germs present. On the other hand, mould developing on surfaces in the house suggests a movement and persistence of real microbes, the physical agency of which must be understood to be dealt with. By drawing attention to this movement of things between actual and imagined representations, this notion enables an exploration of how the emergent agency of microbes and chemicals in practice influences the performance of practices. The dynamic interplay between the meanings attached to microbes and chemicals and their physical actions is understood as crucial to the way practices constitute indoor environments.

4.4 IMPLICATIONS FOR METHODOLOGY

As stated at the beginning of this chapter, theories matter for how problems are defined and for how lines of enquiry are formulated. They make certain research questions obvious while obscuring others. They also sensitise researchers to different agents, events and processes. Based on the hybrid more-than-human theoretical framework presented above, that takes social practice theory as the 'lead' (Maller, 2018), while integrating aspects of multispecies ethnography, an approach to qualitative research that is able to account for practice and non-human agency is required. As is the case in most more-than-human qualitative research that conceives of agency as emergent, data generated through

interactions with research participants, such as interviews, is not thought of as separable from the enactments in which they are produced. Humans are not conceived of as 'vessels' that are able to represent and relay objective information about events that take place through words. Rather, data generated from each interaction is considered a product of numerous contextual factors, such as location, temperature, disposition, accents, the material environment and other life circumstances that influence the thoughts and communication styles of the researcher and participant in a given encounter. Mazzei (2013) calls the array of elements that make up the practice of an interview a Voice without Organs (VwO). This concept draws on Deleuze and Guattari's (1983) concept of the Body without Organs, which conceptualises the human being as an 'immanent knot of forces' that produce a voice that does not emanate from a singular subject, but is produced, 'in an enactment among researcher-data-participants-theory-analysis.' (Mazzei, 2013: 733).

In practical terms, the collection and analysis of qualitative data as part of more-than-human research are not intended to elucidate a representation of the subject's actual activities as they happened. Rather, they are intended to describe an assemblage of the human (interviewer, subject) and the more-than-human (gender norms, the physical space, pets, cups of tea, preconceptions about research encounters, products, mess etc.) on that particular day. In other words, the researcher does not extract information, but is involved in capturing an emergence that results from the encounter.

As discussed above, the two approaches outlined above situate agency and the primary unit of social analysis differently. My research design addressed this tension regarding the role of human agency in practices by taking practices as the primary units of analysis, while also being attentive to the particular forms of agency exhibited by non-human practitioners that emerged within a practice. As discussed above, I am open to the situational emergence of agency, which may position human and non-human actors differently according to the unique dynamics of each particular practice performance. For

example, the humans, materials and meanings at play in an average routinised practice of cleaning the lounge-room may be relatively stable. However, if there is a flea infestation, brought into the house by a pet dog, cleaning practices may shift dramatically to accommodate the actions of the fleas. In this case, the autonomous behaviours of the dog in the neighbourhood and the living, breeding and mobility behaviours of fleas are exercising a significant degree of influence in determining the performance of the more-than-human practice in which they are all engaged.

Based on the synthesis of the two broad theoretical approaches described above, the following considerations guided my selection of research methods, and my disposition when entering a research encounter:

- 1) In addition to cognitive reasoning and stated meanings and beliefs, bodily competencies and materials such as microbes and chemicals influence the performance and prioritisation of practices.
- 2) All non-human materials are not alike in agential capacity or proclivity, and they have different kinds of emergent agency in practice.
- 3) Research subjects may not be aware of all of the reasons they are performing tasks in particular ways, and it is therefore important to access practice performances in ways other than narrative.
- 4) Research subjects do not convey pure meaning through language and narrative irrespective of the specific emergent research 'event'.

The methodological approach taken based on these criteria is described in Chapter 5.

4.5 CONCLUSIONS

In this chapter I have outlined how social practice theories are particularly well suited to the investigation of the material arrangements that emerge from repeat practice performances, within a dynamic 'nexus' of practices. It is proposed that this set of

characteristics is particularly useful for understanding how the practices involved in the development and maintenance of homes cumulatively and dynamically builds microecologies. Following Maller (2018), I therefore take social practice theory as the 'lead' theory to guide this research. I propose that an examination of the temporality of the material interactions occurring within and between the routine practices that constitute daily life affords unique insights into potential household exposures, and the creation of particular niches in which certain microbial communities thrive. The integration of concepts from multispecies ethnography into my theoretical framework serves the purpose of further sensitising me to the particular and emergent forms of agency that micro-species exhibit within domestic hygiene practices. Importantly, it also enables an analysis of when the imagined or socially-constructed notions of micro-species agency conflict or align with their real physical actions, which reveals assumption about particular micro-species that are embedded in practice.

The theoretical framework presented here, although not methodologically prescriptive, has a number of methodological implications. These include being sensitive to the interplay of agency in more-than-human research contexts, such as interviews, and the importance of attending to agency beyond what is verbally expressed in narrative. The methodology that emerged from this framework is discussed in the following chapter.

5 METHODOLOGY: INVESTIGATING MORE-THAN-HUMAN HYGIENE PRACTICES

If methods are not innocent then they are also political. They help to make realities. But the question is: which realities? Which do we want to help to make more real, and which less real? How do we want to interfere (because interfere we will, one way or another)?

– John Law and John Urry (2004: 405)

5.1 RESEARCH APPROACH

The research approach is grounded in the theoretical framework outlined in the preceding chapter. Given the identified need for an in-depth exploration of the dynamics of domestic practices involved in parents' attempts to create a hygienic home environment for their children, including the meanings, bodily enactments, micro-species and other materials at play, a broadly ethnographic approach to research was adopted.

Ethnography and ethnographic research have been defined and practised in a diversity of ways. There are now numerous morphologies of ethnography that have evolved in response to the branching concerns of modern anthropologists – and increasingly, other social scientists. Some of these include: realist ethnography, critical ethnography, autoethnography, life history ethnography and feminist ethnography. Across this diversity, Reeves et al. (2008: 1020) define key features of ethnographic research, including:

- a strong emphasis on exploring the nature of a particular social phenomenon, rather than setting out to test hypotheses about it
- a tendency to work primarily with 'unstructured data' – that is, data that have not been coded at the point of data collection as a closed set of analytical categories
- investigation of a small number of cases (perhaps even just one case) in detail

- analysis of data that involves explicit interpretation of the meanings and functions of human actions; the product of this analysis primarily takes the form of verbal descriptions and explanations.

Although the majority of these core features are retained in this research, many ethnographers have moved away from Reeves' emphasis on 'the meanings and functions of human actions' and 'verbal descriptions and explanations' in response to both the 'material turn' across the social sciences and the 'species turn' in anthropology and cultural geography (Hamilton and Taylor, 2017), which brought about multispecies ethnography. As discussed in the previous chapter, increased interest in the material and corporeal aspects of the social world have also brought into question the reliance on verbal representations of actions and experience, resulting in greater use of methods that provide insight into the performance of social life through other means (Thrift, 2008).

This chapter details the research design and methods selected to best address the research questions, in addition to descriptions of the research sample, recruitment process, the approach to data analysis and some reflections on the methodological approach adopted.

5.2 RESEARCH DESIGN

To investigate the dynamics of practice involved in the creation of hygienic home environments, it was determined that a multi-method in-depth qualitative research design with a small sample was the most appropriate approach. As with many ethnographic studies, this study aims at research depth and exploration, rather than breadth or attempts to represent particular populations (Hammersley and Atkinson, 2007). Prior to describing the methods selected, selection criteria and recruitment, I will provide an overview of my approach to sampling.

5.2.1 *SAMPLE SIZE*

A sample size of ten participants was deemed suitable for the purposes of answering my research questions. This size was determined to be appropriate due to the depth of engagement sought with each participant and the utilisation of multiple research methods. A common criticism of research studies that focus on depth of engagement rather than breadth is that the sample is neither randomly selected nor statistically significant (Hennink et al., 2010). However, this study does not seek to be statistically representative of a population. Rather, like many anthropological or phenomenological investigations, it seeks to explore the types of dynamic and diverse phenomena that are contributing to a particular socio-material situation. In other comparable studies where an exploration of complex phenomena or human engagements is an objective, sample sizes of between 6 and 10 (Malterud et al., 2016), over 6 (Morse, 1994) or 5 to 25 (Creswell, 1998) have been recommended. Moreover, Dibley (2011), drawing on Geertz (1973) argues that qualitative data should be considered in terms of 'rich and thick' rather than the size of the sample. Based on the objective of deep exploration in this research, I determined that a substantive engagement with ten participants would provide an opportunity for patterns in data to emerge and to generate data that is rich (multi-layered, intricate, detailed, nuanced) and thick (numerous and detailed) enough to indicate how the dynamics of practice can influence how parents create hygienic home environments for their children in different ways, and how micro-species exert agency within these practices. Given these reasons, the precedents outlined, and the time and resourcing limitations of a doctoral candidature, a sample size of ten was deemed appropriate. The findings produced in this research could be used as a foundation from which to generate research that aims for greater breath, or as a foundation for in-depth investigations in other cultural contexts.

5.3 METHODS

The methods I selected include activity diaries and semi-structured interviews in participants' homes with practice re-enactments. Photographs were also taken during the interviews to create an inventory of materials – such as products, interior furnishings and other environmental conditions related to the enactment of practices with implications for home hygiene. The activity of taking photographs also served as a prompt for participants to gather products from around their houses and discuss particular objects.

Other methods considered included participant observation over longer stays with participants in their homes (e.g. one full day) to observe their practices as they conducted them. However, given the sensitive nature of many hygiene-related topics, and ways in which hygiene routines play out – activities are often conducted once a week or once a month – full immersion over one day may not provide an adequate insight into the breadth and temporality of practices. I also considered video-based methods for recording practice re-enactments, but I decided against this method as the practices that emerged as relevant in the interviews were diverse and often not appropriate for filming due to their sensitive nature (Pink, 2015). These methods could be usefully integrated into future research by employing this methodology to provide insights into the bodily knowledge and sensory engagements that make up specific practices of interest.

The activity diaries were posted or hand-delivered to participants with an information and consent form (see Appendix 2). The diaries were filled out by participants every day for seven consecutive days, after which I collected them. Semi-structured interviews with practice enactments were scheduled for one to two weeks following the return of the diaries. This allowed time to conduct a preliminary assessment of the information recorded in the diaries and adjust interview questions accordingly. All interviews with practice enactments were situated in the participants' homes. Interviews were recorded and professionally transcribed. Field notes were also taken immediately after each interview. The notes included observations of non-verbal practice cues, notable elements of the material environment, the affective responses of the interviewee to me and the

process, and points that seemed particularly important to attend to in analysis. All participants took part in all activities.

To discuss the methods further I will divide them into pre- and post- in-depth participant engagement in their homes.

5.3.1 PRE-ENGAGEMENT

1. Activity diaries

The activity dairy (Figure 7) required participants to record all domestic cleaning or hygiene-related activities conducted over a period of seven days. This method was selected due to its capacity to highlight the associations and motivations that shaped key forms of engagement between participants, objects and perceived sources of environmental risk or 'uncleanliness' that participants responded to throughout a day or a week. The use of activity diaries is increasingly common in social research, and takes many forms (Belli et al., 2009; Bolger, 2003; and Wutich, 2009). This particular format was adapted from Sofoulis' water diaries (2005) which she used to investigate water practices in Australian households. As was the case in Sofoulis's research, the diaries were intended to be kept

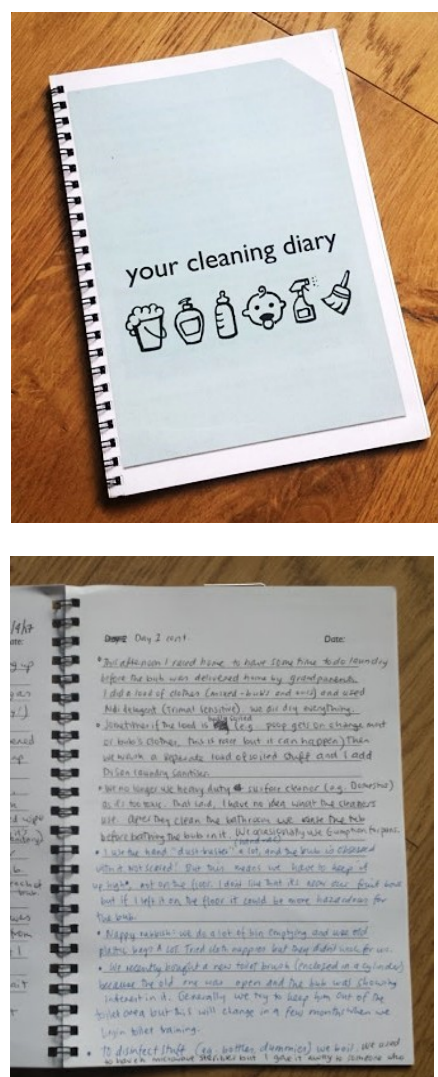


FIGURE 7: EXAMPLES OF ACTIVITY DIARY COVER AND PAGE FILLED IN BY PARTICIPANT

over waking hours for seven days, and they aimed at soliciting a picture of what practices are conducted to create a hygienic home, and for what purpose, and by whom.

A key reason the activity diary method was selected is that it provides participants with an opportunity to reflect on an ordinarily mundane set of actions that they may be consciously or critically engaging with day to day, prior to being interviewed about these activities. Hitchings (2012: 66) reports that in his experience researching practices, 'serial interviews' can help 'respondents work through the reasons behind certain everyday actions and ... their researchers identify effective lines of further questioning.' The reflection enabled by the time delay between consecutive engagements was therefore a crucial motivation for utilising the activity diaries prior to conducting the semi-structured interviews.

Activity diaries were also selected due to their capacity to draw out insights in relation to two crucial factors:

1. The temporality of activities and connections between them

Rather than focusing on *how* and *why* activities are performed, the diary format encouraged participants to record *when* they conducted particular activities during the day and week. This form of recording is able to provide insights into the frequency of tasks, the prioritisation of some tasks over others, and the co-occurrence or co-dependency of particular tasks.

In addition, the request that participants think about what activities they are performing at multiple, semi-regular intervals provides them with more opportunities to reflect on their actions than they would have in a single interview. There are therefore more opportunities for overlooked, or seemingly inconsequential tasks to be included in the record. This is particularly important considering the quotidian, habitual nature of many cleaning tasks.

2. How cleaning and hygiene are defined by participants

A key aim of this research is to examine how operative definitions of hygiene and cleanliness are embedded within domestic practices intended to create healthy and safe indoor environments for children. By providing participants with diaries that do not prescribe definitions of 'safe' and 'clean' home environments, their own definitions and meanings are allowed to emerge, without any external cues from the researcher. These meanings and definitions are then able to be compared with other tasks and meanings that emerge when moving through the material environment in the situated semi-structured interviews.

The following instructions were presented inside the diary for participants:

Thank you for agreeing to help with this research and fill out an activity diary.

Your contribution will help us to better understand how, when and why people clean in certain ways to create a safe environment for their children.

Please fill out this diary at least once per day for the next seven days. Be as honest as possible and do not leave out any dirty details. Over-sharing is okay in here - the researchers won't be sharing it with anyone else.

You can fill the diary out as you wish, with drawings, words or photographs to show what cleaning activities you have carried out and the dirty things or activities that have prompted you to clean.

These are some suggested questions to help guide your entries:

- *Did you perform any tasks to make your child and/or their environment clean today?*
- *What cleaning products did you use for the house and for your child?*
- *How many times did you repeat these tasks during the day?*
- *How did you determine if it achieved the desired result?*

- *Did you perform this activity in response to something messy or dirty or as part of a routine?*

There are some limitations of the diarying method that are important to note. First, in describing what types of things you would like participants to record, even if the descriptions are broad, you sensitise them to noticing particular events, materials and patterns over other that may be equally relevant. Like all methods that rely on self-reporting, participants will inevitably be performing activities that are relevant to the study that they have either not thought of recording or have represented in a different way. Although overcoming these limitations in text- or discourse-based research methods is difficult, I have attempted to access participant practices through different routes through the integration of multiple methods to provide a greater breadth of access to different variables.

5.3.2 *POST-ENGAGEMENT*

1. Semi-structured interviews

The purpose of the semi-structured interviews was to gain insights into how parents attempted to maintain a hygienic home environment for their children, and the interactions between meanings, materials (including micro-species) and bodily competencies involved. Questions were also structured to provide insights into how the dynamic interactions between practices, as well as within practices, influenced how hygiene-oriented actions were ultimately performed day to day. Respondents were asked a range of open-ended questions with probing follow-up questions. Interviews ran for approximately 60 minutes and were combined with practice re-enactments and photography, as described in greater detail below.

Despite hesitation among some social practice theorists, and other non-representational social scientists, around the value of interviews, others make a compelling case for their inclusion. Post-humanist scholars such as Mazzei (2013) have cautioned against over-reliance on verbal accounts of reality, as humans are often unreliable witnesses to their own actions, memories and intentions. However, scholars such as Hitchings (2012), Browne (2016), Maller (2018) and Strengers (2011b) have made a strong argument for the inclusion of interviews as long as the respondent is seen, not as a purveyor of an objective truth, but rather as an agent with access to insights about meanings, material engagements and bodily know-how if prompted in the right way. Indeed, they demonstrate how interviews are invaluable in achieving a degree of depth in engagements with participants, in terms of elucidating important histories, meanings and values. The integration of practice re-enactments and the location of the interviews in participants' homes was also employed as a strategy to ground the interviews in the material and corporeal aspects of practice.

2. Practice re-enactments

Practice re-enactments involve asking participants to show the researcher how they perform certain activities, in this case during the semi-structured interviews. Re-enactments have emerged as a method within visual and sensory, and increasingly digital, ethnography. They involve embodied demonstrations of past events or scenes (Sidnell, 2006, Tutt and Hindmarsh, 2011). A central question motivating these studies is often how different modalities of interaction, such as talk, gaze and gesture, are integrated to form coherent courses of action. Jones and LeBaron (2002: 499) argue that until recently, 'verbal and non-verbal messages' have been 'studied separately, as though they were independent rather than co-occurring and related phenomena'. The introduction of re-enactment methods is a way to begin to overcome this dichotomy.

The re-enactment method employed in this thesis is based on Pink's (2015) approach to 'sensory ethnography', which 'takes as its starting point the multi-sensoriality of experience, perception, knowing and practice' (2015: 1). Generally using digital recording methods, Pink (2014) has employed re-enactments to investigate diverse phenomena such as touring homes, a garden project, re-enacting domestic cleaning, and workplace practices, such as the use of hand gel in healthcare contexts. In my research, re-enactments were not intended to be structured and staged activities; rather, they were merged into the interviews through prompts such as, 'can you show me how you usually do that?' In many cases, my verbal prompts were not necessary, as participants began to re-enact tasks unprovoked. The re-enactments enabled me to gain a sense, beyond what was expressed verbally, of how participants engaged with their homes through material and sensory properties. As my research does not aim to prescriptively study a given set of actions, the actions that emerged as important and were re-enacted were determined within the course of each engagement.

3. Photographs

Photographs were taken by me during the semi-structured interviews and re-enactments for three key purposes. First, they served to create what Collier (1995: 239) has termed a 'photographic inventory' of the field – in this case the homes of participants. The photographs taken were not intended for textual analysis, but as a way of recording the material environment of the home, including the objects used, the way the house was built and furnished and the environment immediately surrounding the home. These aspects of the material landscape were all deemed important elements of the practices analysed. The use of photographs enabled more material information to be captured about products than could have been gained through a list, or through researcher observation *in situ*. They not only capture the product brand and ingredients, but also suggest how the product is to be used. This visual information is then compared to researcher notes and interview

recordings to 'triangulate' (Kanstrup, 2002, Harper, 1987) the findings and build a richer picture. As Collier and Collier (1986: 108) note 'when interview responses are studied against the photographs, overtones and circumstantial detail can be re-evaluated'.

The second key purpose of the photographs was to prompt the participants to present objects and places, which then generated new discussion and reflection. Hopwood (2017) notes that 'interviews are better conceived and done as triadic interactions: between the researcher, the participant, and *something else*'. The addition of a 'third thing' into the interview space means that the process is not one in which the researcher asks the participant about themselves, and the participant uses their memory and self-perception to answer. The introduction of a material thing to focus on changes the scenario, prompting new types of reflection. The use of photographs in the interview served this purpose by prompting participants to find, take me to, or retrieve objects they deemed to be important. In this process they encountered new products and other materials on the way, which prompted the telling of additional stories and the expression of different meanings.

Combining these methods enabled me to gain access to participant practices from different angles. However, there remain a number of limitations of this approach. First, being in peoples' homes may induce in them a sense of vulnerability, eliciting a response of defensiveness or a desire to represent themselves in particular ways. This is a particular risk in the case of hygiene practices, which have historically been linked to being a good parent or citizen (Smith, 2007). In this context the researcher's access to practices is inevitably limited. In an attempt to reduce or mitigate this effect where it may arise, I adopted an approach which was sensitive and friendly. I also emphasised that they could cease the process at any time, or not answer any questions they were uncomfortable with. To help reduce the sense of myself in the space as a cold, objective researcher, I made sure to emphasise the ways in which my behaviours related to cleaning – and other topics that came up – were imperfect and often inconsistent. This served the purpose of making

participants more comfortable in sharing details related to things they felt guilty about, or that they perceived as 'sub-standard'.

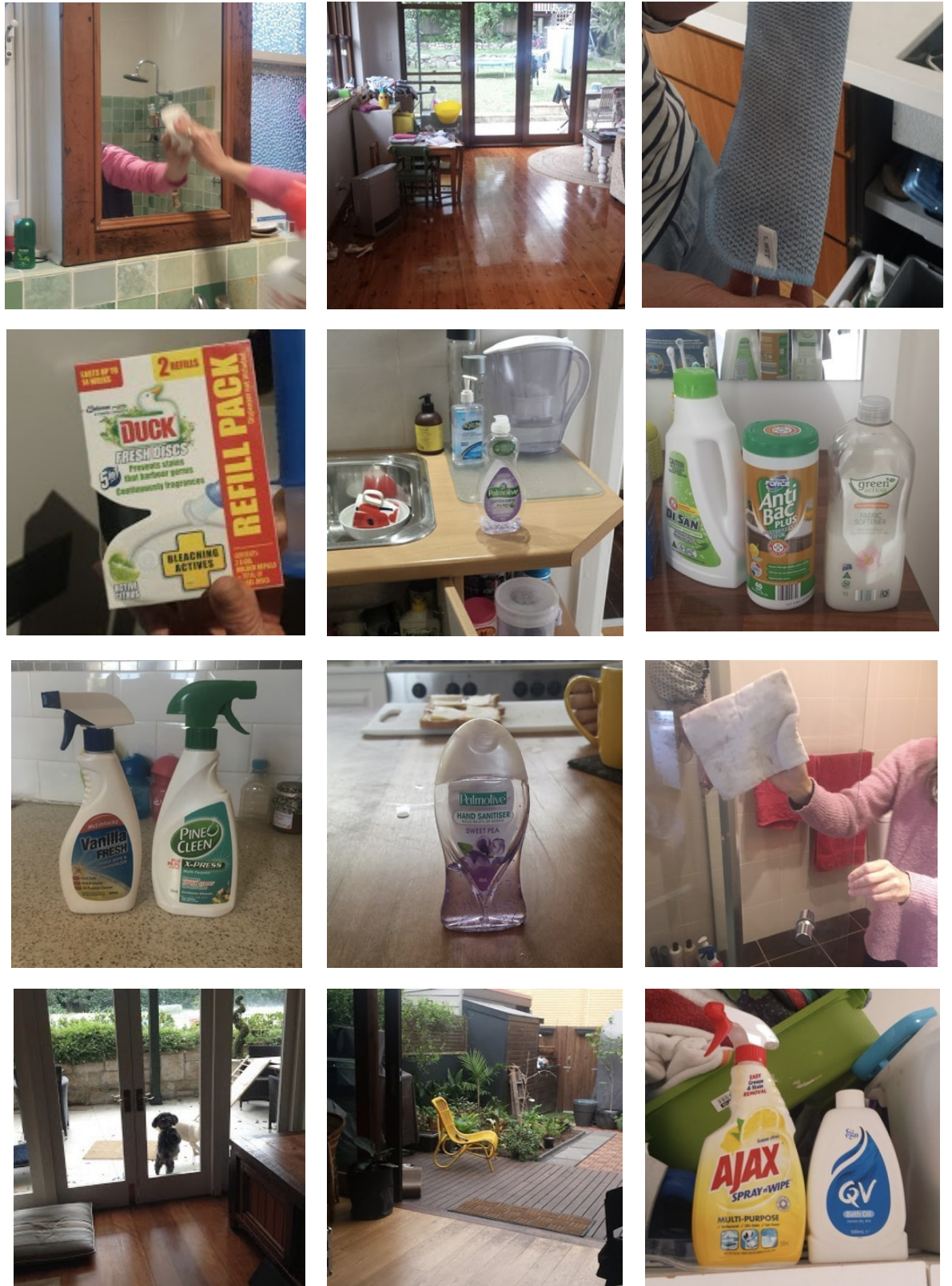


FIGURE 8: ILLUSTRATIVE EXAMPLES OF PHOTOGRAPHS TAKEN DURING INTERVIEWS AND RE-ENACTMENTS

5.3.3 SELECTION CRITERIA FOR PARTICIPANTS

Criteria-based sampling was used to recruit participants who were the primary carers of children under the age of five who lived in Sydney, Australia.

Parents, or primary carers, of children under the age of five were selected because children have been identified as a group particularly vulnerable to health conditions associated with sub-optimal environmental conditions in the home. The development of children's immune systems (Sharma and Gilbert, 2018), and their risk of developing leukaemia (Greaves, 2018) are affected by the microbial communities that occupy the home environment. Similarly, children are particularly vulnerable to a number of the chemicals used in building materials and other common household products, such as cleaning agents and personal care products (Diamanti-Kandarakis et al., 2009). More specifically, research has identified children under five, and in utero, as the groups most vulnerable to numerous environmental health risks in the home (Perlroth and Branco, 2017).

In addition, a number of researchers have contended that parents, and particularly mothers, are currently the key agents held responsible by society for managing environmental health risks in the home (MacKendrick, 2010, Kehily et al., 2014, Cowan, 1983). Given this common attribution of responsibility, I determined that it was important to examine if and how parents were taking responsibility for managing environmental health risks in the home, if these environments are going to be improved in the future.

5.3.4 RECRUITMENT

Ethics approval was obtained in early 2017 to recruit participants for this research via flyers, via online communities and through third-party introductions via email. It was a stipulation of the university ethics committee that the research was framed in such a way

to avoid causing any anxiety in prospective participants. This presented the challenge of developing recruitment material that accurately communicated the aims of the project in a way that was understandable to the general public, while at the same time making participation in the study seem appealing, and that did not induce anxiety in parents about sub-optimal living environments and using products that may have been harming their children. With this set of tensions and objectives in mind, an A5 flyer (see Appendix 3) was developed and distributed to various locations around north, west and central Sydney to medical centres, childcare centres and cafes frequented by parents' groups. They were also distributed to online regional parents' forums, such as 'Inner West Mums' on Facebook. However, distribution within forums is at the discretion of the group administrators and it is unclear whether the flyers were ever seen in these closed groups. These recruitment methods yielded no responses.

There are a number of reasons why this may have been the case. In addition to the ethical challenges associated with accurately representing the project in the recruitment material, there were also challenges associated with asking for access to people's homes to examine their cleaning practices. Research has demonstrated that standards for domestic and personal cleanliness have become more exacting over the twentieth century, and particularly in the twenty-first century. These cleanliness standards have changed against a backdrop of a history of home hygiene, particularly in Westernised countries, that ties one's home and personal hygiene practices to one's moral character and value (Smith, 2007). Considering this history, having someone asking to observe one's home and how one cleans it may still generate shame or anxiety related to upholding perceived norms about good hygiene and parenting. Given the sensitive nature of this topic, it was particularly difficult to recruit participants via 'cold call' methods, where no social connection or trust had been established.

Successful recruitment was achieved via accessing networks of parents that I was able to connect with via six intermediaries. This process of connection turned out to be crucial for

establishing trust between myself and the participants, and it allowed the intermediaries to introduce the project to participants in a way that made sense to them. After an intermediary made contact with a potential participant and the potential participants had signified interest (usually via my email, Facebook or text) and had given me permission to send them more information, introductions were made via email and they were provided with the research flyer.

The risks associated with the use of intermediaries include the participants feeling a lack of anonymity or feeling distance from the researcher, or the intermediary miscommunicating the research purpose and what it involves. In light of this, I ensured that I explained the project, its purpose and intended use clearly and required that participants stated that they understood. Fortunately, all participants demonstrated an eagerness to participate, and did not express any concern around trust in the research or the researchers, or concerns that their information would be used without their permission.

I did not have existing relationships with the parents I recruited. Snowball sampling was used via multiple channels. No more than two participants were recruited from a single social network to ensure diversity. The one exception was two participants who were siblings, allowing a comparison of the practices of participants that were inducted into the same practices as children. Once a participant had agreed to take part in the research, they were posted or hand-delivered (where practical) an activity diary and consent form.

5.3.5 DESCRIPTION OF SAMPLE

The respondents recruited were primarily female (9/10). This high female response rate relative to males may reflect availability, but also a higher degree of engagement with domestic environmental health issues. Other researchers examining domestic environmental health have identified this pattern (Mackendrick, 2014, Altman et al.,

2008). The gendered nature of responsibility for care and for managing children's exposure (Murphy, 2015), and also the disproportionate burden of exposure carried by women and children, is discussed further in Paper 1.

None of the participants were in a low socio-economic demographic and none were considered vulnerable based on criteria related to the ethnic or gender identity. All but one participant was raised in Australia and spoke English as

a first language, and all were subject to the cultural norms and material infrastructures that form the dominant hygiene regime in Australia to some degree. Participants lived in a number of different areas of Sydney (shown in Figure 9) in which property and rental prices are moderate to high. The final sample of participants (shown in Table 2) consequently provides insights into the 'complex' of practices performed by women from English-speaking backgrounds, who work full-time or part-time, and are of a middle to high socio-economic status (based on Australian Bureau of Statistics, 2011). Despite the lack of diversity in socio-economic status in the sample, valuable insights can be gained from examining the practices of this group given the expansion of the 'middle class' in Australia and globally, as the normative lifestyle practices of these groups may form the basis of aspirational changes being made by upwardly mobile families in the future (Koo, 2016).

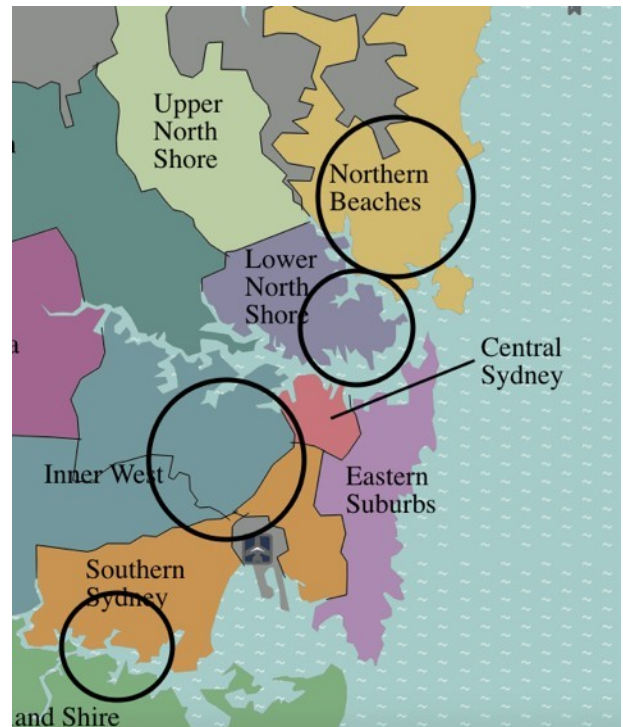


FIGURE 9: AREAS OF SYDNEY WHERE PARTICIPANTS RESIDE
ADAPTED FROM: USER:(WT-SHARED) LTURNER, OPENSTREETMAP [CC BY-SA 3.0 ([HTTPS://CREATIVECOMMONS.ORG/LICENSES/BY-SA/3.0](https://creativecommons.org/licenses/by-sa/3.0/))]

TABLE 2: PARTICIPANT CHARACTERISTICS

	Gender	Children under 5	Employment status	Employs a cleaner	Household composition
Participant 1	F	1	Part time	No	2 adults/2 children
Participant 2	F	2	Part time	1/week	2 adults, 2 children
Participant 3	F	1	Part time	1/month	1 adult, 1 child
Participant 4	F	1	Part time	1/fortnight	2 adults, 2 children
Participant 5	F	1	Part time	1/month	2 adults, 1 child
Participant 6	F	2	Part time, from home	Occasional	2 adults, 3 children
Participant 7	F	2	Part time	No	2 adults, 2 children
Participant 8	F	1	Full time parent	No	2 adults, 1 child
Participant 9	F	2	Part time	1/fortnight	2 adults, 2 children
Participant 10	M	1	Part time	No	2 adults, 1 child

5.4 DATA ANALYSIS

5.4.1 *APPROACH*

Interview data were professionally transcribed and then thematically analysed with the NVivo qualitative data analyses software. Field notes and photographic inventories of materials were manually coded. The approach used for coding is described below.

5.4.2 *CODING FRAMEWORK*

An open approach was taken to coding. However, the process was not entirely inductive as I was sensitised to the occurrence of particular themes in the data around social practices and micro-species agency. Initial categories were identified in the data according to the coding framework outlined below. Axial coding was then undertaken to systematically develop and link subcategories (Hennink et al., 2010). This involved generating codes within NVivo such as, “intergenerational practice change” or “concern over germs” as they emerged within an interview transcript or field notes, and then applying them to all other transcripts and notes. As there were many codes that conceptually overlapped, codes were grouped into categories and then finally selectively assimilated and refined. The Appendix E contains a list of all codes applied.

- 1. What are the dynamics between practices of hygiene and other domestic practices carried out by parents in homes?**
- 2. How do the relationships between materials within practices influence how hygiene is maintained in homes?**

To address these related questions, I first coded the data for types of practices that emerged that relate to the maintenance of a hygienic home environment. These included practices such as floor cleaning, bathing, bathroom cleaning and food preparation. To gain insight into how these practice performances were constituted, the key interacting elements of the practices (such as visceral responses, affective responses, embodied

knowledge, gestures, reasoned explanations, the weather and fungal growth) were recorded, and the agents that appeared to have been crucial in shaping them (micro-species, humans, pets) were coded for.

Given that everyday practices are dynamically interlinked and do not exist in isolation, interactions between practices that influenced how each practice was performed were also coded for. This helped to determine how certain practices were mutually supportive and, conversely, if there were practices that were competing for time and resources, or less integrated into others, and therefore more open to adaptation. Two concepts from Shove et al. (2012) were utilised for coding these concepts: one, 'bundles' of practices, defined as loose-knit patterns based on co-location and coexistences; two, 'complexes' of practice, defined as more entwined arrangements including co-dependent forms of sequence and synchronisation. Examples of 'bundles' of practices included bathing children and cleaning the bathroom, which were not co-dependant practices, but often occurred simultaneously due to time pressures and convenience. This is significant because it meant that the children were often exposed to cleaning products while bathing. Similarly, examples of 'complexes' of practices were evident, such as preparing food for children in the kitchen and washing dishes and wiping benches with cleaning products.

This process also involved coding for indications of the spatio-temporal character of 'complexes' of practices that highlight how and why particular amounts of resources and time were dedicated to particular practices, the prioritisation of practices, and if and how certain tasks were delegated to other actors. Factors that have influenced how different practices have persisted or changed, and why, were also coded for, such as having children, moving house or infestations of insects or fungi in the home. This focus gives an indication of the practices and practice elements that may be more 'stubborn' or resistant to change in the future, and those that may be relatively more malleable. Particular attention was given to post-partum practice changes, such as: disruption of pre-child practices; changes in priority and concern with regard to the safety of the home

environment; the influence of new knowledge sources on practice; new material engagements that accompanied child-related practices; intergenerational practice dynamics; and new demands on time (Blue, 2013, Shove et al., 2012, Strengers and Maller, 2014, Keller and Ruus, 2014, Hui et al., 2017).

I also specifically coded for instances where material interdependence manifested, primarily between products, elements of the home structure and other environmental conditions (such as leaves that get blown into a house, or mould in the bathroom). The points at which attempts were made to replace particular products with others, and the effects of this on the network of interacting materials and on the performance of the practice were also recorded. This is important because replacing a product with a less toxic alternative may disrupt the network of other materials it interacts with. For example, if shower gel is replaced with a bar of soap issues may arise associated with the bar soap leaving a residue on the glass and tiles or drying one's skin under well-heated shower water. Similarly, some participants tried swapping their normal cleaning products for vinegar and bicarb soda, only to swap back because those products did not work well when judged according to the expectations associated with connected material arrangements (e.g. glass shower screens and tiles). In these instances, codes such as 'Interdependent products', 'Abandoned attempt at new practice' were used.

3. How does micro-species agency emerge within practices enacted to create a hygienic home?

As my data analysis progressed, it became apparent that theoretical concepts of practice were limited in their capacity to fully account for some of the forms of agency that were being represented in the data. In particular, the emergent agency of micro-species (microbes and chemicals) challenged the notion of materiality presented in practice theories. The claim that material arrangements are emergent properties of practice was supported to some degree in my data, but it also appeared that non-static non-humans

that displayed some behavioural autonomy, such as micro-species and other animals, not only altered how practices are performed in each given instance, but played a role in shifting the 'practice as entity'.

To account for the forms of biological and chemical agency emerging, I introduced concepts from other more-than-human theories (discussed in detail in Chapter 4) into my coding framework (full list of codes in Appendix E). While both social practice and more-than-human theories place importance on practice, decentring humans and distributed agency, their emphasis differs. Within practice theories, practices, carried out by humans, are the primary units of analysis. Conversely, more-than-human approaches are more attentive to the actions of all of the actors in a given enactment of a practice, and they understand agency as an emergent property of a particular enactment (Haraway, 2008, Mol, 2002, Whatmore, 2002). To gain a better understanding of how micro-species act to shape practices involved in home hygiene, I have drawn on the more-than-human literature which explores this when coding. The following concepts were utilised to code for this type of agency within the practices observed.

5.4.2.1 Species agency

Within more-than-human theories, particularly multispecies ethnographies, the boundaries between different species, and the consequent agency they exhibit, are considered to emerge within practices.

My coding framework integrates ideas from multispecies ethnography related to tracing the emergent agency of micro-scale non-humans in social life. Concepts from Haraway (2008) and Hird (2010) regarding the roles of species at different scales (micro or macro) in shaping practices were utilised. Engagements with micro-species are largely hidden, meaning that we have to rely on sensory proxies and culturally entrained practices, such as bathing, to engage with them. The way they come to have agency in practices is

therefore determined by both their actual behaviours and their assumed behaviours as judged through proxies. The ways in which micro-species were invoked in both of these registers were consequently a key focal point of my coding. This involved being attentive to the bodily movements and reactions (such as when a discolouration of a surface is observed and reacted to by using a cleaning product) to different species within a practice (such as fleas, dogs, trees, and shower mould), and the boundaries between them (when it is assumed, for example, that microbes are foreign sources of infection rather than an integral part of human bodies). It also involved attending to how different species were engaged with dialogically, for example, fleas may elicit disgust and invoke a war-like narrative involving terms such as bombing and extermination, whereas microbes in yoghurt are considered “friendly”.

5.4.2.2 Accommodation and resistance

Pickering (1993: 567) asserted that agency for both humans and materials is dialectical: ‘human and material agencies [are] reciprocally engaged in the play of resistance and accommodation’. He termed this reciprocal play of resistance and accommodation the ‘mangle’ of practice. This concept was used to draw out of the data how different agents within the practice being examined accommodated the other human or material agents resisting them, and how this manifested in particular compromises in the performance of practice.

5.5 REFLECTION ON METHODOLOGICAL APPROACH

Given the objective of understanding human/micro-species engagements within practices, it was important that human attempts to rationalise practices were not given precedence. Rather, the combination of methods was chosen in an attempt to diminish the human/environment dichotomy or assumed separation. Although the activity diaries, and,

to a degree, the interviews, relied on self-reporting, the combination of research methods which accessed practices from multiple angles was able to mitigate against purely cognitive or attitude-based recollections of practices. In addition to considering the limitations of self-reporting, the research encounter itself can create a particular dynamic which is conducive to certain actions and ideas being expressed. As Mazzei notes: 'in analysis one would need a way to account for the material and discursive simultaneously – the bodies of those whom we interview, our own bodies, and how they/we are constituted in the BwO [body without organs]' (Mazzei, 2013: 732). Ingold (2015: 11) extends this line of thinking by examining not just how bodies emerge through interaction, but also how objects, material entities and one's whole mode of being in the world emerge. He uses the compelling metaphor of lines and knots to explain:

For minds and lives are not closed-in entities that can be enumerated and added up; they are open-ended processes whose most outstanding characteristic is that they carry on. And in carrying on, they wrap around one another, like the many strands of a rope. A whole that is made up from individual parts is a totality in which everything is articulated or 'joined up'.

For similar reasons to do with decentring the individual, Martens (2012) reflects on the importance of combining discourse-based methods with other ways of investigating actions when studying practices. In her analysis of dish-washing practices she found that qualitative interviews encouraged discussion about the teleo-affective qualities of dish-washing, and to some extent the rules and principles operative in the practice. However, talking was less able to elucidate an understanding of the activity of dish washing. Similarly, I found that the situated re-enactments of aspects of practices, movement around the domestic space, and the temporal recording of activities in the diaries, were crucial to complement the concerns expressed in the interviews. The combination of methods employed here therefore enabled insights to be generated that no single method could have reached on its own. Perhaps more importantly, they enabled me

to situate participants in their environments, both in the moments of my interaction with them, and more broadly. Within traditional interviews, a detachment between individuals and their environments can be reinforced by decontextualising their thoughts from the actual actions that take place in the course of day-to-day life.

Although different types of discourse-based methods formed the basis of my methodology, the inclusion of bodily movements and material agency were crucial to decentre human explanations of their own actions in the interview and diary contexts. The use of reflective interview notes that recorded aspects of the research interactions beyond what was verbally communicated, and how these interactions might affect participant expression, proved to be equally crucial. In addition, as participants were being examined in their own homes, in relation to a set of practices that have historically been linked to moral judgements of 'good parenting' (Mackendrick, 2014) it was important to be aware that participants may have been feeling vulnerable, defensive or even embarrassed about their practices. This introduced the risk that the descriptions provided may have omitted significant details due to their embarrassing nature. Attempts were made to reduce any potential sense of shame or unwillingness to share details that were usually taboo through wording in the diaries, such as 'Be as honest as possible and do not leave out any dirty details. Over-sharing is okay in here – the researchers won't be sharing it with anyone else', and through adopting a manner in all interactions which was open, friendly and non-judgmental.

Fortunately, in all cases, trust was established quickly (to the best of my knowledge).

There are a number of reasons this may have been the case. The sense of security established through an intermediary who was able to vouch for my integrity may have been important here. Another factor could have been that I am a female in my early 30s from a similar cultural background to many of the participants I was engaging with. More generally, I have found that in professional engagements in numerous contexts such as community forums and workshops in Sydney, young females, such as myself, can be

perceived as unthreatening and can establish trust quickly. This assessment would clearly not be applicable in all cultural contexts, even in Sydney, but may go some way to explaining the responses of this group. The other potential reason that my participants displayed trust quickly was their interest in the topic and their desire to learn about how they could create a healthier home environment for their children. This sense of reciprocity and belief in the values informing the project may have made participants willing to be generous with the intimate details that they shared.

The peer-reviewed articles that comprise the following sections further elucidate, and on occasions briefly reiterate, aspects of this methodological approach in the context of key research findings. My attempts to decentre not only individuals, but singular disciplinary priorities, epistemologies and language, becomes apparent in the juxtaposition of the papers. Reading the papers alongside one another makes explicit the translation work, and the types of theory and history that are foregrounded for different audiences.

INTRODUCTION TO PAPERS

In the four papers that follow, I present the primary findings from my research in response to the research questions. Given the issues identified thus far in relation to epistemological divergences in how indoor environmental health issues are conceptualised and addressed, a key objective in writing these papers was to ‘translate’ my research findings for the disciplinary audiences concerned with this issue. This involved engaging audiences using the language and subjects appropriate to each journal, while attempting to introduce objects of study and theoretical propositions that often sat outside of their normal boundaries of concern. The tension that emerged from these competing interests often made for an interesting review process. One journal editor, after expressing enthusiasm for the paper, noted that: ‘Given the nature of the topic we are having considerable difficulty in finding suitable referees who would be able to evaluate

your paper'. This paper was ultimately accepted by this journal, but its publication, like the other four papers, involved a process of negotiation and compromise, requiring me to make adjustments to the ways in which the issues addressed in each one were framed. This process significantly influenced how the papers were pitched, and which aspects of the problem, methodology and analyses were included in each. The process of negotiating cross-disciplinary research that will inevitably characterise future attempts to progress inter- or transdisciplinary research into indoor ecologies are subtly embodied and explicated in the papers included in this thesis, although this is not always overtly apparent.

One thing the reader will notice in reviewing the articles included is that none of them are published in a traditional scientific journal. Disciplinary conventions across the natural sciences often prevent the inclusion of qualitative, or non-scientific data more broadly, and articles that do not conform to strict scientific reporting and formatting criteria. As a result, the findings of this research are targeted at audiences that are broadly social scientific. Although I have still been able to access a diverse range of fields through these publications, it has been difficult to find appropriate fora at which to present this research to audiences in the 'hard' sciences.

Table 1 provides an overview of the specific contributions, intended audiences and development of my argument through each of the papers below. I also provide some context for each paper as it is introduced in the text. I have included the papers exactly as they were formatted and referenced upon acceptance for publication by the journals. The list of references for each paper therefore comes at the end of the relevant paper, rather than at the end of the thesis. This helps the reader to understand the different in-text citations and it means that each reference list complies with the formatting requirements of the relevant journal.

The fifth paper presents recommendations for future research and is introduced in Chapter 6.

PAPER 1: ROUTINE EXPOSURE: SOCIAL PRACTICES AND ENVIRONMENTAL HEALTH

JOURNAL: SOCIAL THEORY AND HEALTH

This paper, published in the journal *Social Theory and Health*, lays the groundwork for the subsequent papers by establishing the value of a social practice approach for investigating indoor ecologies. It analyses findings from literature across the sociology of consumption, design and exposure science to argue that many of the issues associated with indoor environments that are maladapted to supporting human health cannot be addressed without attending to social practices. In particular, it highlights how the adverse effects of home microecologies cannot be resolved by replacing single products, despite this being the primary approach observed in common marketing and narratives advocating for enhanced consumer engagement and decision-making. This point is illustrated through an example of endocrine disrupting chemicals (EDCs), which provide a compelling case for why practices, rather than products, or even ingredients, should be the focus of analysis and intervention. The other important contribution of the EDC example is to highlight that interventions in the domestic space oriented towards achieving environmental sustainability, or other objectives, that exclude micro-ecological interactions can maintain or even exacerbate potentially harmful conditions. This situation indicates a need to introduce revised problem definitions that incorporate more diverse knowledge perspectives.

This paper targets sociologists of health and illness, public health researchers and practitioners and researchers across the consumption studies field. Researchers in these fields have been instrumental in drawing attention to, and intervening in, many pressing environmental health issues, and the socio-political factors that influence them.

Wakefield-Rann, R., Fam, D., & Stewart, S. (2018). Routine exposure: social practices and environmental health risks in the home. *Social Theory & Health*, 1-18.

ABSTRACT

The post-war introduction of new chemicals to consumer products created a range of complex environmental health issues. Despite recent evidence demonstrating the issues associated with using particular chemicals in the home, responses from industry and regulators have failed to account for the complex ways that chemicals interact with each other, humans and microorganisms to cause harm. This paper draws together scientific and social science literature to make two key contributions: first, it demonstrates why investigating everyday practices will be crucial to improve knowledge of how human/environment interactions in the home are contributing to certain health conditions; second, it draws on examples of Endocrine Disrupting Chemicals to show how these health conditions cannot be addressed by replacing individual products, or chemicals, as many toxic ingredients have become central to the functionality of interdependent networks of products, and the routines they enable. By failing to engage with these issues, future research and planning to establish healthy homes will not be able to account for these crucial sources of harm. We conclude that further research addressing indoor environmental health should expand the boundaries of inquiry across disciplines and knowledge perspectives to analyse how social practices structure micro-scale interactions between humans, microbes and chemicals, in the home.

Keywords: social practices, chemical exposure, household consumption, microecology, environmental health, indoor pollution.

INTRODUCTION

Household environmental contaminants are pervasive and pose a significant threat to human health around the world (Weschler, 2009, Ott et al., 2006). The key sources of

household contaminants include: consumer products, how the environment surrounding the house has been used, and the building materials and furnishings used within the house (Altman et al., 2008, Ott et al., 2006, Carbajo et al., 2015). Over the past 60 years there has been a rapid development in new building materials, furnishings and consumer products containing new classes of chemicals that humans had not previously been intimately exposed to in their everyday lives (Weschler, 2009, Rudel and Perovich, 2009). During this time, people in industrialised countries are also estimated to have increased the amount of their time they spend indoors to 90%. Simultaneously, the rate of airflow between indoors and outdoors has decreased in many areas as buildings have become tighter and more energy efficient (Luongo, 2016). As a result of these developments, people around the world are spending more time in atmospheres imbued with new classes of chemicals, many of which are known or suspected to be toxic.

Despite increasing exposure to these chemicals over this time, weak regulatory requirements for chemical testing around the world have meant that the onus is largely on consumers and scientists to prove that a chemical *is harmful*, rather than for producers to prove that it *is not* (Zimmerman and Anastas, 2015, Silbergeld et al., 2015). Moreover, traditional regulatory toxicology is largely unable to account for chemicals that cause harm in complex non-linear ways, whereby their adverse affects are dependent on the amount and frequency of exposure, the age of the body exposed, and what other chemicals they are combined with (Schug et al., 2013, Olsson, 2014, Zoeller et al., 2012).

Consequently, only a portion of the chemicals used in consumer products have ever been tested, and even less data is available on how different chemical use scenarios influence the behaviour of chemicals in humans and the environment (Ott et al., 2006, Weschler, 2009, Ha et al., 2016).⁴ As a result, regulation has only effectively protected consumers

⁴ The European Union's REACH (Registration Evaluation Authorisation and Restriction of Chemicals) framework proposes to shift this 'burden of proof' to chemical manufactures and the industries that use

and the environment against a handful of noteworthy chemicals, such as Dichlorodiphenyltrichloroethane (DDT), Polychlorinated Bisphenols (PCB) and Chlorofluorocarbons (CFCs), in some countries (Boudia and Jas, 2014).

Chemicals that are now common in home products and furnishings not only cause harm via direct or cumulative exposures (Ott et al., 2006), but indirectly, through the elimination of microbial life essential for human development (Adams et al., 2016, Dunn et al., 2013). There is a growing body of research linking the type and diversity of microbes living in the home to the development of children's immune systems and other health conditions. The ways that homes are used, ventilated and cleaned with particular chemicals have all been identified as factors that can contribute to the types of microbial communities that flourish and how they affect humans (Dunn et al. 2013). For example, the absence of particular types of microbes in homes and overall microbial diversity have been linked to higher rates of allergies in children (Heederik and von Mutius, 2012, Lynch et al., 2014).

Debate around the relative responsibilities of individuals and structural factors in determining adverse health outcomes has long been prominent in health theory (Brown and Nettleton, 2017, Petersen, 1996, Williams, 2003). Recently, this debate has extended to encompass the complex problem of exposure to ubiquitous indoor contaminants. Some scholars (Szasz, 2007, Scott et al., 2017, Moncure, 2016, Patterson and Johnston, 2012) argue that responsibility for mitigating harm has unfairly been placed solely on the consumer. They argue that this individualisation of risk management will be ineffective as only some exposures can be reduced through consumer decisions. Exposure from

them, however its capacity to protect people and the environment is from the vast array of chemicals in use is still unknown SCRUGGS, C. E., ORTOLANO, L., SCHWARZMAN, M. R. & WILSON, M. P. 2014. The role of chemical policy in improving supply chain knowledge and product safety. *Journal of Environmental Studies and Sciences*, 4, 132-141..

chemicals in the environment, such as pesticides, and from infrastructure, water, or building materials, cannot be easily controlled through consumer decision-making. Moreover, consumer products often contain chemicals that are not stated on the label or are not known by consumers to be harmful. Proponents of this perspective believe that framing the problem as one of consumer choice also makes individuals disinclined to pursue more effective routes for change, such as environmental health advocacy, that puts pressure on governments and industry. The other implication of individualised risk management, in what Szasz (2007) has labeled 'inverted quarantine', is that those without the education or the means to limit their exposure to potentially harmful consumer products are still at risk (Szasz, 2007).

The counter-perspective does not deny that environmental health action based on consumer choice is insufficient, but contests the idea that 'inverted quarantine' will subvert broader structural reform (MacKendrick and Stevens, 2016, Baumann et al., 2015, Lorenzen, 2012). Rather, it is argued that attempts to control the chemical 'body burden' via consumer choice represents an attempt to claim some control and minimise exposures. Lorenzen (2012) found that individuals who attempted to manage exposures via purchase decisions understand their decision to purchase safer products as both a work in progress and a 'provisionally coherent life narrative'. This rationale is reflected in the broader literature around how the figure of the consumer is mobilised politically. Barnett et al (2010: 85) suggest that campaigning often involves the mobilisation of consumers by intermediaries representing "their expressed preferences as 'ethical' subjects to other actors involved in making markets including state agents, corporations and regulatory agencies". Similarly, Evans et al (2017) contend, through an example of food waste practices, that the rhetorical figure of the 'responsibilised' consumer is generative of a politics that resembles an ideal of shared responsibility. These examples suggest that narratives framing decisions to protect oneself through consumption choices do not necessarily preclude participation in change movements focused on broader political and

cultural reform.

Positioning responsibility for change solely with individuals, governments, manufacturers, or a normative culture, critically oversimplifies the issue. First, it disregards the ways in which particular chemicals have fundamentally changed the performance and functional qualities of many everyday products, and consequently the expectations we have of them and the daily routines in which they perform (Shove, 2007b: 114). Second, products do not exist in isolation, but in networks of interdependent things they are designed to work within (Latour, 1992, Park, 2016). This interdependence between products restricts the capacity of single products to break with their current functions and the materials that facilitate them. For example, one generally does not use toothpaste in isolation, but as part of a practice involving a toothbrush, dental floss, bathroom sink and running water. Finally, the capacity of many chemicals of concern to cause harm is determined by the ways that they interact with other chemicals, microbes and bodies in practice over time (Ott et al., 2006, Gosens et al., 2014). Therefore, the different ways in which certain objects and substances are used in particular indoor spaces will produce different outcomes. To effect change entire networks of objects, services and infrastructures, and how they enable essential daily activities, must be problematised, reevaluated and redesigned.

To develop alternative product-service systems for domestic life that do not necessitate harmful chemical use, it is first necessary to understand the roles played by problematic chemicals in products, and the ways in which they are essential to modern domestic life. Technological and scientific advances in the post-war era have bound concerning chemicals not only to particular products, but also to concepts such as hygiene, freshness and beauty (Ouimette, 2011, Liljenquist et al., 2010). Chemicals provide many of the smells, textures and other aesthetic qualities that now represent virtues such as cleanliness. Acquiring evidence of how certain chemicals are integral to the performance of particular practices will be central to identifying the ways in which these practices persist. This is crucial, as it is through the repetition of practices that particular types of

chemicals and microbes create microecologies that adversely affect human health.

The structure of the home microecology depends on how chemical and microbial ‘micro-species’ interact in everyday home practices. We use the term ‘micro-species’ in a unique way to refer to both the biological and chemical species⁵ that exist at a micro-scale (invisible to the human eye) in homes. The utility of the species concept is also recognised by Kisksey (2015), who argues that it remains a valuable sense-making tool that acknowledges how political, economic, and ecological forces bring new forms of life into being. The use of species as a categorisation to encompass both types of entities is useful for distinguishing the distinctive types of influence and interactions exhibited at the micro-scale. The standard categorisations of microbes and chemicals as living and non-living respectively obscures important shared traits related to how they act, react and influence the environments they exist in. Micro-species are unique because they display a degree of behavioural autonomy, unlike inert materials, yet because they are invisible, the way they are behaving and interacting is not always perceptible. Rather, micro-species make their presence known through proxies that are interpreted (or misinterpreted) by humans, such as odour, discolouration of surfaces and clothes, and skin rashes. The significance of the agency of micro-entities in ecological interactions is beginning to gain traction in socio-political examinations and critiques of dominant scientific and ecological management narratives and practices (Barad, 2007, Waterton and Tsouvalis, 2015, Granjou and Phillips, 2018, Münster, 2017). However, research that engages with the role of micro-agency in generating indoor ecological assemblages could not be found. This omission is significant, as the complex interactions between micro-species, and the objects, humans and infrastructures they inhabit in daily life shape the home environment at a micro scale, and determine whether its microecology is supportive of or damaging to

⁵ Chemists refer to identical molecular entities as ‘chemical species’.

the health of occupants (Ott et al., 2006, Gosens et al., 2014).

The ubiquity of industrial chemicals in consumer products around the world, along with the standardisation of many domestic practices (Mylan and Southerton, 2017, Shove, 2003)) and increases in time spent indoors, mean that unhealthy home microecologies are not geographically restricted. Although the composition of home microecologies are far from homogenous across geographic and cultural contexts, research suggests that the standardisation of common everyday domestic practices, and the common materials that they incorporate, are producing similar health outcomes across much of the industrialised world (Biesterbos et al., 2013, Loretz et al., 2008). For this reason, this paper does not focus on a specific region, but on addressing how common everyday practices entail micro-species interactions that contribute to maladaptive microecologies.

An approach to understanding everyday life grounded in theories of social practice could improve knowledge of the specific roles that potentially harmful micro-species play in home life, and identify potential points of intervention to make home microecologies more healthy and safe. Theories of social practice are heterogeneous, but the dominant approaches that form the basis of this analysis are grounded in the account first refined by Schatzki (1996) and Reckwitz (2002), and since appropriated and further refined by scholars such as Shove (2003, Shove et al 2012) and Warde (2005). Reckwitz has provided a useful conceptualisation of social practices that remains one of the most widely cited:

"Practice is a routinised type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge."
(2002b: 249)

A practice-oriented approach is distinct from other traditional social theories because it sees human action and social order as products of practices, rather than the traditional

spectrum of social theoretical approaches which generally position individuals respectively as self-interested rational agents, passive dupes at the mercy of structural forces, or as motivated primarily by symbols, attitudes and beliefs (Reckwitz, 2002b, Strengers and Maller, 2012, Shove, 2004). In theories of social practice, 'consumers' are seen as participants in, and 'carriers' of, practices. Consumer behaviour is grasped not as an outcome of individual decision making, but as an emergent property of practice (Warde, 2005). From this perspective, individual actions and decision-making occur within the context of the dynamic, routinised interplay between the co-constitutive elements of practices, commonly defined as material things, meanings and embodied knowledge (Shove, 2004, Strengers, 2010a, Spurling et al., 2013).

In the following sections we demonstrate why theories of social practice are well placed to provide insights into the complex assemblages of bodily competencies, material things, and meanings that structure maladaptive home microecologies. To articulate why an orientation to practices will be necessary to investigate these complex assemblages, we use an example of Endocrine Disrupting Chemicals (EDC). EDCs effect the normal functioning of the hormonal system in animals by either blocking hormone receptors or signaling them to work at the wrong time (Liboiron, 2015). As hormones are integral to the functioning of numerous bodily processes such as reproduction, metabolism and brain development, the disruption caused by EDCs can affect multiple bodily systems (Muncke, 2011). As a result, exposure to EDCs can manifest in a diverse range of health conditions, including: early-onset puberty, low sperm count in males, diabetes, obesity, cancer and impaired development of reproductive organs and the brain (Reuben, 2010). Reference to the scientific literature is used to identify the complex relationships between contexts of use and the potential for chemicals to cause harm. We then offer two examples that demonstrate how EDCs have become essential to the everyday performance of household practices, highlighting why practices, rather than consumer products, should be the key unit of analytical attention and re-design.

A review of research drawing on practice theory to investigate contexts of consumption reveals an absence of studies on microecologies and the impact of contaminants. At present, there are a number of instructive studies published that focus on intervening in practices that promote unsustainable patterns of household resource consumption. Investigations of micro species interactions have the potential to compliment and extend these studies to more comprehensively address the environmental health impacts of domestic practices (see Scott et al., 2012, Strengers and Maller, 2012, Shove, 2004, Kuijer and De Jong, 2011, Jack, 2013a). The consideration of micro-species interactions is particularly important given that interventions to reduce the resource intensity of practices will have an impact on the microecologies of homes, and consequently the bodies and ecosystems with which they are connected. We therefore advocate for approaches to investigating practices that are sensitive to both their resource intensity and the interactions with micro-species taking place within them.

SOCIAL PRACTICE-ORIENTED APPROACHES TO INVESTIGATING DOMESTIC CONSUMPTION PRACTICES

Over the past 20 years theories of social practice have increasingly been adopted by social scientists concerned with the contextual, adaptable and complex nature of everyday consumption (Warde, 2005, Strengers and Maller, 2014, Verbeek and Mommaas, 2008, Shove, 2003, Strengers, 2011b, Wahlen, 2011, Keller and Ruus, 2014). Social practice theories focus on the dynamic interplay between material things, embodied knowledge, and meanings over time as the primary unit of social analysis. This focal point contrasts with more reductive units of social analysis, such as cognitive reasoning, texts and symbols that characterise more traditional social theories (Shove et al 2007). In refocusing analytic attention on practices, practice theories are able to provide insights

into how diverse elements of social life evolve, are reproduced and interact through everyday life.

Within the social practice theory literature, the term 'practices' is used to refer to both coordinated entities, and the performances that enable these entities to exist and persist over time (Schatzki, 1996: 89). These mutually constitutive aspects of practice, proposed originally by Schatzki (1996), have become a central feature of theories of social practice (Warde, 2005, Hitchings, 2012, Shove et al., 2012, Pullinger et al., 2013). Practice as entity refers to groupings of 'doings and sayings' that are temporally and spatially ordered in a particular way. These groupings include practices like cleaning, commuting, dining and shopping. The elements within each of these practices are linked into a 'nexus' by shared understandings of what to say and do, by rules and instructions, and by beliefs, meanings and purpose (Schatzki et al., 2001, Warde, 2005). From this perspective, none of these elements is superior to the other, and they each take form and gain meaning via their connections to one another over time. The performance of 'practice' refers to the regular enactments of these routinised groupings of doings and sayings, which are required to sustain the practice over time. We propose that routinised practices are central to the generation and configuration of household contaminants. As the site at which processes of production (cultural and material) meet processes of consumption⁶, everyday practices curate the composition of artifacts and substances that comprise the home environment.

By moving beyond individualised decision-making or cultural determinism as explanations for social behaviour, practice theories are able to account not only for

⁶ Following Warde (2005), consumption is not understood to mean shopping, but the process by which items are appropriated in the course of engaging in particular practices. Consumption is therefore considered to be a dispersed practice that occurs often, on many different sites, rather than a practice in and of itself.

collective conventions, but also the diversity that exists within them. As Warde (2005) notes: "Practice theories comprehend non-instrumentalist notions of conduct, both observing the role of routine on the one hand, and emotion, embodiment and desire on the other." This conceptualisation of consumption behaviour undermines theories that individualise responsibility for consumption choices that have a negative impact on the environment or human health, and theories that attribute responsibility to the market, advertising and 'consumer culture', without totally negating the roles of these respective forces. Similarly, Barnett et al (2010) contend that a practice-based approach allows us to see that the consumer can be an entry point into problematising conventions, routines and habits, that bind people into certain systems of provisioning. From this perspective, consumer choice is recognised as emerging from diverse and distributed patterns of agency, rather than a single hegemonic neoliberal ideology. Moreover, the relative roles of different agents for change in the evolution, persistence or disappearance of practices, be they human, animal or material, differ across practice contexts. Practice theories are consequently able to sensitise the researcher to the interplay between human and non-human elements within a practice without giving priority to any particular agent as the most significant driver of a practice.

A number of important studies into everyday practices have improved our knowledge of the drivers of environmentally significant forms of 'inconspicuous consumption': the consumption of resources associated with everyday utility use, such as energy and water, which had previously been neglected in favor of more culturally visible forms 'conspicuous' consumption within social theory (Shove and Warde, 2002b, Strengers and Maller, 2012, Strengers, 2011b, Jack, 2017). Mundane acts of consumption not explicitly linked to the use of consumer goods to communicate social meaning were generally excluded from the consumption research agenda in the twentieth century (Shove and Warde, 2002b, Miller, 2010, Campbell, 2013). These studies have shown how the type and amount of resources consumed per capita is profoundly influenced by the mundane,

everyday practices in which the majority of consumption acts take place. Practice theories have also been constructively used to develop design intervention prototypes to encourage less resource intensive domestic practices, such as Kuijer's 'splash'-based bathing system, which requires less operational energy and water than a conventional shower or bath (Kuijer and De Jong, 2011). They have also been used to investigate how shopping practices influence unhealthy food choices and how interventions could be designed to encourage healthier food practices (Keller and Ruus, 2014).

Practice-oriented investigations into resource intensive or unhealthy practices have provided valuable insights into how resource consumption could be reduced. However, given that these studies do not account for micro-species interactions, the proposed interventions that may flow from them could maintain existing, undesirable, microecologies, or change them in unintended ways. The composition of materials that constitute everyday practices and how they interact with other substances, materials and bodies over their lifecycle have a significant impact on human health. Therefore, if a domestic practice is defined and investigated without including interactions with micro-species as a key variable, the interventions and solutions devised are unlikely to adequately account for the potential harm these interactions could cause.

There are a number of reasons why micro-species interactions may have been largely excluded from investigations into everyday life to date within the practice turn in social theory. Shove (2007b) has noted that there has been an inattention to the material composition of objects across the social sciences, and speculated that this may be due to a suspicion of their social significance. It is commonly held across various streams of the contemporary social sciences that the significance of 'things' is not determined by the raw materials they are made from, but by how they participate in social life (Miller, 2010, Shove, 2007b, Ingold, 2016). There is consequently a wariness towards giving weight to the material composition of an object in social analysis, because it risks a type of functionalist reasoning that suggests material composition has power to determine

meaning.⁷ Regardless of its causes, Shove argues that this absence has meant that our knowledge of the co-evolution of substances and objects has been obscured to the point that our knowledge of each has become critically limited (Shove, 2007a). Perhaps more importantly, this inattention to materials has meant that the ways in which the material composition of objects contributes to their agency in social life has been under-examined. This is not to say that material dynamics that include micro-agents have not been the subject of research in other forms of social theory, as 'New Materialist scholars within Science and Technology Studies such as Barad (2007) and Bennett (2010) have influentially theorised ways in which matter may be considered queer and 'lively'. Similarly, chemo-ethnographers within anthropology are interested in the role of invisible chemicals in creating new socio-political realities (Kirksey and Helmreich, 2010). However, this nuance in conceptualisations of material agency has been largely absent in the practice literature. This paper proposes that an interrogation of agency that emerges from micro-material dynamics will be crucial to improving knowledge of the role of interactions with and between micro-species in domestic practices that result in sub-optimal indoor living environments.

THE INFLUENCE OF MICRO-SPECIES INTERACTIONS WITHIN PRACTICES ON INDOOR ENVIRONMENTAL HEALTH

To illustrate how practices help structure the harm caused by home microecologies this section draws on the scientific literature that examines how EDCs become harmful via the repeated enactment of certain domestic practices. Children under the age of five, and women who are pregnant or of childbearing age have been identified as the most vulnerable to EDC exposure (Reuben, 2010). This means that home microecologies

containing EDCs do not affect home occupants in uniform ways. Rather, harm depends on the age and sex of the body exposed, frequency of exposure, other chemicals present and mediating factors.

Chemicals classified as EDCs are currently embedded in multiple categories of domestic consumer products and building materials, some of which include: flame retardants in electronics, furniture, clothing and bedding; polychlorinated biphenyls (PCB), in electrical equipment, paints and surface coatings; phthalates, used in fragrances, vinyl, plastics, and other cleaning and personal care products; parabens, used to preserve body lotions and sunscreens; and alkylphenols, used in detergents, pesticides, and polystyrene (Rudel and Perovich, 2009, Schug et al., 2013, Weschler, 2009, Gosens et al., 2014, Biesterbos et al., 2013). This ubiquity and diversity of EDCs is important because the number of exposure sources within a living environment, how the chemicals have interacted with other chemicals and microbes, the amount of a chemical released, and the duration of each exposure all influence how an EDC will act in a body and if it will cause harm (Ott et al., 2006, Rudel and Perovich, 2009). The way EDCs travel, interact and persist within a home is influenced not only by the presence of products containing EDCs, but by the way a home is designed and used. This has been demonstrated in a number of studies examining the amounts of particular EDCs that persist over time in house dust (Wilson et al., 2003, Von Goetz et al., 2010, Koch and Calafat, 2009). Knowing the nature of how products containing EDCs are used and interact within a microecology of a home is consequently essential to knowing how they may cause harm.

Investigations of the role of EDCs in the products that enable everyday domestic practices also reveals that removing them from homes cannot simply be achieved by replacing single products or product ingredients (Loretz et al., 2008, Zimmerman and Anastas, 2015). EDCs provide the essential performative qualities that allow products to work interdependently with other products within everyday practices. Two examples of household practices illustrate these networks of interdependence well: food preparation

and cleaning.

EDCs are essential to the way many families shop for, store and prepare food. For example, Bisphenol A (BPA), a known EDC, is used as a protective lining in the inside of many metal-based food tins and in polycarbonate, a hard plastic used in many consumer products, including food packaging and baby bottles (Muncke, 2011, Von Goetz et al., 2010, Clayton et al., 2011). BPA has been found to leach out into food products from tins and plastic packaging (Yang et al., 2011). However, BPA plays an essential role in enabling food products to be easily transported through global food chains, and to remain uncontaminated with bacteria on the shelves of supermarkets and in homes (Sutton et al., 2011). If individuals could not buy food that lasts more than a few days before spoiling, they would no longer be able to shop irregularly or store food at home. Furthermore, foods contained in tins or plastic packaging are often more processed and require less preparation and cooking. To remove these food products would therefore also alter, and potentially increase, the amount of time many people must spend cooking, which would have flow on effects on other daily routines (Evans, 2012).

Due to the essential role that BPA plays in food distribution systems, many food companies have responded to research about the potentially harmful health impacts of the chemical by replacing it with the closely related chemicals bisphenol S (BPS) and F (BPF) (Zimmerman and Anastas, 2015, Žalmanová et al., 2016). These chemicals were able to provide the same function in the product, but had not been subject to the same amount of research. BPS and BPF have since been found to be as likely to cause endocrine disruption as BPA (Žalmanová et al., 2016, Rochester and Bolden, 2015). This situation has been termed 'regrettable substitution' by scientists, and is a common occurrence in industries that rely on chemicals that are regularly found to be unsafe (Zimmerman and Anastas, 2015). The reason regrettable substitution is so common is because the affordances provided by particular chemicals in many products are central to the product's role within a network of interdependent things that are used together to enable a current practice,

such as cooking or shopping. It will consequently not be possible to remove chemicals such as BPA and its relatives from homes until their role in enabling everyday practices has been further investigated and alternative ways of fulfilling practice outcomes with different networks of things have been explored.

EDCs are also essential to the way that we define, sense, measure and perform cleanliness in the home (Wakefield-Rann, 2017). Take body wash as one illustrative example.

Chemical scents such as synthetic limonine (lemon scent) and pinine (pine scent) have become synonymous with 'cleanliness' in a range of products, including body wash, bathroom cleaners, surface sprays and 'air-fresheners' (Ott et al., 2006: 153). These artificial scents that are crucial to the way we have come to sense and define cleanliness are commonly provided by EDCs called phthalates (Reuben, 2010). Similarly, the extent to which a body wash product foams and lathers has become central to the perception that it is cleaning well, even though the lather is generally functionally unnecessary. As a result, manufacturers often include additional surfactants in products, such as the EDCs Nonlphenol exthoxylates, to make them lather more. There is also often an expectation that a body wash will have antimicrobial properties, which are commonly provided by EDCs like Triclosan and Triclocarban (Clayton et al., 2011). The growing consumer preference for body wash over hard soap, due to its greater convenience, ease of use and reduced 'mess', also necessitates certain product preservatives, due to the high water content of liquid products (Kessler, 2015). One of the most common types of body wash preservative are a group of EDCs called parabens (Carbajo et al., 2015). In addition to the active product ingredients, the squeezable plastic packaging that contains body wash is also impregnated with EDCs in the form of plasticizer chemicals that make plastic more malleable (Reuben, 2010). The example of body wash reveals how EDCs have become essential to the way that cleanliness has come to be sensed and defined, and the way a product is expected to function in the routine it performs in.

Although there are some cases where replacement chemicals are found that have the same

properties as EDCs, in the majority of cases, chemicals that behave like EDCs, are EDCs (Zimmerman and Anastas, 2015). As a result, EDCs are commonly replaced with new chemicals that are later discovered to be EDCs, because they are the only chemicals able to provide the functions required. As in the case of BPA, BPS and BPF in the food industry, regrettable substitution is common in the personal care and cleaning product industries (Zimmerman and Anastas, 2015). The recurrence of regrettable substitution across categories of consumer products demonstrates that the removal of EDCs from home microecologies will necessitate their removal from practices. For this to happen, the performance of practices such as food preparation and cleaning, and their attendant materials, infrastructures, meanings and physical competencies, will require a fundamental reevaluation.

LUSH Cosmetics provides a compelling example of how a reconfiguration at the scale of a product-service system can influence the performance of practice. By introducing appealing alternatives to liquid body wash and shampoo in the form of solid bar soaps, shampoos and conditioners, LUSH has been able to provide an alternative that avoids regrettable substitution by eliminating the necessity of preservative and exfoliating chemicals, surfactants and plastic packaging from personal care routines (LUSH, 2016, Buchwalter, 2007). These products still work with existing infrastructures (baths and showers) but promote new sensory engagements and expectations (Buchwalter, 2007). Importantly, they have successfully countered the rapid trend towards liquid, chemical intensive products, by adopting a 'deli style' retail model where consumers can touch and smell the products and have the desired amount cut for them. This product-service system is explored further in Wakefield-Rann (2017). By examining how existing product-service systems and building designs perpetuate current practices and infrastructures, interventions in these systems to support new practices can begin to be constructively devised.

A NEW PROBLEM FRAMING IS REQUIRED TO ADDRESS DOMESTIC MICROECOLOGIES

To begin to account for the ways that practices structure home microecologies, a new way of framing household practices will be necessary. The following section examines how the boundaries drawn around the systems of concern that define healthy and safe household consumption practices could be reframed and expanded to include the effects of micro-species interactions within and between objects, substances and bodies.

The way the problem of unhealthy households and lifestyles is conceptualised influences the types of solutions that are considered, promoted or obscured, and the types of actors that are considered responsible for creating change. By taking a practice as the starting point for investigation, researchers can allow the nature of the problem to emerge through situated observation over time, rather than beginning with assumptions about the problem elements and key drivers in each context. However, in observations of what people do, researchers will be more sensitised to certain practice elements than others. As previously noted, many investigations of practices focus on the materials, meanings, and competencies (Shove et al., 2012, Scott et al., 2012, Spurling et al., 2013) as the core practice elements, with some modifications, including the addition of 'rules' by Strengers (2010a). These categories do not obviously accommodate the micro- scale of material interactions and how they influence other practice elements. In particular, microbial and chemical agency are influenced by how they are brought together within a practice, yet their semi-autonomous modes of action and reaction may lead to effects on practices that are not immediately evident. For example, the combination of limonene and ozone in indoor air produce carcinogenic formaldehyde when combined (Sarantis, 2010).

If interventions intended to alter domestic consumption practices to improve household sustainability or environment health do not consider micro-species interactions, these interventions could have unknown and unintended consequences for the composition of

home microecologies. To take one of the many potential examples within bathing practices, if the EDCs in body wash are not considered to be a concern when researchers, government or industry define how to transition contemporary urban dwellers to sustainable bathing practices, a more water and energy efficient bathing practice may be proposed that still necessitates the use of body wash. Similarly, when attempting to improve the energy efficiency of buildings one common strategy of architects and builders is to seal the interior as tightly as possible to prevent the leakage of heated or cooled air. However, research has found that a key factor in achieving good indoor air quality is a high level of exchange between indoor and outdoor air (Steinemann et al., 2017). This airflow enables a necessary microbial exchange and chemicals (such as Volatile Organic Compounds) to be adequately flushed out. These examples highlight that the health effects that stem from poor microecologies will not necessarily be resolved, and may even be exacerbated by attempts to improve infrastructures and other practices according to other parameters. They also indicate the vital importance of engaging actors with knowledge and authority pertaining to different aspects of the problem. To avoid further individualising responsibility, it is important that government, designers, architects, exposure scientists, microbiologists and social scientists acknowledge their shared responsibility for addressing this issue.

To ensure that harmful micro-species interactions are not generated through other forms of well-meaning practice interventions, for example, health and resource intensity, researchers and other key stakeholders must work together to begin to ask: what needs to be taken into consideration if the micro-species interactions that underpin this practice are to be accounted for?

CONCLUSIONS

The microecologies of homes are an under-investigated source of contaminants implicated in numerous human health conditions. This paper has sought to bring to light, first, how

the micro-species interactions that form home microecologies are structured by everyday practices, and second, how the adverse effects of home microecologies cannot be resolved by replacing single products or product ingredients, as the removal of certain problematic ingredients will render whole networks of domestic products dysfunctional. The example of household EDC use demonstrated why the removal of harmful chemicals from practices such as food preparation, bathing and cleaning, would require the performance of these practices, and their attendant materials, infrastructures, meanings and physical competencies, to be fundamentally reconsidered.

By failing to engage with these issues, there is a risk that future research, design, policy and planning attempting to establish healthy, safe homes will not account for these crucial sources of harm, or may even exacerbate them. Consequently, we suggest that a new research agenda is developed that focuses on investigating how social practices structure the microecologies of homes. Like many complex problems, addressing this issue will necessitate an investigative approach that transcends traditional disciplinary boundaries and methodologies. Ethnographic and other social investigations of domestic practices, the dynamic interconnections between them, and how they influence the material things that constitute a living environment, must be integrated with research into the bio-physical impacts and design implications of each environment. For example, research must incorporate not only microbiologists and chemists, but designers and architects with expertise in the affective and material properties of particular buildings and consumer products. This focus enables an assessment of the complex interactions and reactions between micro-species in an environment. The inclusion of such diverse disciplinary perspectives will require a process by which the problem space, and methodology for investigating it, is collectively defined and a range of disciplinary perspectives of the problem sought and integrated. Scholars such as Fam et al (2017) and Stokols (2014) have demonstrated through research case studies how this type of transdisciplinary approaches to integrating knowledge across disciplines and knowledge perspectives

requires a dedicated, consultative and reflective approach to ensure that ontological disparities and power dynamics between different perspectives of the problem are addressed.

The highly specific nature of each home microecology also demands a greater engagement with home occupiers in research, as 'environmental sensors' and 'carriers' of practices (Altman et al., 2008). Empowering individuals to contribute to investigations of indoor environmental quality by valuing their own bodily experiences, felt effects of contaminants and allergens, and how materials flow, accumulate and interact in their homes is vital knowledge unable to be acquired by any expert (Pink, 2015). The incorporation of citizen science or sensing methods may be an invaluable element of a new research agenda to improve knowledge of the practices structuring home microecologies.

Any examination of the physical environment and incorporated practices should ideally be grounded in an investigation of broader physical and political structures that both enable and constrain particular forms of action. The analysis presented in this paper has highlighted issues at a macro-political scale in regulatory systems that enable EDCs to persist in products, but it has also drawn attention to significant micro-political dynamics which result in women and children bearing a disproportionate burden in terms of vulnerability to indoor ecological hazards. MacKendrick (2014) and Altman (2008) contend that women also more often take on the responsibility of managing their entire family's chemical body burdens through consumer choice. By addressing the role of these political dynamics in shaping practices, wider systemic issues related to uneven health burdens according to age and gender can be identified, and addressed through planning and public health policies, and amenities and services.

As a starting point, this paper has proposed that a new approach that extends the purview of research into domestic consumption practices to consider micro-scale interactions is

required. By incorporating the above elements, further research could contribute to new ways of defining, measuring and planning for healthy and safe homes. Future research should account not only for the resource efficiency of buildings, consumer products and appliances, but the networks of actors and systems of practices, from the micro to the macro, and the interactions and flows between them that construct the micro-worlds of indoor spaces. Research that values the crucial role of practices in determining how indoor environments effect humans and the environment might produce new standards and forms of analysis that are iterative, adaptable and able to account for vast contextual diversity.

REFERENCES

- ADAMS, R. I., BHANGAR, S., DANNEMILLER, K. C., EISEN, J. A., FIERER, N., GILBERT, J. A., GREEN, J. L., MARR, L. C., MILLER, S. L. & SIEGEL, J. A. 2016. Ten questions concerning the microbiomes of buildings. *Building and Environment*, 109, 224-234.
- ALTMAN, R. G., MORELLO-FROSCH, R., BRODY, J. G., RUDEL, R., BROWN, P. & AVERICK, M. 2008. Pollution comes home and gets personal: women's experience of household chemical exposure. *Journal of health and social behavior*, 49, 417-435.
- BARAD, K. 2007. *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*, duke university Press.
- BARNETT, C., CLOKE, P., CLARKE, N. & MALPASS, A. 2010. *Globalizing responsibility: The political rationalities of ethical consumption*, John Wiley & Sons.
- BAUMANN, S., ENGMAN, A. & JOHNSTON, J. 2015. Political consumption, conventional politics, and high cultural capital. *International Journal of Consumer Studies*, 39, 413-421.
- BIESTERBOS, J. W., DUDZINA, T., DELMAAR, C. J., BAKKER, M. I., RUSSEL, F. G., VON GOETZ, N., SCHEEPERS, P. T. & ROELEVELD, N. 2013. Usage patterns of personal care products: important factors for exposure assessment. *Food and chemical toxicology*, 55, 8-17.

- BOUDIA, S. & JAS, N. 2014. *Powerless science?: Science and politics in a toxic world*, Berghahn Books.
- BROWN, N. & NETTLETON, S. 2017. Bugs in the blog: Immunitary moralism in antimicrobial resistance (AMR). *Social Theory & Health*, 15, 302-322.
- BUCHWALTER, C. 2007. Living A LUSH Life With.
- CAMPBELL, C. 2013. A critique of the consumption as communication thesis. *Buy this book: Studies in advertising and consumption*, 340.
- CARBAJO, J. B., PERDIGÓN-MELÓN, J. A., PETRE, A. L., ROSAL, R., LETÓN, P. & GARCÍA-CALVO, E. 2015. Personal care product preservatives: Risk assessment and mixture toxicities with an industrial wastewater. *Water research*, 72, 174-185.
- CLAYTON, E. M. R., TODD, M., DOWD, J. B. & AIELLO, A. E. 2011. The impact of bisphenol A and triclosan on immune parameters in the US population, NHANES 2003-2006. *Environmental health perspectives*, 119, 390.
- DUNN, R. R., FIERER, N., HENLEY, J. B., LEFF, J. W. & MENNINGER, H. L. 2013. Home life: factors structuring the bacterial diversity found within and between homes. *PLoS One*, 8, e64133.
- EVANS, D. 2012. Beyond the throwaway society: ordinary domestic practice and a sociological approach to household food waste. *Sociology*, 46, 41-56.
- EVANS, D., WELCH, D. & SWAFFIELD, J. 2017. Constructing and mobilizing 'the consumer': Responsibility, consumption and the politics of sustainability. *Environment and Planning A*, 49, 1396-1412.
- FAM, D., PALMER, J., RIEDY, C. & MITCHELL, C. 2017. *Transdisciplinary research and practice for sustainability outcomes*, Taylor & Francis.
- GOSENS, I., DELMAAR, C. J., TER BURG, W., DE HEER, C. & SCHUUR, A. G. 2014. Aggregate exposure approaches for parabens in personal care products: a case assessment for children between 0 and 3 years old. *Journal of Exposure Science and Environmental Epidemiology*, 24, 208-214.
- GRANJOU, C. & PHILLIPS, C. 2018. Living and labouring soils: metagenomic ecology and a new agricultural revolution? *BioSocieties*, 1-23.
- HA, S., SEIDLE, T. & LIM, K.-M. 2016. Act on the Registration and Evaluation of Chemicals (K-REACH) and replacement, reduction or refinement best practices. *Environmental health and toxicology*, 31.

- HEEDERIK, D. & VON MUTIUS, E. 2012. Does diversity of environmental microbial exposure matter for the occurrence of allergy and asthma? *Journal of Allergy and Clinical Immunology*, 130, 44-50.
- HITCHINGS, R. 2012. People can talk about their practices. *Area*, 44, 61-67.
- INGOLD, T. 2016. *Evolution and social life*, Routledge.
- JACK, T. 2013. Laundry routine and resource consumption in Australia. *International Journal of Consumer Studies*, 37, 666-674.
- JACK, T. 2017. Cleanliness and consumption: exploring material and social structuring of domestic cleaning practices. *International Journal of Consumer Studies*, 41, 70-78.
- KELLER, M. & RUUS, R. 2014. Pre-schoolers, parents and supermarkets: co-shopping as a social practice. *International Journal of Consumer Studies*, 38, 119-126.
- KESSLER, R. 2015. More than cosmetic changes: taking stock of personal care product safety. *Environmental health perspectives*, 123, A120.
- KIRKSEY, E. 2015. Species: a praxiographic study. *Journal of the Royal Anthropological Institute*, 21, 758-780.
- KIRKSEY, S. E. & HELMREICH, S. 2010. The emergence of multispecies ethnography. *Cultural anthropology*, 25, 545-576.
- KOCH, H. M. & CALAFAT, A. M. 2009. Human body burdens of chemicals used in plastic manufacture. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364, 2063-2078.
- KUIJER, L. & DE JONG, A. M. 2011. Practice theory and human-centered design: A sustainable bathing example. *Nordes*.
- LATOUR, B. 1992. 10 "Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts".
- LIBOIRON, M. 2015. Redefining pollution and action: The matter of plastics. *Journal of Material Culture*, 1359183515622966.
- LILJENQUIST, K., ZHONG, C.-B. & GALINSKY, A. D. 2010. The smell of virtue clean scents promote reciprocity and charity. *Psychological Science*, 21, 381-383.
- LORENZEN, J. A. 2012. Going Green: The Process of Lifestyle Change¹. *Sociological Forum*, 27, 94-116.

- LORETZ, L., API, A., BABCOCK, L., BARRAJ, L., BURDICK, J., CATER, K., JARRETT, G., MANN, S., PAN, Y. & RE, T. 2008. Exposure data for cosmetic products: Facial cleanser, hair conditioner, and eye shadow. *Food and chemical Toxicology*, 46, 1516-1524.
- LUONGO, J. C. 2016. *Towards Defining Healthy Buildings: Investigating the Effect of Building Characteristics and Interventions on Indoor Air Microbial Exposures and Energy Efficiency*. University of Colorado at Boulder.
- LUSH. 2016. *Liquid Soap vs. Solid Soap* [Online]. Available: https://www.lushusa.com/Liquid-Soap-vs.-Solid-Soap/Article_Liquid-Soap-Vs-Solid-Soap.en_US.pg.html?fid=tips-tricks [Accessed 23 March 2016].
- LYNCH, S. V., WOOD, R. A., BOUSHEY, H., BACHARIER, L. B., BLOOMBERG, G. R., KATTAN, M., O'CONNOR, G. T., SANDEL, M. T., CALATRONI, A. & MATSUI, E. 2014. Effects of early-life exposure to allergens and bacteria on recurrent wheeze and atopy in urban children. *Journal of Allergy and Clinical Immunology*, 134, 593-601. e12.
- MACKENDRICK, N. 2014. More work for mother: Chemical body burdens as a maternal responsibility. *Gender & Society*, 28, 705-728.
- MACKENDRICK, N. & STEVENS, L. M. "Taking Back a Little Bit of Control": Managing the Contaminated Body Through Consumption. *Sociological Forum*, 2016. Wiley Online Library.
- MILLER, D. 2010. *Stuff*, Polity.
- MONCURE, K. P. 2016. *Inverted Quarantine: Individual Response to Collective Fear*. Oberlin College.
- MUNCKE, J. 2011. Endocrine disrupting chemicals and other substances of concern in food contact materials: An updated review of exposure, effect and risk assessment. *The Journal of Steroid Biochemistry and Molecular Biology*, 127, 118-127.
- MÜNSTER, D. 2017. Zero Budget Natural Farming and Bovine Entanglements in South India. *RCC Perspectives*, 25-32.
- MYLAN, J. & SOUTHERTON, D. 2017. The social ordering of an everyday practice: The case of laundry. *Sociology*, 0038038517722932.
- OLSSON, M. 2014. *The Cost of Inaction: A Socioeconomic analysis of costs linked to effects of endocrine disrupting substances on male reproductive health*, Nordic Council of Ministers.
- OTT, W. R., STEINEMANN, A. C. & WALLACE, L. A. 2006. *Exposure analysis*, CRC Press.

- OUIMETTE, M. Y. 2011. *Cleaning house: Considerations of ecological health and sustainability in the selection of household cleaning products*. Boston College.
- PARK, M. 2016. Defying obsolescence. *Longer Lasting Products*. Routledge.
- PATTERSON, M. & JOHNSTON, J. 2012. Theorizing the obesity epidemic: Health crisis, moral panic and emerging hybrids. *Social Theory & Health*, 10, 265-291.
- PETERSEN, A. R. 1996. Risk and the regulated self: the discourse of health promotion as politics of uncertainty. *The Australian and New Zealand Journal of Sociology*, 32, 44-57.
- PINK, S. 2015. *Doing sensory ethnography*, Sage.
- PULLINGER, M., BROWNE, A., ANDERSON, B. & MEDD, W. 2013. Patterns of water: The water related practices of households in southern England, and their influence on water consumption and demand management.
- RECKWITZ, A. 2002. Toward a theory of social practices: A development in culturalist theorizing. *European journal of social theory*, 5, 243-263.
- REUBEN, S. 2010. Reducing Environmental Cancer Risk: What We Can Do Now. President's Cancer Panel, Annual Report 2008-2009.
- ROCHESTER, J. R. & BOLDEN, A. L. 2015. Bisphenol S and F: a systematic review and comparison of the hormonal activity of bisphenol A substitutes. *Environmental Health Perspectives (Online)*, 123, 643.
- RUDEL, R. A. & PEROVICH, L. J. 2009. Endocrine disrupting chemicals in indoor and outdoor air. *Atmospheric Environment*, 43, 170-181.
- SARANTIS, H. 2010. Not so sexy: The health risks of secret chemicals in fragrance. *Breast Cancer Fund CaEWG*.
- SCHATZKI, T. R. 1996. *Social practices: A Wittgensteinian approach to human activity and the social*, Cambridge University Press.
- SCHATZKI, T. R., KNORR-CETINA, K. & VON SAVIGNY, E. 2001. *The practice turn in contemporary theory*, Psychology Press.
- SCHUG, T., ABAGYAN, R., BLUMBERG, B., COLLINS, T., CREWS, D., DEFUR, P., DICKERSON, S., EDWARDS, T., GORE, A. & GUILLETTE, L. 2013. Designing endocrine disruption out of the next generation of chemicals. *Green Chemistry*, 15, 181-198.
- SCOTT, D. N., HAW, J. & LEE, R. 2017. 'Wannabe Toxic-Free?' From precautionary consumption to corporeal citizenship. *Environmental Politics*, 26, 322-342.

- SCOTT, K., BAKKER, C. & QUIST, J. 2012. Designing change by living change. *Design Studies*, 33, 279-297.
- SCRUGGS, C. E., ORTOLANO, L., SCHWARZMAN, M. R. & WILSON, M. P. 2014. The role of chemical policy in improving supply chain knowledge and product safety. *Journal of Environmental Studies and Sciences*, 4, 132-141.
- SHOVE, E. 2003. *Comfort, cleanliness and convenience: The social organization of normality*, Berg Oxford.
- SHOVE, E. 2004. Sustainability, system innovation and the laundry. *System innovation and the transition to sustainability: theory, evidence and policy*, 76-94.
- SHOVE, E. 2007a. *The design of everyday life*, Berg.
- SHOVE, E. 2007b. The Materials of Material Culture: Plastic. *The design of everyday life*. Berg.
- SHOVE, E., PANTZAR, M. & WATSON, M. 2012. *The dynamics of social practice: Everyday life and how it changes*, Sage.
- SHOVE, E. & WARDE, A. 2002. Inconspicuous consumption: the sociology of consumption, lifestyles and the environment. *Sociological theory and the environment: classical foundations, contemporary insights*, 230, 51.
- SILBERGELD, E. K., MANDRIOLI, D. & CRANOR, C. F. 2015. Regulating chemicals: law, science, and the unbearable burdens of regulation. *Annual review of public health*, 36, 175-191.
- SPURLING, N. J., MCMEEKIN, A., SOUTHERTON, D., SHOVE, E. A. & WELCH, D. 2013. Interventions in practice: reframing policy approaches to consumer behaviour. Sustainable Practices Research Group.
- STEINEMANN, A., WARGOCKI, P. & RISMANCHI, B. 2017. Ten questions concerning green buildings and indoor air quality. *Building and Environment*, 112, 351-358.
- STOKOLS, D. 2014. Training the next generation of transdisciplinary researchers. *Enhancing communication & collaboration in interdisciplinary research*, 56-81.
- STRENGERS, Y. 2010. Conceptualising everyday practices: composition, reproduction and change. *Carbon Neutral Communities Working Paper*.
- STRENGERS, Y. 2011. Negotiating everyday life: The role of energy and water consumption feedback. *Journal of Consumer Culture*, 11, 319-338.

- STRENGERS, Y. & MALLER, C. 2012. Materialising energy and water resources in everyday practices: Insights for securing supply systems. *Global Environmental Change*, 22, 754-763.
- STRENGERS, Y. & MALLER, C. 2014. *Social practices, intervention and sustainability: beyond behaviour change*, Routledge.
- SUTTON, P., WALLINGA, D., PERRON, J., GOTTLIEB, M., SAYRE, L. & WOODRUFF, T. 2011. Reproductive health and the industrialized food system: a point of intervention for health policy. *Health Affairs*, 30, 888-897.
- SZASZ, A. 2007. *Shopping Our Way to Safety*
How We Changed from Protecting the Environment to Protecting Ourselves, University of Minnesota Press.
- VERBEEK, D. & MOMMAAS, H. 2008. Transitions to sustainable tourism mobility: The social practices approach. *Journal of Sustainable Tourism*, 16, 629-644.
- VON GOETZ, N., WORMUTH, M., SCHERINGER, M. & HUNGERBÜHLER, K. 2010. Bisphenol A: how the most relevant exposure sources contribute to total consumer exposure. *Risk Analysis*, 30, 473-487.
- WAHLEN, S. 2011. The routinely forgotten routine character of domestic practices. *International Journal of Consumer Studies*, 35, 507-513.
- WAKEFIELD-RANN, R. 2017. More Than Skin Deep: A Service Design Approach to Making the Luxury Personal Care Industry More Sustainable. *Sustainable Management of Luxury*. Springer.
- WARDE, A. 2005. Consumption and theories of practice. *Journal of consumer culture*, 5, 131-153.
- WATERTON, C. & TSOUVALIS, J. 2015. On the political nature of cyanobacteria: intra-active collective politics in Loweswater, the English Lake District. *Environment and Planning D: Society and Space*, 33, 477-493.
- WESCHLER, C. J. 2009. Changes in indoor pollutants since the 1950s. *Atmospheric Environment*, 43, 153-169.
- WILLIAMS, G. H. 2003. The determinants of health: structure, context and agency. *Sociology of Health & Illness*, 25, 131-154.
- WILSON, N. K., CHUANG, J. C., LYU, C., MENTON, R. & MORGAN, M. K. 2003. Aggregate exposures of nine preschool children to persistent organic pollutants at day care

and at home. *Journal of Exposure Science and Environmental Epidemiology*, 13, 187-202.

YANG, C. Z., YANIGER, S. I., JORDAN, V. C., KLEIN, D. J. & BITTNER, G. D. 2011. Most plastic products release estrogenic chemicals: a potential health problem that can be solved. *Environmental Health Perspectives*, 119, 989.

ŽALMANOVÁ, T., HOŠKOVÁ, K., NEVORAL, J., PROKEŠOVÁ, Š., ZÁMOSTNÁ, K., KOTT, T. & PETR, J. 2016. Bisphenol S instead of bisphenol A: a story of reproductive disruption by regrettable substitution—a review. *Czech Journal of Animal Science*, 61, 433-449.

ZIMMERMAN, J. B. & ANASTAS, P. T. 2015. Toward substitution with no regrets. *Science*, 347, 1198-1199.

ZOELLER, R. T., BROWN, T., DOAN, L., GORE, A., SKAKKEBAEK, N., SOTO, A., WOODRUFF, T. & VOM SAAL, F. 2012. Endocrine-disrupting chemicals and public health protection: a statement of principles from The Endocrine Society. *Endocrinology*, 153, 4097-4110.

PAPER 2: MICROBES, CHEMICALS AND THE HEALTH OF HOMES: INTEGRATING THEORIES TO ACCOUNT FOR MORE-THAN-HUMAN ENTANGLEMENTS

JOURNAL: BIOSOCIETIES (IN PRESS)

Having established the value of a social practice-oriented approach, and the co-constitution and interdependence of networks of materials in Paper 1, in Paper 2 I grounded these arguments in a qualitative investigation of everyday hygiene practices conducted by parents of young children in Sydney, Australia. Drawing on this investigation, this paper further develops my hybrid theoretical framework based on social practice and multispecies approaches by illustrating the unique insights that the application of this framework affords in practice. In particular, this paper shows how multispecies ethnography can complement social practice theories to develop more nuanced ways of conceptualising the ways that micro-species culturally and physically participate in practices that are contributing to sub-optimal home environments. It also presents significant findings related to a number of operative assumptions embedded across the practices observed that may be contributing directly to sub-optimal home microecologies.

This paper has been accepted for publication by the journal *BioSocieties*. This journal was selected because it encourages transgressions of disciplinary boundaries between the social sciences, humanities and the natural sciences, to develop new ways of thinking about the relations between the life sciences and society. Given that one of the key contributions of this paper is the development and application of a novel theoretical approach to investigating the physical and social interactions within microecologies,

BioSocieties is a valuable forum in which to address theoretically-interested thinkers working at the intersection of the social and life sciences.

Wakefield-Rann, R., Fam, D., & Stewart, S. (in press) Microbes, chemicals and the health of homes: integrating theories to account for more-than-human entanglements, *BioSocieties*

Abstract

In the post-war period, the health risks posed by indoor environments have both transformed and challenged notions of environmental health centred on pathogenic germs. The composition of home spaces, particularly in developed nations, has been fundamentally altered by the introduction of formerly industrial chemicals to everyday products and building materials. Further, the changing nature of building design, cleaning practices and urban life have altered the ‘microbiomes’ of homes, contributing to a rise in certain immune system conditions. This paper contends that to begin to address these concerns, the microscopic elements of ‘indoor ecosystems’, and how they are created and maintained, must become a focal point for research. It proposes an approach that integrates social practice theories and multispecies ethnography to investigate the cumulative composition constitution of indoor spaces. Findings detail the application of this approach to research into the domestic hygiene practices of parents with young children in Sydney, Australia. This approach highlights crucial assumptions about the ways micro-scale agency is embedded in everyday domestic practices that are contributing to sub-optimal indoor environments.

Keywords: multispecies ethnography, social practice theory, indoor environmental health, micro-species

Introduction

Homes are intended to be safe spaces that protect the body from external sources of harm. It is widely accepted that safety and comfort are denied when people do not possess the

means to build adequate shelter or cannot occupy homes on land that is safe from pollution, extreme environmental conditions or political upheaval. However, the maladaptive environmental conditions that characterise many homes in modern industrialised countries are more subtle, insidious and often physically and politically invisible. The new classes of post-industrial chemicals that afford modern homes and lifestyles and many of their crucial aesthetic and functional qualities, are interfering in bodily and environmental processes in unprecedented ways (GSPI 2016; Lakind and Birnbaum 2010; Kessler 2015). Chemical contamination is no longer exclusively an issue of the poor and marginalised, but an integral and often *essential* part of the materials that characterise lifestyles to which wealthy and middle classes aspire. Moreover, the types of microbial communities that are mutually supportive of human health and development are increasingly absent under modern, urban 'hygiene regimes', contributing to a rise in health conditions such as allergies (Maizels 2005; Rook 2012). As the middle class grows across many developing and industrialised countries, the materials and practices that accompany definitions of prosperity, success and the domestic 'good life' must become a point of greater critical reflection.

The hygiene regime that has developed and proliferated in the context of this research, in Sydney, Australia, has followed a similar trajectory to its colonial and settler colonial counterparts in the Global North, to which the dominant state institutions and culture looked for structural and moral guidance. Invariably, the manifestations and evolution of hygiene practices and institutions in Australia developed with their own flavour, emerging in response to (although not necessarily well adapted to) its geographical peculiarities. As in Europe and North America, the lineage of hygiene practices in Australia is owed to a Victorian culture which made 'cleanliness' into a civic responsibility and duty. However, Bashford (2003, p. 3) argues that hygiene has been particularly central to modern identity formation in Australia:

The pursuit (at many levels) of health, hygiene and cleanliness was one significant way in which the 'whiteness' of white Australia was imagined, as well as technically, legally and scientifically implemented.

Aside from the moral imperatives and anxieties associated with colonisation, particular events, such as the 1880s smallpox epidemic, shaped and solidified hygiene bureaucracy and its associated measures to prevent pathogens from spreading, in Australia (Bashford 2003). During this time, Davison (2008, p. 42) notes that "English visitors hailed the apparent superiority of Australian bathing arrangements". Although variously diluted and altered, the fundamental tenets of the 'hygiene regime' instituted in this period, comprised of institutions, practices and beliefs about disease, persist today (Bashford 2003).

Similarly, the post-war chemical boom infiltrated the domestic environment, and its throng of new modern products, with a gusto that paralleled other wealthy, industrialised nations (Benn 2004). The benefits of these developments remain out of reach for many Australians, particularly the first Australians living in remote communities, often without access to basic services, but who nonetheless experience the effects of the ecological alterations wrought by the last century (or more) of hygienic and chemical 'improvements' (Lea and Pholeros 2010). Although the emerging indoor health risks discussed in this paper are affecting bodies irrespective of social status, the inequitable distribution of benefit and harm adds additional urgency to addressing the drivers of maladaptive indoor ecologies.

The emerging concern for health risks associated with low microbial diversity and post-industrial chemicals is part of, and made legible by, a rise in technoscientific practices and modes of thinking that have increasingly focused on health in a molecular register. Rose (2007) has theorised how the 'molecularisation' of life is part of a new politics of life within biomedicine, which has not only refocused our understanding of what life is, and

the risks posed to it, but what it means to be a good citizen. Rose and Novas (2005) employ the term 'biological citizens' to refer to the ways individuals use biological knowledge to both comprehend their bodies, and to conform to the norm of a healthy citizen. The current context in which biological citizenry is defined is tied up with what Paxson has termed 'microbiopolitics' "the recognition and management, governmental and grassroots, of human encounters with the vital organismic agencies of bacteria, viruses, and fungi" (Paxson 2008, p. 23). This concept links Foucault's notion of biopolitics—how governments seek to manage the health of populations by determining what types of life are allowed to thrive—and Latour's (1988) account of 'Pasteurian' hygiene, as the dominant way in which microbial entities have been made detectable in order to be controlled. From this, she argues, emerged a 'germophobic' hygiene regime which became normalised in the Victorian period, and remains embedded in the definitions and measurements of hygiene operationalised through scientific instrumentation, institutions, urban infrastructures and individual practices.

Murphy (2008) suggests that these theorisations of the molecularisation of life could be usefully extended to make sense of the toxic exposures that accompany the proliferation of post-industrial chemicals. She proposes the concept of a 'chemical regime of living', characterised by new forms of molecular relations and risk that must be conceptualised at a global scale. New instruments for scientific measurement at the molecular level have enabled these molecular exchanges to become detectable and traceable in different landscapes across scales. However, unlike the 'germs' that make themselves known through entrenched institutions, infrastructures and practices, post-industrial chemicals have been often deliberately excluded from narratives of harm and responsibility (Murphy 2008). That is, the harm created by toxicants has been purposefully designated as outside of the responsibility of the industries that produce and regulate them, creating what Murphy (2006) calls a 'regime of imperceptibility' around synthetic molecular relations.

There are research programs and literature beginning to recognise and address aspects of these issues at the micro-scale of indoor ecologies. This research not only details the unique ecological niches developing for different microbes, through the emergence of new materials and architectural forms in homes around the world (see Dunn et al. 2013; Green 2014), or how chemical compounds in indoor air interact and transform throughout a normal day (see The Chemistry of Indoor Environments

Program: <https://indoorchem.org/>) but is beginning to challenge 'germophobic' conceptions of microbial relations. Collaborations between microbiologists, social scientists and citizens in projects such as the UK-based *Good Germs, Bad Germs* have investigated and challenged normative hygiene practices in peoples' homes (Greenhough et al. 2018). This type of challenge is also occurring at broader ecological scales, through investigations of the relationship between urban ecologies, microbial biodiversity and human health (Mills et al. 2017). These projects can be considered as part of what Paxson (2008) has termed a 'post-Pasteurian' turn, in which hygiene regimes oriented to germ-extermination are being contested in certain spaces and activities (Spackman 2018; Lorimer 2017). However, the ways in which 'post-Pasteurian' relations with microbial communities are infiltrating institutions and everyday practices to challenge dominant hygiene regimes, and how they intersect with other practices that influence indoor ecologies, such as chemical use, remain largely unknown.

Similarly, there is a growing number of collaborations between environmental sociologists, chemists and citizens in the tradition of 'popular epidemiology' (Brown 1997) that monitor how exposures to household chemicals affect home occupants. Well-known examples such as the *Household Exposure Study*, - a North American project that evaluated exposures to pollutants from legacy contaminants, consumer products, and local emissions (Brody et al. 2009) - and studies into the health impacts of fragranced products in Australian homes (Steinemann 2015) and many others (see Loretz et al. 2008; Wilson et al. 2003; Morawska et al. 2018; Weatherly and Gosse 2017) are making visible, and

political, previously obscured molecular interactions. Given that harm must be demonstrated in a molecular register to be recognised by chemical regulators, these sensing and biomonitoring activities have provided one of the few ways that molecular relations can be made legible and political. However, concerns have been raised that by participating in evidence creation at the molecular scale, there is a risk of reproducing a conceptualisation of harm that requires individual offending chemicals to be identified, traced and linked directly to the manifestation of harm in an individual (Murphy 2008). This type of measurement cannot capture the scope of contingent, complex ways in which both post-industrial chemicals and microorganisms interact and move through bodies and landscapes to cause harm.

This paper proposes another potential avenue for making indoor chemical and microbial relations knowable beyond isolated interactions at the molecular level, by focusing on how common, normative domestic practices performed by individuals structure material flows within homes. In doing this, we do not further situate blame or responsibility for creating problematic conditions or changing them with individuals. Rather, a focus on collective practices—as enactments of both a ‘hygiene regime’ and a ‘chemical regime of living’—can reorient attention away from the individual, to examine the intersection of macro-political and macro-infrastructure factors, with the micro-political and micro-material interactions that comprise everyday life. A practice-oriented inquiry is not intended as an alternative to approaches, such as citizen sensing or biomonitoring, that make micro-entities perceptible at the molecular scale, but as another route of insight that could situate these data in the everyday relations that generate it.

This paper divided into two parts. The first half develops a theoretical lens that integrates social practice with multispecies ethnographic and chemo-ethnographic approaches to investigating practices that embody and reproduce regimes of hygiene and chemical living. The latter half then applies this framework to explore the socio-material processes

that influence the composition of indoor spaces through an investigation of the domestic hygiene practices of parents with young children in Sydney, Australia.

Investigating more-than-human practices: a hybrid approach

We propose that the integration of theories of social practice with aspects of multispecies- and chemo-ethnography may yield novel insights into the composition of practices, and the emergent agency of their invisible participants. Social practice theories offer a way of tracing collectively held, repeated sequences of action, to investigate how they configure, and are configured by, the environments in which they take place. The proponents of this theoretical lens, although heterogeneous, are united by the premise that social practices constitute the basic unit of enquiry into social life (Hui et al. 2016). Social practices are commonly characterised as organised sets of linked actions repeatedly performed across time and space that connect, support and compete with one another to make up the observable socio-material world (Schatzki 2016). These organised sets of linked actions involve interactions between ‘elements’, often conceived of as meanings (thoughts, beliefs, values), bodily competencies (corporeal skills and embodied knowledge) and materials (infrastructures, artefacts, bodies) (Shove et al. 2012; Cass and Faulconbridge 2016; Ryghaug and Toftaker 2014). Examples of practices include cooking, cleaning and commuting, or the routinised work practices of builders, office workers, regulators and scientists, which although infinitely diverse maintain common characterises in particular places and times that are shared by the members of a group that performs them. By setting the normative criteria that shapes notions of how everyday activities *should* be performed, practices generate not only the expectations and measurements through which ideas such as cooking and cleaning ‘well’ are maintained, but many of the assumed needs that these practices service.

We propose that a focus on practice enables an examination of how the ecologies of homes are cumulatively and interactively built through repeat performances of coordinated

activities. Importantly, it also provides a way of recognising and interrogating the ways in which these configured indoor terrains produce effects beyond those intended on human, and more-than-human, ecologies. By attending to practices in the analysis of socio-material conditions, attention is reoriented not only to *what* materials people interact with, but to *how, when, why* and *how often*.

This paper specifically addresses the assumptions embedded within practices that generate expectations of what a healthy home should look and feel like, and how these practices may consequently be affecting indoor microecologies. Collective lifestyle practices establish criteria for, and make sense of, what a kitchen is *for*, what wall paint should look like, or how many bathrooms a single family should have to meet expectations of cleanliness and comfort. An analytical focus on practices can bring into view the entities and interactions that reproduce existing conceptions of domestic health and hygiene, and the structures that are, in part, built to facilitate these perceived needs. From this perspective, social practices are seen to embody and reinforce ‘regimes of imperceptibility’ in which infrastructural sources of toxicant exposure, and the need for home and urban design that fosters microbial diversity, have been excluded.

By advocating a focus on practices, we do not suggest that producers of toxicants and toxic infrastructures should not be addressed at a structural level, nor do we imply individuals enacting these practices should be held responsible for managing toxic exposures in the home. Indeed, this approach suggests the opposite. One of the central tenets of a social practice lens is the rejection of the individualisation of responsibility in favour of attending to the dynamic interplay between practices that evolve over time and are recurrently maintained at a broad societal level (Schatzki et al. 2001; Sahakian and Wilhite 2014; Shove et al. 2012). For normative practices to persist, they must be collectively ‘carried’ by multiple members of a social group over time. It is at this scale they become relevant, and a useful analytical unit to begin thinking about how certain socio-material conditions evolve and what interventions may be effective. In the event that

structural issues related to chemicals allowed in products, building materials, and the land that buildings can be built on were politically rectified, the normative expectations of hygiene and cleanliness embedded in practices may still persist. These practices, and the definitions of hygiene physically and materially embedded within them, must consequently still be addressed.

Although the value of an orientation to practices is increasingly recognised across the social sciences, currently dominant ways of theorising materiality within social practices have attracted criticism (Maller 2018; Hui et al. 2016). Social practice theories are currently being challenged with regard to their conceptualisations of non-human agency. Although practice theories decentre human agency in favour of a relational conceptualisation of agency that emerges through interactions between humans and non-humans, they generally maintain that practices are necessarily performed and ‘carried’ by humans (Maller 2018). This position is being problematised by findings, particularly in the life sciences, that microorganisms and chemicals display forms of relational and emergent agency within human bodies and the environment that significantly influence practices and broader ecological processes beyond human-led actions. As a result, scholars such as Nicolini (2016) and Thrift (2016) are increasingly drawing on other more-than-human approaches such as non-representational and assemblage-based thinking, to add additional nuance to investigations of the material element of practice. Compelling examples are provided by Maller (2016) and Fox et al. (2017) who argue that social practice theories are not sufficiently attentive to the materiality of bodies, and that while bodies are acknowledged, their physical and sensory qualities are largely “unrecognised or dematerialised” (Maller 2016, p. 72). Maller consequently integrates concepts from epigenetics, geography and anthropology to add nuance to the role of affective and biophysical properties of bodies in social practices (Maller 2018, p. 78).

In this paper, we propose a theoretical lens that endeavours to expand the notion of materiality within social practice theories to account for the emergent agency of microbial

communities and post-industrial chemicals, by drawing on ideas from multispecies- and chemo-ethnography. Multispecies- and chemo-ethnographers focus on the emergence of new social realities through dynamic interactions between other living species and chemicals, respectively. In recognising the dynamic effects produced through interactions between human practices, other living species, and chemical actors, we propose that a more adequate account of practice can be developed to aid in the investigation of complex more-than-human entanglements within indoor ecologies.

Multispecies ethnographers are interested in how political, economic and cultural forces shape the livelihoods of a multitude of organisms. As Kirksey and Helmrich (2010) state, multispecies ethnographers are studying the contact zones where lines separating nature from culture have broken down and where human and other species can be seen as mutually constituting their shared ecological habitats and one another. Haraway's insight in *When Species Meet* that "I am vastly outnumbered by my tiny companions... To be one is always to *become with many*" (2008, p. 4) is foundational to this 'species-turn' in anthropology, and the emerging understanding that humans are constituted by a multitude of species all of which exhibit specific forms of agency unique to the more-than-human entity of which they are part. Multispecies research into the mutually constitutive role of humans and the microorganisms with which they cohabit has enriched our understanding of, for example, what makes healthy soil in agro-ecosystems (Granjou and Phillips 2018), and the role of social relations in the proliferation of bovine tuberculosis (Robinson 2018).

Chemo-ethnography adopts a similar mode of attention to account for the ways that modern chemistry is producing new social, political and economic relations, which create possibilities for life, while also adversely affecting human health and landscapes (Shapiro and Kirksey 2017). By following chemicals, and their reactions, emergence, and decay in more-than-human worlds, anthropologists are starting to investigate how chemical agents are perpetuating certain social arrangements and transforming others (Landecker and

Panofsky 2013; Myers 2015; Liboiron 2015). Central to these approaches is the attention to material difference and relationality, and how these differences produce emergent forms of 'chemo-sociality'. Its central questions are thus "how are molecular frictions, catalytic dynamics, forms of not-Life, and other-than-life reconfiguring our conditions of knowing, being, and sociality?" (Shapiro and Kirksey 2017: 482). By attending to multispecies and chemical relations, multispecies-and chemo-ethnographic approaches enable the living and non-living non-humans¹ that are creating present chemo-socialities in indoor environments to be articulated and followed.

Social practice and multispecies ethnographic² approaches share an interest in the materiality and ordering of daily life, a methodological commitment to ethnography, a decentralisation of individual agency in favour of more emergent and relational conceptualisations, and a normative concern with the implications of practices, particularly in relation to environmental justice (Phillips 2014). Following Maller (2018), we take social practices as a 'lead' theoretical framing to orient this investigation to tracing and accounting for the practices that continuously configure the material world. Multispecies approaches are integrated to interrogate how particular forms of human and non-human agency are influenced by, and emerge from, practice with a particular focus on micro-scale interactions. The synthesis of these ideas enables an examination of both emergent agency and forms of repetition which build indoor environments over time.

Theorising micro-species

We propose that in analysing the micro-ecological relations in homes it is useful to theorise chemical and microbial entities together. Following thinkers such as Abrahamsson et al. (2015) and Povinelli (2016), we resist a flattening of distinctions between these different forms of entities, or their designation as all similarly 'living'. Rather, we are interested in how their specific kinds of difference and dynamism result in the expression of particular kinds of emergent entanglements that build and transform

everyday domestic ecologies. To do this requires a different theorisation of matter to those that rely on certain kinds of living/non-living distinctions. We propose that a useful category for the purposes of this theorisation is 'micro-species'.

Species, a term now perhaps most commonly associated with biology, is defined in that field as "A group of living organisms consisting of similar individuals capable of exchanging genes or interbreeding. The species is the principal natural taxonomic unit, ranking below a genus..." (OED 2019). However, it is also commonly used in physics and chemistry to refer to "a particular kind of atom, molecule, ion, or particle" (OED 2019). At one point within biology it was considered that the taxonomic system to which species belongs was a way of detecting 'natural' or 'essential' kinds that pre-existed in nature, although this is no longer a prominent debate, traditional conceptions of species in biology maintain that species are relatively stable, fixed, autonomous units with set boundaries (Dupré 1992). Conversely, it is commonly acknowledged that chemical species can shift and morph according to their environmental conditions and interactions. These different applications of the term species show how the conditions for denoting 'kinds or sorts' of entities are determined by the priorities of the classification system.

We propose that for our purposes, distinguishing the morphological scale of the 'micro' in relation to species is useful for two key reasons. First, as O'Malley and Dupré (2007) contend, the micro-scale of biology is offering some of the greatest challenges to species concepts that have traditionally dominated the philosophy of biology, as the evidence of practices, such as 'horizontal gene transfer', have shown that the boundaries between organisms appear to be comparatively more malleable than what has been traditionally observed in macro species. Transgressions of microbial boundaries are often the product of changed environmental conditions, meaning that microorganisms need to search for resources or new ways of performing different roles within a system (Darling et al. 2016). This boundary plasticity is also applicable to chemical species at the micro-scale. As noted above, chemical species can change from one categorically distinct entity to another

according to environmental conditions (Shapiro and Kirksey 2017). By employing the term 'species', we aim to highlight the limitations of operative concepts of species as single, autonomous entities, and attempt to reimagine the term as a useful, expanded category for understanding distinction within a complex, interactive ecosystem.

The first reason we propose a joint theorisation of microorganisms and chemicals as micro-species is this environmentally contingent morphological capacity. Numerous scholars across the social and natural sciences have postulated about the extent to which humans are co-constituted by microorganisms, and the implications for what humans are, and where the boundaries around our bodies as discreet entities can be drawn (Paxson and Helmreich 2014; Hird 2010; O'Malley and Dupré 2007). Others (see Liboiron 2015; Murphy 2008) have argued that other non-living micro-actors, such as post-industrial chemicals, also 'participate' in and alter the ways bodies function based on environmental variables, due to their unique properties. Within an ecosystem such as a body, or a bath, chemical and microbial species' boundaries can shift as they transform one another interactively based on material flows through that space over time, while retaining core characteristics afforded by the molecules from which they are made.

The second reason is that both chemicals and microbes exert agency in everyday practices dynamically between imagined and physical registers. The assumed or potential presence of 'germs' and chemical toxicants has considerable influence over everyday enactments of hygiene, even when no pathogens or toxicants are physically present (Jack 2017; Smith 2007). Where micro-species are physically present, they shape practices differentially according to how they are present, how much of them is present, how often, and how they can be removed. Whether or not micro-species become perceptible is therefore not always related to their actual existence in a location, but the presence of particular material and cultural conditions in which they emerge as detectable, become hidden, or are imagined to exist.

By following emergent manifestations of micro-species, the researchers' attention is drawn to relational forms of agency at the micro-scale. We propose that understanding how micro-species boundaries shift in response to environmental conditions, and their continual transition between real and imagined entities, will be central to improving knowledge of how microbial and chemical agents collectively and repeatedly assemble indoor environments and their occupants.

In this initial theorisation of micro-species for the purposes of our research, micro-species include microorganisms, ³viruses, active organic and inorganic chemical species and other non-inert entities that demonstrate degrees of autonomous reactive action at a micro-scale. Further applications of this category could be explored in future research engaging with different types of dynamic micro-entities.

In the following section, we provide an overview of the ethnographic fieldwork to which this hybrid theoretical approach is applied, and the types of insights it affords into emergent micro-species agency in hygiene practices.

Integrating theories in practice

Addressing the multitude of interacting forces that can produce harm in home microecologies will require large structural changes with inputs based on extensive cross-disciplinary and contextually sensitive research. To begin this journey, we suggest it is essential to start to investigate how particular socio-material arrangements are generated in the home through situated dynamic interactions between agents within and across practices.

The research presented here focuses particularly on practices enacted by parents to create a safe, hygienic, home environment for their children. Greenhough et al. (2018) propose that domestic spaces, such as the kitchen, are key sites in which Pasteurian microbiopolitics are combined with the production of biological citizens. An examination of these sites can provide insight into the cultural reproduction of what is considered

healthy and safe—and what it means to be a good citizen—and how these notions are and can be challenged. Although notions of hygiene are embedded across a multitude of practices, ‘hygiene practices’ are taken here to mean the practices performed wholly, or in part, to maintain health and prevent disease in an environment. These encompass practices such as cleaning a bathroom, aspects of meal preparation and personal care that are guided by normative conceptions of what cleanliness is and how it is supposed to be maintained. Although all practices influence the flow of materials and microorganisms through the home, research suggests that practices enacted to achieve a clean home, particularly via antimicrobial products, play an especially important role in adding or removing material entities that contribute to health outcomes (Bloomfield et al. 2006; Jeon et al. 2013; Hartmann et al. 2016).

With the intention of gaining insight into the role of domestic practices in reproducing particular notions of hygienic living, we explored the routine hygiene practices of ten parents with children under the age of five in Sydney, Australia during 2017.⁴ Parents with children under five were selected because research suggests these children are in critical “windows of vulnerability” and are consequently more susceptible to the health risks associated with sub-optimal indoor microecologies, including auto-immune conditions and the multitude of conditions associated with endocrine disrupting chemicals (Landrigan and Goldman 2011; Crain et al. 2008). Despite attempts to recruit broadly through community groups and organisations throughout Sydney, and online, the group of individuals engaged was comprised of well-educated, predominantly female (9/10), parents living in moderately affluent to affluent areas of Sydney, in medium to large duplex or free-standing houses. All participants, aside from one, spoke English as a first language. Although greater insights could be achieved with a larger and more diverse sample, this research provides insights into the practices of relatively well-educated and economically advantaged parents in Sydney. It also represents a set of lifestyle practices that emerging middle classes may adopt into the future.

As with all investigations of practices, the findings presented here are deeply situated. A similar investigation in another location, or with families from different cultural backgrounds, would certainly reveal significant cultural and geographic variation. The international standardisation of practices that conform to a 'germophobic' hygiene regime (Shove 2003; Jack 2017; Quitzau and Røpke 2009) and chemical regimes of living (Murphy 2008) have been consistently detailed, and are a product of global forces and structures. However, the dynamics that shape these practices and their ecological outcomes are always contingent on local particularities, distortions, rejections and reappropriations. This investigation is not intended to be representative, but a cautious exploration of how the dynamics of everyday practice can mobilise certain micro-species entanglements.

In addition to examining parents' descriptions of their behaviours and preferences, and their deployment of particular materials and meanings, the way micro-species come to exercise agency in the performance of practices was studied. A number of complementary research methods were employed to investigate these interactions. First, participants were given 'activity diaries', in which they recorded all activities related to how they conceptualise and endeavour to create a hygienic home, for seven days. The diaries provided a sense of the temporality of practice and the types of activities participants considered relevant to maintaining a hygienic home environment. After completion of the diaries, semi-structured interviews and practice re-enactments were conducted in participants' homes. Although the products used by participants, and their constituent chemicals, were recorded, our primary interest was not in measuring molecular interactions, but in how micro-species physically and symbolically interact within and co-construct practices.

The remainder of this paper will introduce findings from this investigation with a focus on four key assumptions made by participants about micro-species embedded in the performance of practices. These assumptions are not considered to represent individual

judgements or perceived failures, but the ways in which both regimes of hygiene and chemical living are manifesting and being reproduced in this specific context of parental practices.

One: specific micro-species behaviours are assumed to accompany particular activities and material arrangements

One observation consistently noted among participants was that micro-species behaviours are associated with particular common sites of human and animal activity within the home, and that cleaning practices are focused on the material arrangements that structure these sites. Given that micro-species are not immediately detectable by the senses, cues within the observable material environment are used to judge their presence and action. Objects and interior surfaces in the home provide numerous signals that suggest the presence of potential microbial action and hence the need for cleaning. The most consistent proxy for microbes mentioned by research participants was dirt on floorboards and tiles. The majority of participants had floor boards instead of carpet in their living areas, citing them as a cleaner option that did not 'hide' dirt as carpets did. The capacity of floorboards to reveal any kind of viscous or opaque substance they come into contact with provides immediate feedback on the presence of dirt.

The perception that the floor is likely to be carrying germs, combined with the material signal conveyed by the floor surface that there is something on it, often prompted frequent cleaning with antibacterial products. For most participants, the efficacy of a floor cleaning product was judged based on its claims to kill bacteria. When discussing her preferences for floor cleaners Participant 3 stated:

At the moment, I'm using Dettol wipes for the floor. I just went into the supermarket looking for something that was antibacterial or antiseptic.

This perceived need to use antibacterial agents in floor cleaning was reiterated by Participant 6 who stated:

I was using it (antibacterial cleaning product) on the floor... I felt like it probably needs to be really clean, like with the cats and stuff like that, it just felt like there could be germs. This is antibacterial and stuff. I don't know whether it's psychosomatic or not.

Similarly, many participants strongly associated kitchen benches with microbial action. Based on the activities recorded in the diaries and the practices discussed and observed, participants reported cleaning kitchen surfaces three times a day on average, even if no physical mess could be seen. The frequent cleaning of benches in the absence of observed dirt suggests an assumption that kitchens, and kitchen activities, generate or attract germs that persist unless there is frequent cleaning. Participant 7 explained that she will clean benches daily even if nothing dirty is perceived, in addition to post meal-time clean up:

probably once a day I'll make sure the benchtops are really clean, so wipe them down and dry them.

The importance placed on frequently cleaning the kitchen was shared by Participant 6:

I try and keep the bathrooms clean but I'm not pedantic about it, like I am with the kitchen... you're keeping it healthy for your kids... because there's ... food prep a couple of time[s] a day, so it's really nice to start that with a clean everything.

Some participants indicated that microbes in the bathroom and toilet require the use of particularly strong chemicals, signifying that they perceive the type, and hence behaviour and resilience of microbes, to differ in different parts of the home. Nine participants used bleach or an equivalent antibacterial cleaning product in the bathroom that they did not use in other parts of the house. For Participant 9, toilet germs were perceived as persistent and malicious enough to necessitate the disposal of the cloth after cleaning:

You know, like wipe (it), chuck it in the bin, because once you've wiped a toilet with a cloth you don't really want to use it again...

Interactions with animals, particularly pets, were also commonly assumed to accompany encounters with germs. An aversion to microbes that live specifically on animals was observed in accounts participants gave of their children's interactions with family pets. In describing how she protects her daughter from hazards in the home Participant 3 explained:

I always put this Dettol stuff on her hands if I know she's been touching the cat bowl.

And from Participant 8:

If I've seen that the cat has been lying on the table... That's when I would get the spray out because I think - you know you don't know where they've been.

Contrary to the common perception that the microbes carried by animals are likely to be harmful, recent research suggests that some of the unique types of microbes carried by household pets may be crucial to the development of children's immune systems (Perzanowski et al., 2002; Fujimura et al. 2010). Multiple studies have found that living with a dog as a child significantly decreases the chances of developing allergies (Bufford et al. 2008; Epstein et al. 2011).

These examples of responses to presumed germs on wooden floors, hard kitchen and bathroom surfaces and animals demonstrate that certain material configurations carry expectations of undesirable microbial encounters. Similar assumptions were also reflected in research by Greenhough et al. (2018) who engaged with citizens in an English town to investigate how and where they conceptualised microbial relations in their homes. In this study, participants indicated that they associated intense microbial action with sites linked to the production of food and disposal of waste, including kitchen bins, door handles, floors and spaces that have historically been targeted in public health campaigns, such as toilets.

These commonly identified sites of microbial activity have been the target of not only successive public health campaigns throughout the industrialised West, but the values and aesthetics that co-evolved with these campaigns, and informed the design of dirt-revealing home interiors. Maller and Strengers (2013) note that people are often inducted or 'recruited' into domestic practices by their parents as children via the material environment. The way one learns to tell if the floor or shower are dirty, and the process and gestures required to do the dishes or mop the floor often emerge from observing and copying parental practices, and may not be critically questioned as they are reproduced throughout life. As a result, the ways that participants have learned to be affected by material environments, and how they consequently conceive of and maintain them, may result from generations of material engagements in domestic spaces.

The association between intense and potentially pathogenic microbial activity and certain domestic spaces has resulted in the common use of antibacterial products in multiple rooms. The frequent application of antimicrobial products to these surfaces has the potential to reduce microbial diversity. Broadly, reductions in microbial diversity in indoor spaces have been correlated with an increased incidence of allergies in children (Heederik and von Mutius 2012) and, more recently, leukaemia (Greaves 2018). Although little is known about the precise nature of the microbial exposures required to enable human immune systems to develop normally, there is strong correlative evidence suggesting a high degree of microbial diversity in the home is linked with lower rates of these conditions. In addition to altering microbial communities, some antibacterial agents such as triclosan and triclocarban have also been linked to endocrine disruption, a process by which certain chemicals begin to participate in the hormonal system, signalling it to develop and act in abnormal ways (Stoker et al. 2010; Vandenberg et al. 2012). The assumption that antibacterial products are necessary in regular, sometimes daily, interactions with floorboards, benchtops and bathrooms may consequently have significant implications for the microecology of the home.

In addition to assumptions about microbes embedded within particular material engagements, participants often relied on a set of sensory cues to determine the presence of micro-species. The following section examines these common sensory signals in greater detail.

Two: the senses can reliably detect harmful micro-species

As discussed in the previous section, participants often assumed that germs accompany particular material arrangements in which ‘dirt’ or ‘grime’ are revealed. The visible presence of dirt on a surface thus serves as a proxy for the presence of harmful bacterial micro-species, while clean surfaces are taken to indicate their absence. However, for the participants in our study chemical micro-species seemed to lack a set of such consistent proxies. Rather, the detectable indicators emitted by chemicals, primarily scent, presented them with a confusing and often contradictory set of signals about the relative harm and desirability of different substances employed.

Among the participants, scent was the most commonly observed method used to detect the presence of potentially harmful chemicals in products. However, chemicals often send confusing messages about potential hazard, as their scents are often carefully engineered to communicate particular product attributes and invoke associations with fresh, fruity and clean environments (Kessler 2015). The majority of participants indicated that they did not like using products that had a ‘harsh’ or ‘strong’ ‘chemically’ smell around their children, yet they were generally prepared to use products with more pleasing chemical scents. Participant 5 explained that she stopped using some cleaning products after having children due to their ‘bleachy’ smell:

We use to use Domestos for surfaces, to make them nice and clean and kill stuff.

Now I just feel like it’s too toxic and yucky and bleachy.

She continued:

We don't use mould sprays anymore, but we do have some in the cupboard. That's probably the same story as the Domestos, in the sense that I didn't want to use something as potent as that.

These quotes suggest that scent can be experienced as an indicator of the capacity of a chemical to cause harm, its persistence in the environment, and its ability to affect children.

Many of the most hazardous classes of chemicals present in the home environment lack a stable set of sensory attributes, as they transform into different states based on how, when and by whom they are used. Chemical classes used in cleaning and personal care products that have reported carcinogenic or endocrine disrupting properties, such as antimicrobials, bisphenols, phthalates and highly fluorinated chemicals, do not become harmful in consistent and linear ways. Rather, their capacity to cause harm is based on what each chemical is combined with in the environment, the age of the body exposed and how often. For example, common household bleach is relatively benign; however, if it is combined with ammonia, drain cleaners or other acids, it produces chloramine gases, which are harmful to human health (Nazaroff and Weschler 2004). Importantly, how and when a chemical becomes harmful within a given environment is variously determined by 'aggregate exposures' (the effects of cumulative exposures) (Gosens et al. 2014), 'low dose effects' (when a chemical behaves differently in low doses) (Vandenberg et al. 2012) and 'cocktail effects' (when a chemical's behaviour in the body changes based on what other chemicals it is combined with) (Ott et al. 2006). The lack of stable sensory cues for many potentially harmful chemicals means that one cannot safely assume that the potential toxicity of a chemical can be detected through scent.

Reliance on scent as a proxy for potential chemical hazard is additionally problematic because synthetic chemicals are commonly added to personal care and cleaning products expressly to produce effects that make these products seem more effective and desirable.

Specific chemical fragrances were effective in convincing many participants of the desirability and efficacy of different types of products. For example, Participant 6 noted that she associates lemon and pine scents with 'hospital-grade' cleanliness, affording a sense of efficacy when present in floor and bathroom cleaning products:

if you're cleaning you're killing the bacteria, but I don't know if it's psychosomatic.

It smells like Dettol clean. You feel like...Smell really influences what I buy.

However, scents that Participant 6 describes as "like a hospital floor" were deemed undesirable and did not represent a similar state of cleanliness when used in personal care products. She continues:

I like eucalyptus and tea tree smells, but I hate... bleachy, lemony smells, or that piney smell, or anything that smells too chemically I can't handle...in terms of personal care products, there's heaps of smells that I just don't like... I like fruity smells, or natural. I don't like vanilla-ery or sickly-sweet smells, or things that are spicy, like wintery smells. I like fresh smells.

Participant 8 also emphasised the importance of scent as a key determinant of product choice, although she had very different preferences to Participant 6:

I'm more likely to pick things based on scent. So if it's a vanilla or a coconut scent, they're my favourites, I would generally pick those... Vanilla - anything with vanilla in it. I'm a sucker for vanilla. I just love vanilla.

These examples demonstrate that culturally developed associations between certain smells and attributes such as 'freshness' lead people to desire particular sensory effects from their cleaning practices.

Although many different natural and synthetic chemicals are used to create product fragrances, the Environmental Working Group's (EWG) review of scientific research into ingredients regularly labelled as 'Fragrance' or 'Parfum' in personal care and cleaning

products found they are commonly toxic to organ systems and allergenic (2011). EWG consequently gave Fragrance the highest hazard rating.

The capacity for individuals to detect the presence of harmful chemicals is complicated by the fact that the specific chemicals are generally not required to be revealed on labels due to 'trade secret' regulations. This lack of disclosure, in addition to the inconsistency and instability of chemical states in the environment, means that products provide little information, through labelling or sensory attributes, to denote the presence of hazardous chemicals.

More broadly, the issue of unreliable sensory proxies has highlighted the divergence between how micro-species exert agency symbolically and physically in practices. The proxies that have culturally come to represent the presence of harmful microbes (dirt and grime) and chemicals ('bleachy', 'chemically' smells), through a history of socio-material interactions, are not reliable and often provoke actions that lead to more harmful micro-species interactions, such as the use of 'air fresheners' or vanilla-scented antibacterial floor cleaners. This discrepancy between how people react to perceived or symbolic micro-species actions that may not physically be taking place, and the actual micro-species interactions with human bodies in the home environment, indicates a kind of sensory disorientation. This situation suggests further that individuals should not be held responsible for evaluating potential hazards at the molecular scale.

The following section examines further assumptions in relation to how and when different micro-species act in the home and the consistency with which they are considered to do so.

Three: micro-species are consistent entities

Throughout the interviews and practice re-enactments it was often observed or indicated that micro-species are thought to exist in the home environment and interact with human bodies in consistent ways. All participants engaged in spot cleaning, in response to food or

nappy spillages, and routinised cleaning in which products are used to clean regardless of perceived micro-species activity. The repeat performance of practices intended to remove perceived or imagined micro-species, either consciously or through habitual actions, assumes a degree of consistent micro-species behaviour. However, micro-species often do not act consistently, but respond differently according to changing environmental conditions. Three interlinked assumptions emerged indicating expectations of consistency: first, that the type and rate of microbial recolonisation after cleaning is consistent; second, that chemicals applied dissipate within a short timeframe and are not harmful if they can no longer be smelled; and third, that micro-species primarily enter and affect the body through ingestion.

Inherent in the routinised application of antibacterial chemicals is the expectation that the rate and types of microbial colonisation of an area in the home will be consistent. The use of the same antibacterial products in the routine cleaning of a surface or object assumes that microbes will continue to respond to a product, and re-colonise surfaces, in a uniform way. Given the lack of tangible signals for the presence and activity of microbes, the regular use of cleaning products in routine activities suggests cleaning acts as a form of insurance against potential or assumed microbes. This form of routine precautionary cleaning has been observed in normative cleaning practices since 'germ theory' was popularised (Smith 2007). However, the regular application of antibacterial agents and other chemicals does not necessarily produce uniform outcomes, but can progressively and cumulatively alter the composition of the micro-environment, and the types of microbial communities that become dominant. For example, research suggests that after the application of antibacterial products the most resilient types of species of bacteria are likely to survive, thus becoming dominant and potentially resulting in a reduction in microbial diversity (Levy 2001; Hartmann et al. 2016). This pattern of product application and recolonisation by particular species may be linked to a rise in antimicrobial resistant bacteria found in house dust (Levy 2001; Hartmann et al. 2016). Practices oriented around

the expectation that microbes will all respond to a chemical consistently, regardless of species or the context of application, must be revised if more healthful indoor environments are to be cultivated.

The practices observed and discussed also carried assumptions about the consistency with which chemicals dissipate in the environment and cease to become harmful. For example, Participant 9 explained:

I went through a phase where'd I'd clean the bathroom when they (children) were in the bath, because I'm stuck in the bathroom with them anyway, standing there. I might as well clean. Then I stopped doing it, because then the whole bathroom stunk like products. So I'm like, oh my God... I was conscious of them being there, and it stinking like... spray and wipe... I was probably conscious of them breathing in the product, and staying in that room for a while, because they stay in the bath for ages.

In this case, the chemical was assumed to be potentially harmful when the strong 'chemical smell' was apparent in the air, also presumably implying that the chemical would be less harmful if used when the children were not in the room at the time of application and the chemical scent had a chance to dissipate. Similarly, Participant 6 explained that when she purchased a strong chemical insecticide to exterminate a flea infestation, the chemicals would have left the environment after a couple of days:

The bombing is a chemical. It's like a Mortein stuff... I tried to do it last time when we were away for the weekend, and then I did it - I'll do another one this weekend just to be sure, because we're away and it's an opportune time.

However, chemicals can often remain on surfaces and in the air beyond the time that they are able to be smelled, and can enter the body through multiple pathways, in ways that cannot be consistently predicted.

It was also often assumed that using cleaning chemicals is likely to be okay if in small amounts. As Participant 4 notes:

I guess I've resigned myself to the fact that a cleaning product has chemicals in it that you don't want to ingest or you know [don't want to come] into contact with. I guess I subliminally allow that into the house; whereas other things I probably wouldn't I guess. I think if I was a big cleaner and I was mopping my floor every couple of days, or once a week even, then maybe I would care.

In addition to assumptions about how much exposure to a chemical is needed before its effects become toxic, and how long the chemical remains present on surfaces after application, there was also a common belief expressed that the primary route by which chemicals pass into the body is ingestion. Three participants indicated that they thought it was necessary to use surface sprays containing chemicals to remove germs, yet they did not want their children to interact with the sprayed surfaces for a specific period of time after spraying for fear of them ingesting the chemicals. Participant 9 worried that:

I don't like the idea of using spray and wipe on this, and then the kids dropping food onto it and eating food straight off it. Because I don't really know what's in the products, and - yeah. So, I think I'm conscious of them touching a product and putting it in their mouth.

The assumption here was that chemical contaminants would become harmful to the child primarily through ingestion, rather than through skin contact, or through the inhalation of aerosolised particles that remain in the air once the product has been sprayed. However, the skin and lungs are also highly effective at absorbing many household chemicals known or suspected to be toxic (Ott et al. 2006).

Another shared assumption was also that the potential harm of household cleaning chemicals can be mitigated if applied only to surfaces that the child will not directly encounter, particularly with their mouths. Participant 1 expressed a belief that using

products containing potentially concerning chemicals was okay if not applied directly to the child's belongings:

I do look at things and think about, okay, well what am I using this product for and read the label. I mean I do use bleach and things like that but obviously I'm careful about where I use it with the kids and things like that. I use spray and wipe and some of those sort of products as well, but I wouldn't use them necessarily on the kids' things.

She subsequently speculated that 'rinsing' objects or surfaces that have been exposed to chemicals is sufficient to cleanse them:

the washing up detergent you use for plates and cups and things like that... as long as you rinse it it's okay. Whereas I guess the spray and wipe I wouldn't want them to be...(trail off)

The oral consumption of chemicals may be more concerning to some parents than other routes of absorption because of the potential for immediate and severe poisoning. This message is reinforced through product labels which warn against ingestion, but often provide no safety information about the effects of long-term exposure through the skin or lungs. This focus on the immediate, obscures the long-term cumulative impacts of chemicals.

Perceptions of when and how bodies become permeable to particular micro-species are also influenced by the age of the body exposed. In the following section we examine assumptions related to the way age influences perceived vulnerability.

Four: vulnerability decreases as children begin to walk

Participants perceived that the relative vulnerability of children to different micro-species changes as children grow older. The practices observed indicated that parents often assume their children become less vulnerable to indoor environmental hazards, including both chemicals and microbes, around the age of two. However, research suggests they can

still be in a critical window of vulnerability at the age of five (Landrigan and Goldman 2011; Crain et al. 2008). Common assumptions have made about how the porousness of children's bodies, or their capacity to be infiltrated by micro-species, changes at different stages of development, influencing what parents allow them to be exposed to.

The role of children's skin as both sensor and boundary was alluded too frequently throughout the interviews. Multiple parents indicated that the sensitivity they initially attributed to their children's skin as babies disappeared as the child became more mobile and begun interacting with a greater variety of materials. For example, Participant 3 stated that:

When she (her child) was younger, I was really focused on really gentle stuff on her skin so I used to use (natural brand); it's all natural. Now I really don't care... When they're newborn you just want to be so - you think they're so delicate. When they get older, they're just so robust. She's into everything...

Participant 8 also shared this assumption that as children grow older and begin walking, they become more 'robust':

I think once they get past the age of about two and a half they're like little people. They're not babies anymore. They're talking and they're running around. I think they're probably old enough to use anything now and especially she's not allergic to anything. I don't think it matters.

This perception of robustness not only influences parents' willingness to allow children to interact with more objects in daily life, but also their product choices:

When she was a little baby I used special baby products for her skin "... As soon as she started kind of coming into the shower with me, that's when we... I just use what I use" (Participant 3).

Participant 7 also notes that the products she uses on her children changed as they got older. She commented that the older one is “so germy anyway” that she stopped worrying as much about what he came into contact with. Soap and bubble bath are used on the toddler “to entertain” him; however, no soap is used on the baby “because it [the baby] is more sensitive”. She also suggested a relationship between when her eldest child (two years old) started eating solid food and him becoming more generally resilient.

As parents see their children increasingly interacting with products and surfaces that they previously thought were too harsh or unclean, the absence of immediate illness or health impact may be creating a perception that their children are becoming less vulnerable and it matters less which cleaning and personal care products they are exposed to. Put another way, the lack of direct feedback on how materials actually impact children’s bodies at a micro-level results in the continued use of potentially toxic products. The time delay (often decades) between chemical exposure and the potential bodily manifestation of harm demonstrates a clear need for assessment mechanisms beyond immediate visible feedback.

As discussed throughout this paper, germophobic hygiene practices are often enacted when no immediate evidence of pathogenic activity is available. The persistence of these practices was also observed even where there was verbal acknowledgement that some exposure to dirt or germs is good. Participant 8 stated: “I try not to be a germaphobe”, and from Participant 9: “I kind of think that a bit of grime is probably good for them” followed later by “...it’s about getting the right bacteria into their system at a really early age, and that actually kind of can protect them from allergies”.

However, these beliefs were not generally represented in the practices discussed and re-enacted for keeping the house safe and hygienic, which still primarily focused on the extermination of germs. This occurrence may be related to the findings of Greenhough et al. (2018) discussed above that beneficial or probiotic microbial action is associated with

particular domestic locations and material arrangements, such as the ‘garden’, while such positive associations have not been developed for locations such as kitchen floors.

However, it could also be an indication of disparities that emerge between beliefs and attitudes and practices, particularly those that are habitually enacted without conscious reflection (Jack 2017).

Developing an integrated approach to healthy home microecologies

Investigations of chemical and microbial molecular relations have revealed new disease risks within home practices and infrastructures previously assumed to be safe, and often desirable. To begin to disentangle the practices that reproduce the regimes of hygiene and chemical living in which these relations have been made imperceptible, we have proposed that the integration of concepts from multispecies ethnography and social practice theories can provide a valuable investigative lens. We propose that this approach can assist in identifying operative assumptions within practices that may be generating maladaptive microecologies, contrary to the intent that motivates and perpetuates them. The assumptions discussed in this paper express a number of expectations about how micro-species move and cause harm, and how, when, and for how long human bodies are vulnerable to them. Through understanding the operation of these assumptions in practice, the ways in which they are commensurate with or contradict scientific knowledge about actual micro-species behaviours can be investigated. By combining this approach with scientific modes of sensing and measuring molecular activity into the future, more nuanced ways of conceptualising the way micro-species culturally and physically participate in, change, and reinforce practices that are contributing to sub-optimal home environments may be better understood.

Homes are intended to function as safe havens from external sources of physical and existential harm. When the notion of the home is ‘inverted’ (Edelstein 2004) and becomes a source of risk and insecurity, it can have profound mental and emotional effects, beyond

the physical effects of the risk itself. As conflicting and confusing health messages emerge around the different sources of invisible risk in the home, parents are compelled to negotiate ever more complex relations that are beyond their perception. This paper has shown some of the ways in which parents attempt to sense and manage potentially harmful micro-species based on a set of culturally and materially entrained assumptions about the material conditions under which hazards emerge, and how human bodies become vulnerable to chemical and microbial species. The actions that follow from these assumptions are based on a profound sense of duty and care for the health of their children, a duty that has been socially framed as their responsibility. As Murphy (2015) highlights, the care work and affective labour often performed by and expected of mothers within families places an unjust burden on parents for managing structural risks beyond their control or responsibility.

As urbanisation accelerates around the world, and growing middle classes increasingly achieve the means to create the healthy and hygienic homes they desire, indoor ecologies will continue to be shaped by the practices thought to create these conditions. To make the micro-species rendered imperceptible become legible and political, further efforts to investigate the multitude of ways this imperceptibility is embedded in assumptions, practices and infrastructures across socio-geographic contexts will be required.

1

It is acknowledged that the term ‘non-human’ is imperfect and grounded in human exceptionalism.

2

We will use the term multispecies approaches to refer to both multispecies- and chemo-ethnographies from this point unless specified otherwise.

3

Microorganisms are generally divided into seven types: bacteria, archaea, protozoa, algae, fungi, viruses and multicellular animal parasites. Each has a characteristic cellular composition, morphology, mode of reproduction and locomotion.

4

Given the depth of engagement with each participant and the purpose of the research, a sample size of 10 was deemed appropriate (Malterud et al. 2016).

References

- Abrahamsson, S., F. Bertoni, A. Mol, and R.I. Martín. 2015. Living with Omega-3: New materialism and enduring concerns. *Environment and Planning D: Society and Space* 33: 4–19.
- Bashford, A. 2003. *Imperial hygiene: A critical history of colonialism, nationalism and public health*. Basingstoke: Palgrave Macmillan.
- Benn, S. 2004. Managing toxic chemicals in Australia: A regional analysis of the risk society. *Journal of Risk Research* 7: 399–412.
- Bloomfield, S., R. Stanwell-Smith, R. Crevel, and J. Pickup. 2006. Too clean, or not too clean: The hygiene hypothesis and home hygiene. *Clinical and Experimental Allergy* 36: 402–425.
- Brody, J.G., R. Morello-Frosch, A. Zota, P. Brown, C. Pérez, and R.A. Rudel. 2009. Linking exposure assessment science with policy objectives for environmental justice and breast cancer advocacy: The Northern California Household Exposure Study. *American Journal of Public Health* 99: S600–S609.
- Brown, P.J. 1997. Popular epidemiology revisited. *Current Sociology* 45: 137–156.
- Bufford, J., C. Reardon, Z. Li, K. Roberg, D. Dasilva, P. Eggleston, A. Liu, D. Milton, U. Alwis, and R. Gangnon. 2008. Effects of dog ownership in early childhood on immune development and atopic diseases. *Clinical and Experimental Allergy* 38: 1635–1643.
- Cass, N., and J. Faulconbridge. 2016. Commuting practices: New insights into modal shift from theories of social practice. *Transport Policy* 45: 1–14.

- Crain, D.A., S.J. Janssen, T.M. Edwards, J. Heindel, S.-M. Ho, P. Hunt, T. Iguchi, A. Juul, J.A. McLachlan, and J. Schwartz. 2008. Female reproductive disorders: The roles of endocrine-disrupting compounds and developmental timing. *Fertility and Sterility* 90: 911–940.
- Darling, K.W., S.L. Ackerman, R.H. Hiatt, S.S.-J. Lee, and J.K. Shim. 2016. Enacting the molecular imperative: How gene–environment interaction research links bodies and environments in the post-genomic age. *Journal of Social Science & Medicine* 155: 51–60.
- Davison, G., 2008. Down the gurgler: Historical influences on Australian domestic water consumption. In *Troubled waters: Confronting the water crisis in Australia's cities*. Canberra: Australian National University Press.
- Dunn, R.R., N. Fierer, J.B. Henley, J.W. Leff, and H.L. Menninger. 2013. Home life: Factors structuring the bacterial diversity found within and between homes. *PLoS ONE* 8: e64133.
- Dupré, J. 1992. Species: Theoretical contexts. In *Keywords in evolutionary biology*, ed. E.F. Keller and E.A. Lloyd, 312–317. Cambridge, MA: Harvard University Press.
- Edelstein, M.R. 2004. *Contaminated communities: Coping with residential toxic exposure*. Boulder, CO: Westview Press/Perseus Books.
- Environmental Working Group, 2011. EWG's skin deep cosmetics database. Washington, DC: Environmental Working Group. <http://www.ewg.org/skindeep/site/about>.
- Epstein, T.G., D.I. Bernstein, L. Levin, G.K.K. Hershey, P.H. Ryan, T. Reponen, M. Villareal, J.E. Lockey, and G.K. Lemasters. 2011. Opposing effects of cat and dog ownership and allergic sensitization on eczema in an atopic birth cohort. *The Journal of Pediatrics* 158: 265.e5–271.e5.
- Fox, E., R. Hitchings, R. Day, and S. Venn. 2017. Demanding distances in later life leisure travel. *Geoforum* 82: 102–111.
- Fujimura, K.E., C.C. Johnson, D.R. Ownby, M.J. Cox, E.L. Brodie, S.L. Havstad, E.M. Zoratti, K.J. Woodcroft, K.R. Bobbitt, and G. Wegienka. 2010. Man's best friend? The effect of pet ownership on house dust microbial communities. *The Journal of Allergy and Clinical Immunology* 126: 410.
- Gosens, I., C.J. Delmaar, W. Ter Burg, C. De Heer, and A.G. Schuur. 2014. Aggregate exposure approaches for parabens in personal care products: A case assessment

- for children between 0 and 3 years old. *Journal of Exposure Science & Environmental Epidemiology* 24: 208–214.
- Granjou, C., and C. Phillips. 2018. Living and labouring soils: Metagenomic ecology and a new agricultural revolution? *BioSocieties*. <https://doi.org/10.1057/s41292-018-0133-0>.
- Greaves, M. 2018. A causal mechanism for childhood acute lymphoblastic leukaemia. *Nature Reviews Cancer* 18 (8): 471–484.
- Green, J.L. 2014. Can bioinformed design promote healthy indoor ecosystems? *Indoor Air* 24: 113–115.
- Greenhough, B., A. Dwyer, R. Grenyer, T. Hodgetts, C. Mcleod, and J.J.P.C. Lorimer. 2018. Unsettling antibiosis: How might interdisciplinary researchers generate a feeling for the microbiome and to what effect? *Palgrave Communications* 4: 149.
- GSPI, 2016. *Six Classes* (Online). <http://greensciencepolicy.org/topics/six-classes/>. Accessed 20 Feb 2016.
- Haraway, D.J. 2008. *When species meet*. Minneapolis: University of Minnesota Press.
- Hartmann, E.M., R. Hickey, T. Hsu, C.M. Betancourt Román, J. Chen, R. Schwager, J. Kline, G. Brown, R.U. Halden, and C. Huttenhower. 2016. Antimicrobial chemicals are associated with elevated antibiotic resistance genes in the indoor dust microbiome. *Environmental Science and Technology* 50: 9807–9815.
- Heederik, D., and E. Von Mutius. 2012. Does diversity of environmental microbial exposure matter for the occurrence of allergy and asthma? *Journal of Allergy and Clinical Immunology* 130: 44–50.
- Hird, M.J. 2010. Meeting with the microcosmos. *Environment and Planning D: Society and Space* 28: 36–39.
- Hui, A., T. Schatzki, and E. Shove. 2016. *The nexus of practices: Connections, constellations, practitioners*. Abington: Taylor & Francis.
- Jack, T. 2017. Cleanliness and consumption: Exploring material and social structuring of domestic cleaning practices. *International Journal of Consumer Studies* 41: 70–78.
- Jeon, Y.-S., J. Chun, and B.-S. Kim. 2013. Identification of household bacterial community and analysis of species shared with human microbiome. *Current Microbiology* 67: 557–563.

- Kessler, R. 2015. More than cosmetic changes: Taking stock of personal care product safety. *Environmental Health Perspectives* 123: A120.
- Kirksey, S.E., and S. Helmreich. 2010. The emergence of multispecies ethnography. *Cultural Anthropology* 25: 545–576.
- Lakind, J.S., and L.S. Birnbaum. 2010. Out of the frying pan and out of the fire: The indispensable role of exposure science in avoiding risks from replacement chemicals. *Journal of Exposure Science & Environmental Epidemiology* 20: 115–116.
- Landecker, H., and A. Panofsky. 2013. From social structure to gene regulation, and back: A critical introduction to environmental epigenetics for sociology. *Annual Review of Sociology* 39: 333–357.
- Landrigan, P.J., and L.R. Goldman. 2011. Children’s vulnerability to toxic chemicals: A challenge and opportunity to strengthen health and environmental policy. *Health Affairs* 30: 842–850.
- Lea, T., and P. Pholeros. 2010. This is not a pipe: The treacheries of Indigenous housing. *Public Culture* 22: 187–209.
- Levy, S.B. 2001. Antibacterial household products: Cause for concern. *Emerging Infectious Diseases* 7: 512.
- Liboiron, M. 2015. Redefining pollution and action: The matter of plastics. *Journal of Material Culture*. <https://doi.org/10.1177/135918351562296>.
- Loretz, L., A. Api, L. Babcock, L. Barraj, J. Burdick, K. Cater, G. Jarrett, S. Mann, Y. Pan, and T. Re. 2008. Exposure data for cosmetic products: Facial cleanser, hair conditioner, and eye shadow. *Food and Chemical Toxicology* 46: 1516–1524.
- Lorimer, J. 2017. Probiotic environmentalities: Rewilding with wolves and worms. *Theory, Culture, Society* 34: 27–48.
- Maizels, R.M. 2005. Infections and allergy—helminths, hygiene and host immune regulation. *Current Opinion in Immunology* 17: 656–661.
- Maller, C. 2016. Epigenetics, theories of social practice and lifestyle disease. In *The Nexus of Practices*, ed. A. Hui, T.R. Schatzki, and E. Shove. Abingdon: Routledge.
- Maller, C. 2018. *Healthy urban environments: More-than-human theories*. Abingdon: Routledge.

- Maller, C., and Y. Strengers. 2013. The global migration of everyday life: Investigating the practice memories of Australian migrants. *Geoforum* 44: 243–252.
- Malterud, K., V.D. Siersma, and A.D. Guassora. 2016. Sample size in qualitative interview studies: Guided by information power. *Qualitative Health Research* 26: 1753–1760.
- Mills, J.G., P. Weinstein, N.J. Gellie, L.S. Weyrich, A.J. Lowe, and M.F.J. Breed. 2017. Urban habitat restoration provides a human health benefit through microbiome rewilding: The Microbiome Rewilding Hypothesis. *Restoration Ecology* 25: 866–872.
- Morawska, L., P.K. Thai, X. Liu, A. Asumadu-Sakyi, G. Ayoko, A. Bartonova, A. Bedini, F. Chai, B. Christensen, and M.J. Dunbabin. 2018. Applications of low-cost sensing technologies for air quality monitoring and exposure assessment: How far have they gone? *Environmental International* 116: 286–299.
- Murphy, M. 2006. *Sick building syndrome and the problem of uncertainty: Environmental politics, technoscience, and women workers*. Durham: Duke University Press.
- Murphy, M. 2008. Chemical regimes of living. *Environmental History* 13: 695–703.
- Murphy, M. 2015. Unsettling care: Troubling transnational itineraries of care in feminist health practices. *Social Studies of Science* 45: 717–737.
- Myers, N. 2015. *Rendering life molecular: Models, modelers, and excitable matter*. Durham: Duke University Press.
- Nazaroff, W.W., and C.J. Weschler. 2004. Cleaning products and air fresheners: Exposure to primary and secondary air pollutants. *Atmospheric Environment* 38: 2841–2865.
- Nicolini, D. 2016. *Knowing in organizations: A practice-based approach*. New York: Routledge.
- O'Malley, M.A., and J. Dupré. 2007. Size doesn't matter: Towards a more inclusive philosophy of biology. *Journal of Biology & Philosophy* 22: 155–191.
- OED, 2019. Definition: Species *Oxford English Dictionary*. <https://en.oxforddictionaries.com/definition/species>.
- Ott, W.R., A.C. Steinemann, and L.A. Wallace. 2006. *Exposure analysis*. Boca Raton: CRC Press.
- Paxson, H.J.C.A. 2008. Post-Pasteurian cultures: The microbiopolitics of raw-milk cheese in the United States. *Cultural Anthropology* 23: 15–47.

- Paxson, H., and S.J.S. Helmreich. 2014. The perils and promises of microbial abundance: Novel natures and model ecosystems, from artisanal cheese to alien seas. *Social Studies of Science* 44: 165–193.
- Perzanowski, M.S., E. Rönmark, T.A. Platts-Mills, and B. Lundbäck. 2002. Effect of cat and dog ownership on sensitization and development of asthma among preteenage children. *American Journal of Respiratory and Critical Care Medicine* 166: 696–702.
- Phillips, C. 2014. Following beekeeping: More-than-human practice in agrifood. *Journal of Rural Studies* 36: 149–159.
- Povinelli, E.A. 2016. *Geontologies: A requiem to late liberalism*. Durham: Duke University Press.
- Quitza, M.-B., and I.J. Røpke. 2009. Bathroom transformation: From hygiene to well-being? *Home Cultures* 6: 219–242.
- Robinson, P.A. 2018. Performativity and a microbe: Exploring *Mycobacterium bovis* and the political ecologies of bovine tuberculosis. *BioSocieties* 172: 1–26.
- Rook, G.A. 2012. Hygiene hypothesis and autoimmune diseases. *Clinical Reviews in Allergy and Immunology* 42: 5–15.
- Rose, N. 2007. Molecular biopolitics, somatic ethics and the spirit of biocapital. *Social Theory and Health* 5: 3–29.
- Rose, N., and C.J. Novas. 2005. Biological citizenship. In *Global assemblages: Technology, politics, and ethics as anthropological problems*, ed. A. Ong and S.J. Collier, 439–463. Oxford: Blackwell.
- Ryghaug, M., and M. Toftaker. 2014. A transformative practice? Meaning, competence, and material aspects of driving electric cars in Norway. *Nature and Culture* 9: 146–163.
- Sahakian, M., and H.J. Wilhite. 2014. Making practice theory practicable: Towards more sustainable forms of consumption. *Journal of Consumer Culture* 14: 25–44.
- Schatzki, T. 2016. Practice theory as flat ontology. In *Practice theory and research: Exploring the practice theory and research*, ed. G. Spaargaren, D. Weenink, and M. Lamers. Abingdon: Routledge.
- Schatzki, T.R., K. Knorr-Cetina, and E. Von Savigny. 2001. *The practice turn in contemporary theory*. London: Psychology Press.

- Shapiro, N., and E. Kirksey. 2017. Chemo-ethnography: An introduction. *Cultural Anthropology* 32: 481–493.
- Shove, E. 2003. *Comfort, cleanliness and convenience: The social organization of normality*. Oxford: Berg.
- Shove, E., M. Pantzar, and M. Watson. 2012. *The dynamics of social practice: Everyday life and how it changes*. London: Sage.
- Smith, V. 2007. *Clean: A history of personal hygiene and purity*. Oxford: OUP.
- Spackman, C.C. 2018. Formulating citizenship: The microbiopolitics of the malfunctioning functional beverage. *BioSocieties* 13: 41–63.
- Steinemann, A. 2015. Volatile emissions from common consumer products. *Air Quality, Atmosphere and Health* 8: 273–281.
- Stoker, T.E., E.K. Gibson, and L.M. Zorrilla. 2010. Triclosan exposure modulates estrogen-dependent responses in the female wistar rat. *Toxicological Sciences* 117: 45–53.
- Thrift, N., 2016. Understanding the affective spaces of political performance. In *Emotion, place and culture*. Abington: Routledge.
- Vandenberg, L.N., T. Colborn, T.B. Hayes, J.J. Heindel, D.R. Jacobs Jr., D.-H. Lee, T. Shioda, A.M. Soto, F.S. Vom Saal, and W.V. Welshons. 2012. Hormones and endocrine-disrupting chemicals: Low-dose effects and nonmonotonic dose responses. *Endocrine Reviews* 33: 378–455.
- Weatherly, L.M., and J.A. Gosse. 2017. Triclosan exposure, transformation, and human health effects. *Journal of Toxicology and Environmental Health, Part B: Critical Reviews* 20: 447–469.
- Wilson, N.K., J.C. Chuang, C. Lyu, R. Menton, and M.K. Morgan. 2003. Aggregate exposures of nine preschool children to persistent organic pollutants at day care and at home. *Journal of Exposure Science & Environmental Epidemiology* 13: 187–202.

PAPER 3: 'IT'S JUST A NEVER-ENDING BATTLE': THE ROLE OF MODERN HYGIENE IDEALS AND THE DYNAMICS OF EVERYDAY LIFE IN CONSTRUCTING INDOOR ECOLOGIES

JOURNAL: HUMAN ECOLOGY REVIEW

Paper 2 highlighted assumptions embedded in hygiene practices that express a number of expectations about how micro-species behave and cause harm, and how, when and for how long human bodies are vulnerable to them. The finding that micro-species exert agency in practice in both physical and symbolic registers relates to Pickering's (1994) proposition, discussed in the Theoretical Framework chapter of this thesis, that entities in practice always move between being real and socially constructed depending on the configuration of that particular practice. Paper 3 delves further into how the dynamics of practice influence how this agency is configured and expressed.

Based on the same qualitative investigation of parental practices that informed the previous paper, in this paper I focus on how the relative importance given to the demands of competing domestic practices influence how wholly or partially hygiene-oriented practices are performed and prioritised. I was particularly interested in exploring how definitions of hygiene, and notions of 'cleaning well' embedded within cleaning practices require certain amounts of time, vigilance and labour, which ultimately influence how these practices are performed and prioritised.

This paper was published as part of a special issue of the *Human Ecology Review* titled: 'Addressing the Great Indoors – A Transdisciplinary Conversation'. This journal was targeted because it has a diverse, international readership across geography, ecology and the social sciences, and because it engages with environmental issues as necessarily systemic socio-ecological issues. This paper makes a valuable contribution to the

transdisciplinary conversation occurring within this special issue because it highlights how the multiple social and environmental factors that contribute to the dynamics of practice that play out in the domestic space ultimately influence its ecology.

Wakefield-Rann, R., Fam, D., & Stewart, S. (2018). "It's Just a Never-Ending Battle": The Role of Modern Hygiene Ideals and the Dynamics of Everyday Life in Constructing Indoor Ecologies. *Human Ecology Review*, 24(2), 61.

Abstract

Recent research suggests that the greatest threat to children's health from home environments across much of the industrialized world may no longer be pathogenic microbes, but impoverished microbial communities and the chemicals used in everyday products, including those for cleaning. This paper proposes that concepts of hygiene should be updated, given this reorientation of harm. However, little research has been conducted, which a) integrates knowledge from the diverse disciplinary fields concerned with indoor environments (such as microbiology, chemistry, and design), and b) examines how individuals conceptualize and enact hygiene to create healthier indoor environments for their families, including the extent to which their practices achieve this.

To gain insight into factors influencing how hygiene is enacted in the home, as well as the consequent effects on the composition of indoor environments, it is necessary to transgress traditional disciplinary approaches to investigate indoor environmental health and integrate knowledge from experts and lay people who inhabit these spaces. To do this, recent scientific and design literature addressing key determinants of environmental health in homes are consulted. This is combined with qualitative research into the ways in which parents define, perform, and measure hygiene within domestic spaces. The data collected concerns homes in Sydney, Australia, with the findings showing that common hygiene practices with potentially harmful outcomes often emerge from compromises between competing priorities within complexes of home practices. Factors influencing the

dynamics that determine which activities are prioritized and how they are performed are dually highlighted. Some notable factors include confusion and uncertainty associated with the sensory proxies used to determine cleanliness and risk of harm, increased sensitivity to the potential presence of microbes over other potentially harmful microspecies, and the health histories and experiences of parents and children.

Keywords: cleaning practices, home microbiome, hygiene, indoor ecology, social practice theory

Introduction

Human ecology is concerned with the coevolution of complex cultural–economic–technological systems and physical–chemical–living systems, and the effects of their often-unpredictable emergent properties on the health of humans and ecosystems (Dyball & Newell, 2014). Much of the current literature in the field of human ecology is focused on macroscale interactions between human societies and regional or global environmental conditions, while dedicating relatively less attention to microscale (or indoor) ecosystems.² As such, this paper proposes that the microecology of the indoors warrants greater attention, particularly as it is now considered not only the fastest growing biome on Earth, but also an increasingly significant source of human and environmental health hazards (Martin et al., 2015). Air pollution in the home is now ranked the ninth largest Global Burden of Disease risk (Forouzanfar et al., 2015). Those most susceptible to its effects, including the very young and elderly, and those with compromised health, are likely to have higher exposure than those who spend less time indoors (Kumar et al., 2016). The types of health hazards present in home environments are complex, varied, and geographically contingent (Lyytimäki, 2012). In much of the developing world, key sources of indoor pollution include smoke from fires and cigarettes, while in developed countries pollutants primarily emanate from consumer products (Kumar et al., 2016). Products commonly used in home cleaning and bathing practices also contain classes of

chemicals, such as phthalates and some solvents, identified as harmful to human and environmental health (Clayton et al., 2011; Gosens et al., 2014). Of the approximately 80,000 chemicals registered for use in consumer products, only a small percentage have been tested for their long-term effects (National Toxicology Program, 2018). However, recent research has demonstrated that many of those used in common personal care and cleaning products have carcinogenic or endocrine disrupting effects (Bergman et al., 2013; Weschler, 2009; Zoeller et al., 2012), which are particularly harmful to children. Endocrine disrupting chemicals (EDCs) have in the past been linked to health conditions including diabetes, obesity, some cancers, and impaired reproductive and neurological development (Bergman et al., 2013).

In addition to chemical pollutants, a crucial determinant of indoor environmental health is the microbial communities that thrive therein. Homes can become sites in which pathogenic bacteria and viruses are transferred between people, and fungus can develop in damp areas, which may cause allergic reactions. However, a lack of microbial diversity in homes, and the absence of farm or domesticated animals that carry particular microbes to “train” human immune systems, have been associated with the rise in childhood allergies (Rook et al., 2013) and leukemia (Greaves, 2018). The design of domestic objects, homes, and the use of antibacterial products have all been associated with declining microbial diversity in homes (Dunn et al., 2013; Flores et al., 2013; Rintala et al., 2008). For example, the use of chemically treated finishing such as antimicrobial paint, chemical cleaning products, and home designs that restrict airflow between the indoors and outdoors can all contribute to a decrease in microbial diversity, potentially encouraging more resistant microbial species to thrive and colonize (Adams et al., 2016; Martin et al., 2015; Meadow et al., 2014).

Despite clear evidence from chemistry and microbiology fields that practices central to modern lifestyles influence indoor environmental health, there remains a gap in the literature examining how different material, biological, and cultural forces come together

to create particular “microecologies” in one’s home. Moreover, no evidence could be found of research that examines how modern ways of defining and maintaining a hygienic home affects the composition of domestic microecologies, which, in turn, influence health outcomes.

This paper begins to address this gap by moving beyond discipline-specific investigations to integrate perspectives on indoor environmental health. It examines how home hygiene is enacted in practice, and how these practices might contribute to suboptimal indoor home environments. The transdisciplinary approach that broadly guided this research is defined here through four criteria: problem oriented, participatory or collaborative, transgressing disciplinary boundaries, and seeking to integrate disparate fields of knowledge (Brown et al., 2010; Schoot Uiterkamp & Vlek, 2007; Wickson et al., 2006). Based on this orientation, the following section details how and why an approach focused on social practices was adopted to trace relations between social and material elements within home environments, which may influence the composition of domestic microecologies.

Research Approach: Tracing Home Hygiene Practices

Although heterogeneous, theories of social practice generally focus on the dynamic interplay between material things, meanings and beliefs, and embodied knowledge at different scales of social life (Hui et al., 2016; Shove, 2004). A commonly cited definition of practice provided by Reckwitz (2002) describes a practice as:

a routinized type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, “things” and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge. (p. 249)

Research that foregrounds the importance of practices allows insights that integrate the latent and explicit influences of hygiene in the design of domestic interiors and objects, the

deliberate and the unquestioned ways of performing particular activities (e.g., dishwashing and toothbrushing), and the more deliberate cognitive decisions and beliefs about what constitutes a healthy environment. All routine activities conducted in one's home, such as cooking, watching television, and getting ready for work, determine the flows of materials in, out, and around such buildings. However, some practices, such as cleaning, have a more direct role in structuring a home's microecology, due primarily to the common use of products containing antimicrobials and other EDCs, and the frequency and ubiquity with which they are used (Halden et al., 2017; Sherriff et al., 2005). Some scholars (see Maller, 2018; Wakefield-Rann et al., 2018) have argued that common conceptualizations of materiality in theories of social practice do not sufficiently account for nuances in material agency. They consequently propose that elements of other more-than-human theories are integrated into investigations of practice to explore material agency in greater depth. Nonetheless, this paper contends that practice theories provide a compelling lead framework to enable a necessary investigation and articulation of the ways in which the dynamics of everyday practice structure the composition of indoor environments.

Conceptualizing and Practicing Hygiene

The ways that cleaning practices are conducted are closely linked to how hygiene is understood and measured. Hygiene is defined as the "conditions or practices conducive to maintaining health and preventing disease, especially through cleanliness" (Oxford English Dictionary, 2016). However, since the mass popularization of germ theory, hygiene has increasingly become synonymous with sterility, thus, narrowing its focus on the extermination of "germs" (Campkin & Cox, 2012; Pink & Mackley, 2015; Shove, 2003; Smith, 2007). Moreover, Shove (2003) and others (see Campkin & Cox, 2012; Smith, 2007) have argued that cleanliness conventions have escalated and become standardized across the industrialized world in late modernity. These escalating and increasingly complex standards of hygiene, and the market's capitalization of such trends, have meant that the

networks of products mobilized in daily cleaning practices command ever-higher levels of energy, materials, and chemicals to produce the desired functionality (Shove, 2003).

This paper adopts the term “micro-species” to help broaden its investigation of home hygiene to account for the complex interactions between microbes and other significant micro-entities, which influence health and disease outcomes (Wakefield- Rann et al., 2018). “Microspecies” include microbes (i.e., bacteria, archaea, protists, fungi, and other microscopic animals and plants), and active organic and inorganic chemicals that exist at a microscale (i.e., invisible to the human eye) in homes. For the purposes of this research, the separation of living microbes from non-living chemicals obscures important shared traits related to how they act, react, and influence the environments in which they exist. Unlike visible species, microspecies can only make their presence known through proxies that must be read by humans, such as odor, discoloration of surfaces and clothes, skin rashes, and illness. The complex interactions between microspecies, guided by the actions and objects that populate daily life, shape a home’s “microecology,” and determine if it constitutes a hygienic and healthy environment for human habitation.

Research Sample and Recruitment

This research draws on data collected from a qualitative study conducted in Sydney, Australia, with 10 parents of children under five during 2017. A key aim was to investigate the ways in which competition between complexes of practices structure the enactment of hygiene in domesticity. This necessitated significant depth of engagement with each participant, and the adoption of multiple research methods. The exploration of complex phenomena in this research benefited from a sample size of 10 (Creswell, 1998; Malterud et al., 2016; Morse, 1994).

Respondents were primarily female (9/10; 90%), which may reflect availability and degree of engagement with domestic environmental health issues, as suggested by other research (Mackendrick, 2014). The characteristics of the final participant sample affords

insights into the complexes of practices performed by women from English-speaking backgrounds, who work full or part time, and are of a middle to high socioeconomic status. Although the latter component was not deliberately selected for in the sample, insights into the domestic practices of this group can be considered valuable given the expansion of a “middle class” in Australia and globally. Additionally, the normative lifestyle practices of such social groups may form the basis of aspirational changes made by upwardly mobile families (Koo, 2016).

Given the limitations of the study, a multitude of potential variables that could contribute to the constitution of home microecologies were not investigated. In particular, further research that examines differences in rural and urban practices, cultural practices, house size and composition, and geographic location would add further nuance to studies concerning how hygiene is defined and prioritized, and how it is expressed when the dynamics of practice shift under different influences.

Methods used included a “cleaning diary,” semi-structured interviews, and practice re-enactments in participants’ homes. The cleaning diary required participants to record all domestic cleaning or hygiene-related activities conducted over a period of seven days. This method, adapted from Sofoulis’s (2005) water diaries, highlighted the associations and motivations that shaped key forms of engagement between participants, products, other objects, and perceived sources of environmental risk or “uncleanliness” that transpire throughout a day or week. Although there are clear limitations to self-reporting methods, the diaries provide a valuable indication of the frequency of particular activities, how cleaning and hygiene are defined by participants, and how cleaning is entwined with other practices. After completing these diaries, participants were invited to partake in a semi-structured interview with practice re-enactments in their homes, in which they demonstrated their use of particular products and the ways they approached cleaning different parts of their house.

A combination of the cleaning diary, interviews, and practice re-enactments allowed participants' practices to be accessed from different angles, rather than relying exclusively on narrative descriptions of different activities. The diaries provided a sense of the temporal dimensions of practice, while the situated interviews and re-enactments enabled participants to demonstrate how they engage with particular materials and why. By situating interviews in participants' homes, there were opportunities to be reminded of certain activities, product choices, irritations, quirks, and other features of their homes that guide how they clean while physically moving through space.

Interview data were professionally transcribed and thematically analyzed with NVivo qualitative data analyses software. The thematic codes centered on the focal areas listed above, and how competition within and between practices and practitioners influence how, when, and by whom the home is cleaned, as well as how different activities are prioritized. What follows is an examination of the findings from this research, and how the interactions between practices that structure the flow of daily life shape how and when cleaning is performed, and its implications for home microecologies.

Hygiene Outcomes and Competition Within Complexes of Practices

The interviews and re-enactments situated in participants' homes revealed that all had owned products that contained chemicals known or suspected to contribute to suboptimal indoor environments and health conditions; the most common sources of which were antimicrobial and fragrance chemicals. However, the types, ways, and degrees of product use were determined by numerous factors attributable to competition between rival interests within bundles and complexes of practices. Key factors influencing these dynamics include how hygiene priorities shift after having children, the way time and resources are allocated to different practices under time pressure, how these dynamics influence the delegation and performance of tasks, and the implications for the composition of domestic microecology.

Within social practice literature, coexistent practices are often described in terms of “bundles” of practices, which are loosely intertwined through colocation and coexistence, such as watching television and eating dinner (Shove et al., 2012). Conversely, “complexes” of practice are more integrated and interdependent arrangements, which concern such acts as handwashing and eating. A focus on the dynamics of complexes and bundles of practices, rather than exclusively examining meanings or attitudes toward home hygiene, has generated insights into how competing priorities, such as family time, leisure time, work, the aesthetic of one’s home, and geographic and infrastructural elements, influence how hygiene is enacted.

The majority of parents interviewed reported that time pressures had a significant influence on how they prioritized tasks related to cleaning. For eight of the 10 participants who were engaged in paid employment, the arrival of children simultaneously reduced the amount of time available for maintaining such spaces, while introducing a range of new hygiene concerns.

After having children, greater emphasis was placed on removing potential germs from floors and benches, while activities such as tidying became less of a concern. Participant 6 stated:

there’s probably lots I do now that I never would have been so fussed about. Just in terms of keeping, probably, surfaces way more clean, way more often. Probably, yeah, frequency is the biggest—would be the biggest thing, for sure. Then, yeah, probably floors. Just in terms of using Dettol and stuff. I would have never have thought—I just would have used a floor cleaner rather than an antibacterial thing like that.

This heightened concern over the germs children might encounter (particularly on surfaces) meant the cleaning methods sought were less time and labor intensive, but effectively addressed perceived hygiene risks. As a result, antibacterial surface sprays and

wipes were reported as popular options by all participants. These products enable the effective removal of food, toilet mishaps, or any kind of grime without having to clean an entire surface or area. This is illustrated well by Participant 3: “I’ve got these Dettol antiseptic wipes that I use to wipe the floor and her [participant’s daughter] surface because I actually put the food straight on there, so she’s feeding off that surface.”

The preference for children to dwell in clean environments, coupled with the undesirability of prioritizing cleaning over other pursuits, such as family time or work, means that parents often delegate a certain amount of cleaning to professional services and objects. Although all parents interviewed conducted some amount of cleaning, six of the 10 employed a professional cleaner: one weekly, one fortnightly, three monthly, and one as needed. A common reason provided was that the perceived time required to clean one’s home adequately would detract too much from the time they spend with family. Children also create more constant and new types of mess compared to adults, thus, seeing parents more often engage in frequent “spot cleaning,” and, consequently, delegating the less urgent and more substantive tasks to professionals:

The stuff we’ve let go since we had [child], because we just don’t have the time, is vacuuming, which we basically now have a cleaner that comes every four weeks and does it. We don’t really do dusting. We don’t clean in the inside of the oven. We don’t clean the bathtub or the walls of the shower space. We let the cleaner do all that ... The stuff that we do, continue to do, is the vital kitchen-related [jobs] ... cleaning dishes ... wiping surfaces, kitchen table, high chair. (Participant 5)

Tasks performed by cleaners are often more time and product intensive than those parents reported to conduct on day-to-day bases. An implication of outsourcing more substantial cleaning tasks is that parents are often unaware of what products are being used to clean their homes. Only one of the six participants who hired a professional

cleaner specified the products they wanted used, while the others indicated they were unaware of such details:

Do you know what? ... they come while I'm at work, so I'm not even here. I actually have no idea what they [cleaners] use or what they do ... so I'll come home from work on the day the cleaners have been ... Before I give the boys a bath that night, I actually wash out the whole bath with water, because I can feel that it's got—you know how you can feel it's got residue on it? ... I'm like, oh God, I don't want him soaking in something, I don't know what it is. (Participant 9)

Many of the materials and interactions influencing domestic microecologies are not the result of decisions directly made by parents about a particular micro-species of concern. Rather, the emergent cleaning practices include products selected according to attributes desired by cleaners who are required to achieve a cost-effective, yet satisfactory appearance of cleanliness for their client. Of all the parents who used professional cleaners, only one directed their cleaner to use “more natural products” (Participant 2). For the majority of participants, the delegation of cleaning reduced their awareness of the types of microspecies introduced to their homes through cleaning practices. Consequently, a result of delegation is often a greater reliance on chemical agents, rather than on cleaning practices that involve a significant investment of time and effort.

Time pressure resulting from competition between practices also influences how and where parents shop for products to maintain home hygiene. When asked what factors guide product choices, convenience was a significant aspect. When asked why certain products were selected, Participant 1 noted, “whatever's convenient at the time. So if we're over at [shopping center] doing shopping, that will be where we purchase things.” Even when parents are concerned about particular product attributes, purchasing decisions were not always made on that basis. Rather, competition between practices

within a given timeframe would be resolved by adopting the most convenient bundling of activities, even when that meant compromise on product choice.

Hygiene outcomes emerge from specific resolutions of competing practices, not only in the context of individual decision-making, but also between members of a household. The specific ways of cleaning, how it is valued and prioritized by different individuals, and the combinations of personal care and cleaning products used in different rooms by different people all influence the composition of a home's microecology. In some cases, one person was responsible for the majority of housework and shopping; however, in most cases, these tasks were shared to varying degrees. Consequently, divergent hygiene, aesthetic, and time-related priorities were at play. As Participant 6 explained:

[my partner] and I have a continual disagreement about personal care products ... He likes things that really foam up, like a good body [lather], and I'm just like, that's all not really good for you ... but he wants [sports brand] stuff with beads in it or whatever.

When asked about the use of antibacterial personal care products, Participant 6 also stated:

that's another thing that [partner] and I disagree about ... He's pro, and I'm anti ... Because I just don't feel like it's a necessary step, and I feel like it's quite hard on your skin, especially for kids. I would rather that they just washed their hands.

These examples demonstrate that the flow of microspecies through one's home from different products is guided by a confluence of interests and the tensions between them. Hence, the way practices are prioritized echoes back to transform the meanings used to justify and make sense of how they end up being performed. This effect was particularly apparent in relation to the exposure of children to "dirt" or "grime." In eight cases, after expressing concern about not having time to clean their house to a suitable standard, participants stated that some exposure to dirt was acceptable, or even beneficial. For

example, Participant 9 indicated she felt less guilty about her existing practices when she learned that some exposure to germs was valuable:

I think—actually two things. Maybe just time-wise, I just didn't have time to get on top of him, to get him clean and hands washed. Secondly, I watched a [documentary] on—it was about allergies, but it was about kids that are exposed to different types of bacteria really early on in their life are less likely to have an allergy later on in life ... So, then I think I was more conscious of, well, maybe that—yeah, not—everything doesn't have to be so clean ... Well, it gave justification for me not being very tidy. I don't know. I was like, see, I'm doing something good for him.

Despite the persistence of germ-centric narratives and practices of hygiene risk in the home, the necessity of relinquishing some control over dirt-child interactions recounted by Participant 9 did seem to facilitate a partial erosion of the belief that such interactions are necessarily harmful, even where instinctive commitment to the belief remained.

Similarly, residual discomfort with how competing practices had been prioritized was expressed in parents' attempts to limit the direct exposure of their children to chemicals. Participants expressed a desire to avoid products (such as surface sprays) containing chemicals, particularly on children's skin, despite continuing to use them on other surfaces with which children interact in other ways. For example, Participant 6 stated:

yeah, I just think ... as natural as you can get it as possible, because I think that there's a real issue with plastics and chemicals ... particularly with little boys; in boys it can influence reproductive systems. So, I've tried to reduce the amount of ingredients—chemical ingredients—that go on their skin.

The inconsistency of chemical avoidance around children can be understood as a manifestation of competing practice demands. Antibacterial chemical sprays and wipes generally offer the most convenient options for dealing with the perpetual mess generated by young children, particularly if one is already busy. These products are also imbued with

sensory attributes designed to reassure users they are effectively cleaning, such as scent (e.g., lemon and pine), and lather and shine, all of which are achieved through the addition of chemicals (Wakefield-Rann, 2017).

A number of social theorists have noted the different ways that changing relations between practices have been recognized as influencing the temporal rhythms of daily life (see Blue, 2017; Hui et al., 2016; Schor, 1998; Southerton, 2006). As they argue, the perceived decrease in available time does not result from any single factor, but instead from the “squeeze of practice-related injunctions of sequencing, coordination and personalized scheduling” (Shove et al., 2012, p. 95). As Southerton (2006) noted, each practice is accompanied by a set of requirements that enables competent and meaningful engagement to be achieved. These requirements must be balanced with those of other practices, so that the sets of practices carried, and their respective demands in terms of duration and timing, determine the overall sense of time pressure (Southerton, 2006, p. 440).

Overall, this section has argued the manner in which hygiene is performed in participants’ homes emerges from a negotiation between competing practices and priorities experienced by each individual, and between those who share such responsibility. Participants demonstrated the need to accommodate and synchronize numerous practices that require significant time commitments, such as work, food preparation, taking care of children, shopping, and cleaning. The need to negotiate the requirements of each practice resulted in a mediation of the materials, meanings, and bodily competencies that often give priority to faster, labor-saving methods, such as the use of surface sprays and wipes to conduct reactive cleaning when needed, rather than time-consuming, routinized, and systematic cleaning of whole areas or rooms. As such, this paper next presents findings relating to the crucial elements and perceived practice requirements that influence the ordering of practices, which affect how hygiene is defined and maintained in the home.

Sensory Proxies Biased Toward Microbes

The elements forming a practice determine the amount of time, energy, thought, and skill required for its performance. These relative demands influence how practices subsequently interact with other practices, including how they are prioritized. The preceding section detailed how parents often feel they do not have time to clean their homes to a standard they deem acceptable, resulting in the delegation of particular tasks to others and the use of products perceived to be more effective and efficient at eliminating microbes. However, this section presents findings that suggest the way hygiene and “cleaning well” have been defined in practice instead necessitate a degree of engagement and rigor not achievable without significant time and labor commitments. Participant 9 captured this notion:

I just found that ... even with one kid, never mind two ... everything was always filthy. I think it's the adjustment to having a child in the house and being tired. So I got a cleaner once a fortnight, and we've kept it since.

This section draws on the data to examine the standards and sensory proxies that have come to represent hygiene and “cleaning well,” and the implications these have for how and when cleaning is performed. In particular, it highlights a significant oversensitivity embedded within cleaning practices to the potential risks posed by microbes.

The sensory qualities of microspecies play a significant role in how their capacity to cause harm is assessed. A unique characteristic of microspecies (compared to macro-species, such as humans and pets) is their lack of detectability, which sees individuals instead rely on sensory proxies, such as scents or visual clues, to determine their presence. However, these are not always reliable indicators of microspecies' presence, or of the type of threat they may pose. If a house constantly presents signals of germs—such as discolored white tiles, dirty marks on flooring, or lingering bathroom odor—the time and energy that

parents perceive they must dedicate to cleaning becomes considerable, influencing how tasks are performed and prioritized in dynamic daily negotiations between practices.

In all cases, the study research indicated that participants were more sensitive to sensory proxies for microbes than chemicals. This finding supports existing research that suggests the minds and senses, particularly of people in Western industrialized cultures, have been trained to perceive microbes through multiple sensory inputs, including foul odor, sticky surfaces, or visible dirt or discoloration (Smith, 2007), while other microspecies lack the proxies that enable their detection. This exemplifies what Murphy (2006) termed a “regime of perceptibility,” in which the skills required to perceive harmful chemicals have not been as culturally or physically entrained as those required to perceive “germs.” This “regime” was expressed not only through narratives, but also in product designs that make certain forms of dirt more detectable, and in the ways bodies are trained to recognize and react to the presence of particular materials and substances.

The design of one’s home, interior furnishings, and building materials all influence how participants determined how and when certain areas required cleaning. All participants were particularly sensitized to the presence of visible dirt on flooring, and its implications for their children’s health. The non-porous, light-reflecting qualities of floorboards reassured participants that dirt would not be “hidden” as it would in carpet. The following quote from Participant 8 illustrates how floorboards reveal dirt in particular ways that other surfaces, such as carpet, may obscure:

Because it’s all floorboards in this house ... I get up in the morning and the sun comes beaming through this window here and it will show every single cat hair ... I always think, I thought that floor was clean. It’s actually just covered in cat fur [laughs]. So that’s when I think, okay, I’ve got to clean the floors today. So even though without the sun shining on, it’s actually—it looks okay, it’s really not. It really just needs cleaning.

The revelation of “dirt” on surfaces influences the flow and prioritization of practices by commanding immediate attention. The ways in which dirt and other substances materialize on surfaces also guides product choices. For example, three participants noted their aversion to soap because of the “scum” it creates on shower tiles and glass. The aesthetic qualities of surfaces were also identified as key deterrents for parents attempting to use less chemical-intensive products for cleaning, such as vinegar and bicarbonate soda. The expected “sparkle” and “shine” of surfaces, which are thought to represent cleanliness, are often not achievable without such harsh intervention. As Participant 1 noted, “I have tried some other things and I’ve tried some natural methods. I’ve tried vinegar and water and ... That didn’t quite do it. It didn’t get that sparkle.”

These examples corroborate historical accounts of domestic objects demonstrating how the design of cleaning appliances has not only been guided by the increased demand for convenience and efficiency, but also by an imperative to make pathogen- carrying dirt more visible (Smith, 2007). In their history on the aesthetics of modern homes, Lupton and Miller (1996) described the process by which hygiene became the driving aesthetic in bathroom design from 1890s England, where white porcelain fixtures made from vitreous china and enamelled iron were liberated from their moisture and germ-gathering dark wooden enclosures, and made flush with both floors and walls, thus, rendering dust and grime immediately visible. Similarly, when vacuum cleaners became standard household appliances in post- war periods within Europe, the United States, and Australia, dirt on flooring was able to be aggregated and made visible in the dust-collector of such machinery, hence, providing persuasive evidence of the necessity and virtue of the task and its performance (Lupton & Miller, 1996).

The intertwining of hygiene, design, and aesthetics throughout the twentieth century complicates the meanings, materials, and skills that constitute cleaning practices. Although microbes are made more perceptible by many modern furnishings and objects, cleaning may be further motivated by a desire to maintain surface aesthetic than by the perceived

need to remove microbes. However, due to the legacy of hygiene in twentieth- and twenty-first-century design, definitions of a presentable and attractive home are inextricably bound to a “clean” aesthetic of uninterrupted, simple surfaces, which require active and ongoing maintenance.

This section has argued that the evolution of cleaning practices, alongside definitions of hygiene that require dirt to be revealed and removed, has resulted in aesthetic norms that demand significant time and labor investments. Parents’ inability to meet these perceived norms, given that other practices demand their attention, has made faster and more efficient cleaning options more attractive. A key way that greater efficiency is achieved is through targeted applications of chemical-intensive products, such as antibacterial sprays and wipes. As such, focus now turns to the instances in which parents have become sensitized to non-microbial environmental risks in the home, and how this has influenced the performance and negotiation of domestic cleaning practices.

Health History Sensitizes Parents to New Microspecies

Despite the relative dominance of microbes over other microspecies (such as chemicals) in the perceptual landscape of one’s home, disruptive factors were identified that increased the sensitivity of parents to chemicals in particular circumstances. The reactivity of children’s skin, especially due to eczema, was the most pronounced factor that sensitized parents to new microspecies affecting children’s health. Rashes that appear as a result of eczema and other allergies are disruptive events that introduce new variables to consider within cleaning practices, often causing confusion and uncertainty. Such disruptions to normal cleaning practices made many parents begin to read the labels on cleaning and personal care products for the first time. The two most notable disruptions were reactions in children’s bodies, particularly on skin, and the health experiences of mothers. These two types of incidence enabled the perceptual dominance of microbes to partially recede,

and chemicals and other allergens to become more apparent. In relation to learning about chemicals in products, Participant 2 noted:

I'd never thought about it before ... then I think it all started because my son had eczema and I think then the first thing was to consider what washing powder you're using because it can be irritating to the skin. Then that was what started the whole journey into reading more about these types of things.

The other significant factor that sensitized parents to new microspecies was the health experiences of mothers. For example, Participant 2 had undergone a long process of diagnosing "ongoing low energy and digestive problems." A lack of solutions led her to newly examine the ingredients of products, and prompted her to start removing certain chemicals from her family's diet and home practices. Participant 2's increased awareness of chemicals in products resulted in a heightened sensitivity and an aversion to the proxies for chemicals, such as strong product scents:

With the laundry powder, I can't stand the strong commercial [products]—like, I can smell when the neighbors are doing their washing. I just can't—I hate that smell. Like, a friend just gave me some pants that didn't fit her and I just can't stand the smell of them because I've quite a strong sense of smell, I think, and I can't stand the really strong—like, I like things that have the natural, pleasant smell, not if it's really super strong.

Other participants' health experiences influenced their sensitivity to chemicals in other, more conditional ways, which resulted in a practice change for a limited period of time. For example, Participant 1 explained how she became more aware of the chemicals in products, and began to avoid them when she commenced in vitro fertilization (IVF):

I mean, the reason why I was sort of a little bit more conscious of it is because I had to do IVF with both the boys. So I guess I was trying to sort of think, okay, I'm not going to jeopardize anything ... So I think at the time I made sure that I wasn't

using any nail polishes unless they were chemical free ... I avoided any sort of hair products and even getting my hair dyed, and things like that for a while.

The participant acknowledged the potential for particular chemicals to cause harm by adjusting her practices, and had limited her use of certain personal care products by avoiding her hairdresser; however, most of these practices were abandoned after the children were born. When asked if these chemicals and products were only ceased during pregnancy, Participant 1 stated, “yeah, yeah probably ... Also, going back to work and things like that.”

Participant 1’s experience meant her practices were altered for a duration in which she believed particular products might cause her body harm. However, the demands of other practices, such as working and looking after two children, meant she reverted back to using products in practices that enabled her to achieve a state of personal and home hygiene efficiently, which satisfied her usual high standard. In contrast, the chronic nature of Participant 2’s health condition resulted in a permanent alteration to her practices to avoid harsh chemicals.

This section has highlighted that participants often dissociate “vulnerability” from mainstream practices and chemical use, except when alerted to the susceptibility of particular bodies by rashes and other symptoms. This finding suggests it is frequently assumed that mainstream practices are not harming our bodies, except when particularly reactive bodies express vulnerability. Depending on other experiences, this expression can be understood as exceptional rather than a symptom of something ongoing and ubiquitous. Moreover, Participant 1’s reversion back to her old practices once the risk posed by chemicals in products was perceived to be less acute demonstrates the persistence of a notion of cleanliness centered on the elimination of microbes.

Developing a New Research Agenda

Ordinary domestic routines, and particularly cleaning practices, are contributing to unhealthy indoor home environments. To improve the environmental health of homes, the conceptualizations of hygiene embedded in current normative procedures must become more nuanced and encompassing of a broader range of hygiene risks beyond microbes. Practices that implicitly define “good” home hygiene and “cleaning well” as the extermination of dirt and germs require a significant amount of time, vigilance, and labor. This paper has highlighted that in the context of homes characterized by significant competition between practices for time, parents often feel they do not have the capacity to meet normative expectations of cleanliness. This combination of time pressure and high-demand cleaning practices results in the delegation of cleaning tasks to professionals and products that are perceived to clean fast and effectively. Most products, such as antibacterial wipes and surface sprays, generally contain a range of chemicals that help them smell fresh, create a “sparkly” surface, and sterilize with antibacterial agents. However, scientific research suggests that none of these product attributes are more effective than soap and water in creating a home environment free of potential pathogens (Aiello et al., 2007). They are creating a *sense* of cleanliness, while contributing significantly to the amount and diversity of chemicals in a home’s microecology.

To investigate how cleaning practices could be reformed to address actual risks posed by microspecies in domestic spaces, it is proposed that the research approach presented herein is extended to develop a new transdisciplinary agenda. Based on the findings presented in this paper, a method for investigating indoor environmental health that continues to include, but does not prioritize, scientific understandings of the problem and potential solutions are evidently required. The dominant research discourses on indoor environmental health often presented in scientific journals frame such issues based on disciplinary orientation—notably particulate matter in indoor air (Meadow et al., 2014), chemicals in consumer products (Loretz et al., 2008), or the microbiology of built environments (Adams et al., 2016). A single discipline’s exclusion of all variables within

these indoor “ecosystems” and how they interact with one another leads to narrow definitions of the problem, and obfuscates solutions that do not fit disciplinary framings. Scientists examining the microbiome of built environments have begun to call for a new research program that accounts more for chemical use practices (National Academies of Sciences, Engineering, and Medicine, 2017). However, the integration of relevant scientific knowledge is only half the task. Unless social scientists, policy-makers, product manufacturers, and “users” are engaged to analyze how and why certain practices are leading to the development of particular microecologies, the designs of effective interventions will remain obscured. Finally, in addition to social and physical scientists, this paper has demonstrated the crucial role the design of both built environments and objects play in the reproduction of dominant domestic cleaning practices. Urban planners, architects, and designers will consequently contribute in any attempt to reorient material engagements to sensitize people to risk, and encourage practices that more accurately reflect the actual needs required for hygienic human habitation.

For a transdisciplinary research agenda addressing suboptimal home environments to be effective and genuinely transdisciplinary, the boundaries that separate and stratify the disciplines and interest groups detailed in this paper must be transgressed. This will involve critical reflection on the politics of knowledge, which has prioritized scientific methods of knowing over “softer,” more qualitative forms of inquiry or lay experiences in indoor environmental health research to date (Brown et al., 2010). As the body of research into social practices now attests (Blue, 2017; Hui et al., 2016; Shove et al., 2004), the outputs of this new research agenda must move beyond targeted messaging to individuals around behavior change. Rather, they must address the systemic, structural, material, bodily, and cognitive drivers of current practices at multiple scales, and across diverse populations. Such a research agenda has the potential to match knowledge about health risk with knowledge about the material culture, meanings, and habituated actions that

constitute current home hygiene practices to gain a more sophisticated understanding of how this issue can be addressed, and by whom.

References

- Adams, R. I., Bhargar, S., Dannemiller, K. C., Eisen, J. A., Fierer, N., Gilbert, J. A., ... Waring, M. S. (2016). Ten questions concerning the microbiomes of buildings. *Building and Environment*, 109, 224–234. doi.org/10.1016/j.buildenv.2016.09.001
- Aiello, A. E., Larson, E. L., & Levy, S. B. (2007). Consumer antibacterial soaps: Effective or just risky? *Clinical Infectious Diseases*, 45(Suppl 2), S137–S47. doi.org/10.1086/519255
- Bergman, A., Heindel, J. J., Jobling, S., Kidd, K. A., & Zoeller, R. T. (Eds.). (2013). *State of the science of endocrine disrupting chemicals 2012*. Geneva, Switzerland: World Health Organization/United Nations Environment Programme. Retrieved from www.who.int/ceh/publications/endocrine/en/
- Blue, S. (2017). Institutional rhythms: Combining practice theory and rhythmanalysis to conceptualise processes of institutionalisation. *Time & Society*. doi.org/10.1177/0961463X17702165
- Brown, V. A., Harris, J. A., & Russell, J. Y. (2010). *Tackling wicked problems through the transdisciplinary imagination*. London, UK, Washington, DC: Earthscan.
- Campkin, B., & Cox, R. (Eds.). (2012). *Dirt: New geographies of cleanliness and contamination*. London, UK, New York, NY: I. B. Tauris.
- Clayton, E. M. R., Todd, M., Dowd, J. B., & Aiello, A. E. (2011). The impact of bisphenol A and triclosan on immune parameters in the U.S. population, NHANES 2003–2006. *Environmental Health Perspectives*, 119(3), 390–396. doi.org/10.1289/ehp.1002883
- Creswell, J. W. (1998). *Quality inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA: Sage.
- Dunn, R. R., Fierer, N., Henley, J. B., Leff, J. W., & Menninger, H. L. (2013). Home life: Factors structuring the bacterial diversity found within and between homes. *PloS One*, 8(5), e64133. doi.org/10.1371/journal.pone.0064133
- Dyball, R., & Newell, B. (2014). *Understanding human ecology: A systems approach to sustainability*. London, UK: Routledge.

- Flores, G. E., Bates, S. T., Caporaso, J. G., Lauber, C. L., Leff, J. W., Knight, R., & Fierer, N. (2013). Diversity, distribution and sources of bacteria in residential kitchens. *Environmental Microbiology*, 15(2), 588–596. doi.org/10.1111/1462-2920.12036
- Forouzanfar, M. H., Alexander, L., Anderson, H. R., Bachman, V. F., Biryukov, S., Brauer, M., ... Murray, C. J. (2015). Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: A systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, 386(10010), 2287–2323. doi.org/10.1016/S0140-6736(15)00128-2
- Gosens, I., Delmaar, C. J. E., ter Burg, W., de Heer, C., & Schuur, A. G. (2014). Aggregate exposure approaches for parabens in personal care products: A case assessment for children between 0 and 3 years old. *Journal of Exposure Science and Environmental Epidemiology*, 24(2), 208–214. doi.org/10.1038/jes.2013.33
- Greaves, M. (2018). A causal mechanism for childhood acute lymphoblastic leukaemia. *Nature Reviews Cancer*, 18(8), 471–484. doi.org/10.1038/s41568-018-0015-6
- Halden, R. U., Lindeman, A. E., Aiello, A. E., Andrews, D., Arnold, W. A., Fair, P., Blum, A. (2017). The florence statement on triclosan and triclocarban. *Environmental Health Perspectives*, 125(6), 064501. doi.org/10.1289/EHP1788
- Hui, A., Schatzki, T., & Shove, E. (Eds.). (2016). *The nexus of practices: Connections, constellations, practitioners*. London, UK: Routledge.
- Koo, H. (2016). The global middle class: How is it made, what does it represent? *Globalizations*, 13(4), 440–453. doi.org/10.1080/14747731.2016.1143617
- Kumar, P., Skouloudis, A. N., Bell, M., Viana, M., Carotta, M. C., Biskos, G., & Morawska, L. (2016). Real-time sensors for indoor air monitoring and challenges ahead in deploying them to urban buildings. *Science of the Total Environment*, 560–561, 150–159. doi.org/10.1016/j.scitotenv.2016.04.032
- Loretz, L. J., Api, A. M., Babcock, L., Barraij, L. M., Burdick, J., Cater, K. C., Scrafford, C. G. (2008). Exposure data for cosmetic products: Facial cleanser, hair conditioner, and eye shadow. *Food and Chemical Toxicology*, 46(5), 1516–1524. doi.org/10.1016/j.fct.2007.12.011
- Lupton, E., & Miller, J. A. (1996). *Bathroom, the kitchen, and the aesthetics of waste*. Dalton: Princeton Architectural Press.

- Lyytimäki, J. (2012). Indoor ecosystem services: Bringing ecology and people together. *Human Ecology Review*, 19(1), 70–76. Retrieved from www.jstor.org/stable/24707616
- Mackendrick, N. (2014). More work for mother: Chemical body burdens as a maternal responsibility. *Gender & Society*, 28(5), 705–728. doi.org/10.1177/0891243214529842
- Maller, C. (2018). *Healthy urban environments: More-than-human theories*. Abingdon, UK: Routledge.
- Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: Guided by information power. *Qualitative Health Research*, 26(13), 1753–1760. doi.org/10.1177/1049732315617444
- Martin, L. J., Adams, R. I., Bateman, A., Bik, H. M., Hawks, J., Hird, S. M., ... Dunn, R. R. (2015). Evolution of the indoor biome. *Trends in Ecology & Evolution*, 30(4), 223–232. doi.org/10.1016/j.tree.2015.02.001
- Meadow, J. F., Altrichter, A. E., Kembel, S. W., Kline, J., Mhuireach, G., Moriyama, M., ... Bohannon, B. J. (2014). Indoor airborne bacterial communities are influenced by ventilation, occupancy, and outdoor air source. *Indoor Air*, 24(1), 41–48. doi.org/10.1111/ina.12047
- Morse, J. M. (1994). Designing funded qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 220–235). Thousand Oaks, CA: Sage.
- Murphy, M. (2006). *Sick building syndrome and the problem of uncertainty: Environmental politics, technoscience, and women workers*. Durham, NC: Duke University Press.
- National Academies of Sciences, Engineering, and Medicine. (2017). *Microbiomes of the built environment: A research agenda for indoor microbiology, human health, and buildings*. Washington, DC: National Academies Press. doi.org/10.17226/23647
- National Toxicology Program. (2018). *About NTP*. Retrieved May 31, 2018, from ntp.niehs.nih.gov/about/
- Oxford English Dictionary (2016). Hygiene. In *Oxford English Dictionary*. Retrieved from www.oxforddictionaries.com/definition/english/hygiene
- Pink, S., & Mackley, K. L. (2015). Social science, design and everyday life: Refiguring showering through anthropological ethnography. *Journal of Design Research*, 13(3), 278–292. doi.org/10.1504/JDR.2015.071454

- Reckwitz, A. (2002). Toward a theory of social practices: A development in culturalist theorizing. *European Journal of Social Theory*, 5(2), 243–263.
doi.org/10.1177/136843 1002005002005
- Rintala, H., Pitkäranta, M., Toivola, M., Paulin, L., & Nevalainen, A. (2008). Diversity and seasonal dynamics of bacterial community in indoor environment. *BMC Microbiology*, 8(1), 56. doi.org/10.1186/1471-2180-8-56
- Rook, G. A. W., Lowry, C. A., & Raison, C. L. (2013). Microbial “old friends”, immunoregulation and stress resilience. *Evolution, Medicine, and Public Health*, 2013(1), 46–64. doi.org/10.1093/emph/eot004
- Schoot Uiterkamp, A. J. M., & Vlek, C. (2007). Practice and outcomes of multidisciplinary research for environmental sustainability. *Journal of Social Issues*, 63(1), 175–197. Retrieved from
www.rug.nl/research/portal/files/10244576/2007JSocIssSchootUiterkamp.pdf
- Schor, J. (1998). Beyond work and spend: Time, leisure and consumption. In S. Scraton (Ed.), *Leisure, time and space: Meanings and values in people's lives* (LSA publication no. 57, pp. 7–12).
- Sherriff, A., Farrow, A., Golding, J., & Henderson, J. (2005). Frequent use of chemical household products is associated with persistent wheezing in pre-school age children. *Thorax*, 60(1), 45–49. doi.org/10.1136/thx.2004.021154
- Shove, E. (2003). *Comfort, cleanliness and convenience: The social organization of normality* (vol. 810). Oxford, UK: Berg.
- Shove, E. (2004). *Comfort, cleanliness and convenience: The social organization of normality* (New technologies/new cultures, 1st ed.). Oxford, UK, Berg.
- Shove, E., Pantzar, M., & Watson, M. (2012). *The dynamics of social practice: Everyday life and how it changes*. London, UK: Sage.
- Smith, V. (2007). *Clean: A history of personal hygiene and purity*. Oxford, UK: Oxford University Press.
- Sofoulis, Z. (2005). Big water, everyday water: A sociotechnical perspective. *Continuum*, 19(4), 445–463. doi.org/10.1080/10304310500322685
- Southerton, D. (2006). Analysing the temporal organization of daily life: Social constraints, practices and their allocation. *Sociology*, 40(3), 435–454. doi.org/10.1177/0038038506063668

- Wakefield-Rann, R. (2017). More than skin deep: A service design approach to making the luxury personal care industry more sustainable. In M. Gardetti (Ed.), *Sustainable management of luxury* (pp. 211–231). Singapore: Springer. doi.org/10.1007/978-981-10-2917-2_10
- Wakefield-Rann, R., Fam, D., & Stewart, S. (2018). Routine exposure: Social practices and environmental health risks in the home, *Social Theory and Health*, 1–18. doi.org/10.1057/s41285-018-00084-8
- Weschler, C. J. (2009). Changes in indoor pollutants since the 1950s. *Atmospheric Environment*, 43(1), 153–169. doi.org/10.1016/j.atmosenv.2008.09.044
- Wickson, F., Carew, A. L., & Russell, A. W. (2006). Transdisciplinary research: Characteristics, quandaries and quality. *Futures*, 38(9), 1046–1059. doi.org/10.1016/j.futures.2006.02.011
- Zoeller, R. T., Brown, T. R., Doan, L. L., Gore, A. C., Skakkebaek, N. E., Soto, A. M., ... Vom Saal, F. S. (2012). Endocrine-disrupting chemicals and public health protection: A statement of principles from The Endocrine Society. *Endocrinology*, 153(9), 4097–4110. doi.org/10.1210/en.2012-1422

PAPER 4: MORE THAN SKIN DEEP: A SERVICE DESIGN APPROACH TO CREATING MORE SUSTAINABLE PERSONAL CARE

EDITED VOLUME: SUSTAINABLE MANAGEMENT OF LUXURY

Paper 3 highlighted how cleaning tasks are performed and delegated based on time pressures and perceptions of how a sense of cleanliness can be achieved most expediently. This analysis highlighted how, in attempts to render an aesthetic sense of cleanliness, new micro-species are introduced into the home environment, such as fragrances, that are detrimental to human health. Underpinning these aesthetic requirements is a regime of cleanliness and perceptibility that is embedded in and reproduced by the designed objects and infrastructures that make up the home environment. The importance of addressing these aesthetic considerations and the interdependence of domestic material networks that support current normative practices of hygiene is explored further in Paper 4 through an illustrative case study. Unlike the other papers in this thesis, Paper 4 presents a hypothetical case study of the type of practice intervention that could be implemented in product/service industries to address potentially harmful exposures to post-industrial chemicals in the home. As this thesis is practically-oriented, this type of case study serves to ground the arguments I have made in the preceding paper in a 'messy' real-world context. In this context, the businesses supplying many of the products that participate in and enable hygiene practices have to attend to multiple competing pressures that must be accounted for if they are to participate in positive change. Moreover, this paper explicitly addresses researchers and business owners who are creating products that are entering the world and shaping practices.

This paper first characterises the multiple roles played by interdependent personal care products in personal hygiene practices in the home. In doing this I make explicit the relationship between material (and micro-material) attributes, harm and practices. I then present a case study of the service model pioneered by the international personal care retailer LUSH and its potential capacity to transform the material networks that reinforce current domestic personal care practices. I propose that by reorienting some of the elements of domestic bathing and personal care practices, substantial changes can be made to harmful exposures, without having to entirely overhaul hygiene and sanitation infrastructures. These types of practice-oriented design changes also have the capacity to redefine expectations around hygiene. By focusing on this case study, I am not suggesting that the onus for change should be on companies and individuals. As argued elsewhere, transforming sub-optimal home microecologies will require sustained transdisciplinary inquiry.

Paper 4 is a chapter in an edited volume titled *Sustainable Management of Luxury* intended for business owners and researchers interested in reforming their practices to be more environmentally sustainable. Specifically, it addresses how businesses in the luxury sector can reform their practices to be more sustainable. My contribution to this volume was motivated by a number of factors: first, the volume targets researchers and business owners with the direct capacity to make positive changes; second, research has suggested that products and services that originate in the luxury sector often ‘filter down’ to and change other market sectors; third, significant efforts are already being made to address issues related to sustainability and toxicant exposure in the luxury personal care industry, and there are proportionately more value-motivated consumers shopping in this sector. However, as I identify in this paper, they focus on replacing individual ingredients and products and thus serve to reproduce practices that rely on material networks dependent on post-industrial chemicals and other polluting components. The paper progresses the argument, that consumers are critically limited in their capacity to find hygiene and

personal care products that will not have adverse effects on the microecologies of their homes, and the paper thus redirects responsibility to other agents.

In framing the purpose of this book volume, the editors proposed that the luxury product industries often trade on qualities of purity, freshness, beauty and the 'natural', which are framed to be intrinsically complementary to values associated with environmental sustainability. Although I make statements to this effect in the paper, my reading since its publication has made me cautious of invoking concepts of purity. In particular, I have been influenced by Shotwell's (2016) thesis in her book *Against Purity*, that a quest for 'purity', or a return to a pristine natural state, disregards lasting disturbances within 'natural' systems due to process such as plastic production and disposal and other forms of chemical pollution. Rather, she proposes that if this disturbance is acknowledged, and efforts are made to delineate specific forms of disturbance – and what and who they effect – avenues that could lead to incremental, well-targeted positive changes are more likely to be found.

Wakefield-Rann, R. (2017). More Than Skin Deep: A Service Design Approach to Making the Luxury Personal Care Industry More Sustainable. In *Sustainable Management of Luxury* (pp. 211-231). Springer, Singapore.

Abstract

The core values of both luxury and sustainability are at odds with a consumer culture characterised by cheap, disposable products and undervalued natural resources. Although some product categories within the luxury goods sector have upheld the values of quality and durability, others, such as personal care, have come to rely on materials and processes that are harmful to ecosystems and human health. The luxury personal care industry trades on qualities of purity, freshness, beauty and the 'natural'. However, the industry remains unsustainable through its continued use of single-use plastic packaging and particular synthetic chemical additives. For this to change, the way in which personal care products are delivered and administered must be fundamentally redesigned. This chapter

presents a case study of luxury personal care company LUSH, and examines how its innovative approach to service design could provide a genuinely sustainable model for luxury personal care companies, and potentially the broader industry. The central elements of this model include local production, 'naked' products, short expiry dates, and innovative retail design.

[Production note: this paper is not included in this digital copy due to copyright restriction.]

Wakefield-Rann, R. (2017). More Than Skin Deep: A Service Design Approach to Making the Luxury Personal Care Industry More Sustainable. In *Sustainable Management of Luxury* (pp. 211-231). Springer, Singapore.

View/Download from: [Publisher's site](#) or [eBook platforms via UTS Library](#)

6 TOWARDS HEALTHIER HOME ECOLOGIES: CONCLUSIONS AND FUTURE DIRECTIONS

We live in an age where the search for clear-cut answers, causalities and strict boundaries is being replaced by recognition of the inevitability of uncertainty, ambiguity and interconnectedness – Val Brown et al. (2010: 288).

The indoors is the fastest growing biome on earth, and most of its occupants are microscopic. In this thesis I have explored some of the ways that micro-species are entangled within and influence everyday performances of hygiene in the home in Sydney, Australia. I proposed that this is important because everyday practices cumulatively shape the composition of indoor environments in ways that are supportive of, or harmful to, human health.

This thesis responds to a systemic and ongoing shift in home environmental health risks in wealthy industrialising nations. They include risks associated with pathogens or poisons that result in the immediate manifestation of disease, and risks associated new forms of micro-species interactions that cause harm through slow, complex pathways over extended, often generational, timescales. I have proposed that to address these risks, a more nuanced understanding of the dynamics of emergent micro-species agency in practice is required, along with a collective reimagining of currently operative definitions of hygiene and indoor environmental health.

This concluding chapter is arranged into two sections. The first details the most significant conclusions offered by this thesis in response to the research questions. The second focuses on recommendations for future research. In this second section, I include a paper which represents the first step in an attempt to bring together diverse disciplinary perspectives related to questions about how health and hygiene are defined and enacted in indoor environments. I subsequently conclude with an overview of three emerging

research approaches that could help progress research that may assist in expanding notions of hygiene and improving indoor environmental health into the future.

6.1 KEY CONCLUSIONS

6.1.1 ADDRESSING THE RESEARCH QUESTIONS

1. What are the dynamics between practices of hygiene and other domestic practices carried out by parents in homes?

In seeking to answer this question, I investigated how the requirements of normative hygiene practices were mediated and shaped by the requirements of other practices performed by individuals and others in the same home.

In Paper 3, I present an analysis of how the relative importance given to the demands of competing domestic practices influence how practices which aim to achieve hygiene goals are performed and prioritised. I found that the definitions of hygiene, and the notions of 'cleaning well' embedded within the cleaning practices studied, necessitated significant amounts of time, vigilance and labour to be fulfilled. As a result, in homes where numerous practices were competing for time and resources, parents, and particularly mothers, often did not feel they could meet the normative expectations of a clean home. This combination of time pressure and 'demanding' cleaning practices often resulted in the delegation of cleaning tasks to professional cleaners, and/or products and devices that were believed to clean quickly and effectively, or at least create a sufficient impression of efficacy. These processes of delegation and expediency are not just reactive; they play a role in ongoing reformulations of the actions, materials and meanings that make up cleaning practices. This is important, as analyses of the scientific research into the most effective methods to remove pathogens from oneself and the environment show that many of the products that

create the most immediate aesthetic 'sense' of cleanliness, are ineffective and/or contain harmful chemicals that contribute to different types of disease risk. One of the most pertinent examples of this is the use of products imbued with fragrances that have come to be culturally associated with freshness and cleanliness.

I have also discussed how the current micro-politics being played out in the home have resulted in a disproportionate burden of responsibility and vulnerability being placed on mothers. In my qualitative research, mothers reported conducting the majority practices that involved protecting their families from risks associated with micro-species in the home. They were the ones who decided how much time should be put into an activity and negotiated conflicting information around risks associated with chemicals and microbes. Although the majority of my participants were women, and this sample is not intended to be representative, other research has consistently demonstrated that mothers are more often tasked with attending to their family's 'body burdens', and the associated stress and guilt that comes with the sense that these burdens cannot be adequately managed (Altman et al., 2008, Mackendrick, 2014). It is therefore important to recognise how divisions of labour, and the designation of some issues as women's responsibilities, or unnecessary paranoia, affect the dynamics of practice which determine how hygiene is defined and performed, and who is made vulnerable as a result.

Perhaps most importantly, this situation highlights the need to remove the burden of responsibility for managing micro-species from individuals, and particularly mothers, who cannot reasonably be expected to rely on their senses or their capacity to decode chemical names on labels, to determine the presence of domestic hazards. Within my research, and the research of others into consumer responsibility, participating individuals rarely noted that it was unreasonable that they had to conduct sensory evaluations and read labels to determine whether their products contained harmful chemicals (Altman et al., 2008).

Even in cases where parents had been sensitised to the direct effects of chemicals and practised avoidance, the role of government and industry in removing these hazards was

not independently raised. This situation adds weight to Mackendrick's (2018) assertion that 'precautionary consumption' is broadly culturally accepted as the way that one should protect oneself and one's family from hazardous materials in industrially produced consumer products.

This is not to say that removing risks will simply be a matter of banning particular chemical classes from use in consumer products (although this is clearly necessary), as questions of how our hygiene needs will be defined and met once they are removed remain open. The following section emphasises the importance of recognising how 'cleaning well' requires the fulfillment of particular sensory and aesthetic requirements grounded in interdependent systems of products.

2. How do the relationships between materials within /of practices influence how hygiene is maintained in homes?

I discuss in Paper 4 how common attempts to create more environmentally sustainable and less toxic cleaning and personal care products often fail to question the needs and expectations generated by current practices. As a result, product manufacturers fall into cycles of 'regrettable substitution' of chemicals in an attempt to preserve the precise functions of existing products (Zimmerman and Anastas, 2015). The importance of addressing this issue led to the inclusion of Research Question 2: *How do the relationships between materials within practices influence how hygiene is maintained in homes?*

Several significant and related findings emerged in response to this question. Most importantly: parents, particularly mothers, are subjected to time pressure and the resource demands associated with competing domestic practices; and the sensory attributes of products play a crucial role in defining 'cleaning well' and a hygienic home environment.

The review I present in Paper 4 demonstrates how many companies are creating personal care and cleaning products that display one or more of the following issues: (1) they

attempt to reduce adverse health and environmental impacts by substituting one harmful chemical for another; (2) they address only one element of health or environmental sustainability; or (3) they do not acknowledge how significant alterations to product attributes will have an effect on the rest of the practice, thus making the product unappealing based on current expectations (such as 'bar shampoos' that do not lather). These issues are due to a failure to recognise how products and their expected functions evolve, not only in conjunction with one another, but also in conjunction with the infrastructures they are intended to be used within. For example, the emergence and current market dominance of body wash is directly associated with a decline in baths and the rise of showering.

Important insights related to material interdependence and micro-species agency were particularly gleaned through the qualitative research presented in Papers 2 and 3. For example, the affordances of floorboards, and the products that have co-defined what a clean floor is, have a significant influence on the types of microspecies that thrive in the home. Floorboards (the overwhelmingly preferred type of flooring due to their perceived cleanliness) reveal dirt easily, particularly when accompanied by large windows, thus prompting regular cleaning. Floor cleaning products are expected to have the ingredients needed to make the floor feel smooth, look shiny, smell fresh and kill bacteria. The removal of any of these attributes from a floor cleaning product may result in that product being deemed ineffective based on current definitions of what constitutes a hygienic floor. This thesis has provided a number of insights into the operative definitions of hygiene that are materialised through interdependent systems of materials. I propose that interventions into particular practices, such as floor cleaning, will require this interdependence to be made explicit.

Studying the interdependence of materials within practices is also crucial for improving knowledge of interactive and cumulative exposure to chemicals. As discussed in Papers 1 and 4 in particular, post-industrial chemicals cause harm due to the way exposures are

structured over time, in combination with other things, and depending on the body exposed. Understanding how different material arrangements consistently accompany practices will consequently be crucial for understanding the structure of exposures. These chemicals not only cause harm on their own, but also influence the conditions under which particular microbes thrive, which has implications for children's immune systems, the risk of developing leukemia, and the prevalence of antimicrobial resistance.

In bringing the responses to Questions 1 and 1.1 together, one can see how the dynamics of practice and interdependent groups of materials may influence attempts to redefine hygiene. The dynamics of practice, and the extent to which particular hygiene activities are routinised, have important implications for the home's microecology and the barriers and opportunities for changing it. It was observed that many hygiene-related practices were enacted in a routinised way (such as cleaning the bathroom) or in a consistently reactive way in response to a given stimulus (spray and wipe used to clean food off a high chair). However, the interactive, ecological modes of action that characterise most micro-species behaviours mean that each chemical application enables new microbial and chemical species to emerge, while inhibiting others, and contributing to the burden of chemicals in the environment. This situation may be contributing to the findings emerging in scientific literature that microbial species diversity is declining, the amount of antimicrobial resistant genes in household dust is increasing, and the number of post-industrial chemicals, including many EDCs, is increasing in many indoor environments. The assumption that certain micro-species act in consistent ways, and consistently accompany particular material arrangements in the home, is understandable given the absence of any reliable mechanism for detecting their presence.

One of the key findings with relevance to how practices currently effect, and will likely continue to effect, the constitution of home microecologies, is that sensory evaluations and associated affective judgements of what is clean or dirty often override narratives about new health risks. As a number of scholars have reported, more ecological and probiotic

approaches are entering into thinking in Western health traditions (Paxson, 2008, Lorimer, 2017). However, I found that although the logic of probiotic and low chemical practices resonated with many participants, many of the embodied skills and material arrangements that constitute current cleaning practices remain oriented towards the extermination of ‘germs’ with chemicals. As reported in Papers 2 and 3, this contradiction often results in individuals expressing contrary narratives and practices. For example, some participants espoused the benefits of some exposure to germs, while insisting that their floor cleaning products had to smell sufficiently ‘antibacterial’.

Drawing on William James, Latour (2004: 205) proposes that:

To have a body is to learn to be affected, meaning ‘effectuated’, moved, put into motion by other entities, humans and non-humans ... [it is] what leaves a dynamic trajectory by which we learn to register and become sensitive to what the world is made of.

The germ-oriented conceptualisation of disease that is embedded in the narratives of public health institutions and sanitary infrastructures, and materialised in everyday domestic products, has trained our senses to be affected by micro-species in particular ways. This manifestation of hygiene in Western material culture has taught people’s senses that lemon, pine and fresh fruity smells are associated with cleanliness, and that soap does not clean without lather, while soft furnishings such as carpets in bathrooms and visible dirt indoors are unhygienic. Changing the composition of home microecologies will therefore be, not only a matter of changing hygiene narratives and meanings, but also a sensorial reorientation to new forms of risk. A precondition of this, I propose, is an understanding of the way micro-species agency currently emerges in practice, both physically and symbolically. This is discussed in the following point.

3. How does micro-species agency emerge within practices enacted to create a hygienic home?

This question was included based on an initial review of research that suggested our decisions about the types of micro-species we are responding to in common hygiene practices, and the assumptions we are making about these micro-species, are at least partially misguided.

One of the key findings of this thesis, examined in Paper 3, is that potential 'germs' seem to be made more perceptible via proxies than other invisible hazards in the home. As noted above, this finding aligns with research examining how making 'dirt' and 'germs' visible through everyday objects in the home has played a significant part in material culture since the early twentieth century. As a result, 'dirt' and 'germs' are often sensed through proxy materials such as hard wooden floors, white porcelain bathroom surfaces, and cleaning products. However, as discussed in Paper 2, the sensory proxies commonly relied upon to determine the harmfulness or desirability of micro-species are often untrustworthy. This discontinuity between the sensory apparatus that guides practice and the behavioural drivers of particular micro-species relates back to Pickering's notion of the continual movement of things between being 'socially constructed' and 'real' within practice. The role of practice in determining emergent agency is a particularly crucial point: when one is wiping a sink with disinfectant sometimes we will be killing potential pathogens, sometimes we will just be adding unnecessary chemicals to the surface, and sometimes we will be killing all but the most resistant bacteria, which then recolonise, or some combination of these effects. The agency and outcomes in this situation change based on the concomitant or prior practices that have occurred in that space which determined its micro-ecological structure at that time.

I propose that assumptions about the consistency of the behaviour of particular micro-species, their boundaries and the autonomy with which they act, are at the core of this issue. The assumption that one can predict how a single chemical or microbe will act in all circumstances has been shown to be misguided, yet it is still the central ontological position that informs current normative hygiene practices. I have argued that the agency

of micro-species is contingent on the ecological conditions in which they are acting. Through their investigations and articulation of matter in relation to a number of different contexts, multispecies ethnographers have shown how assumptions about categories, such as species, are not necessarily natural and essential. In this thesis I have proposed that by combining multispecies approaches with social practice theories, one is able to get closer to disentangling the types of unique micro-species agency that emerge in practice and come to cumulatively shape our indoor environments.

6.1.2 THEORETICAL AND METHODOLOGICAL CONTRIBUTIONS

In this thesis I have presented a novel theoretical framework that combines elements of social practice theories and multispecies ethnographies to investigate engagements with micro-species agency in parental home hygiene practices. This combine focus on the role of repetition and routine in structuring material flows in the home, and how micro-species act and are perceived, has enabled a new analytical focus to emerge that attends to the convergence of historical material-cultural interactions, and new political, cultural and material developments in shaping the practices and ecologies of homes. The application of this framework to other situations involving complex more-than-human entanglements may help to characterise, not only emerging forms of *biosociality* and *chemosociality* (Kirksey and Helmreich, 2010, Shapiro and Kirksey, 2017) that result from newly normal microbiological and chemical interactions, but also the role of repetition and routine in constructing these realities and in enabling their persistence.

The combination of methods utilised enabled an investigation of human-ecological relationships that emerge within practice that none of these methods could have elucidated alone. The integration of activity diaries, semi-structured interviews, practice re-enactments and photography enabled the dynamics of practice to be investigated from multiple standpoints, reducing the risk of focusing on one element, as meaning conveyed

through cognitive thought and conversation, and neglecting others. Utilising this suite of methods for similar research into practices in investigations of environmental health could help to situate the participant and researcher in not only the socio-material dynamics of their everyday lives, but also the emergent conditions of the researcher-participant encounter. The cautious addition of sensing tools and devices, as well as more phenomenological approaches, to this suite methods could enable additional emergent entities and dynamics operating within practices to be noticed. I discuss the potential for the cautious introduction of some techno-scientific practices in the final section of this chapter.

In the following section I discuss the potential to reconfigure existing elements of hygiene practices to produce outcomes that may promote home microecologies that are more conducive to human health.

6.2 RECOMMENDATIONS: PROGRESSING A TRANSDISCIPLINARY RESEARCH AGENDA FOR HEALTHIER INDOOR ECOLOGIES

In light of the conclusions presented above, this final section presents suggestions for future research and action to address sub-optimal home environments, and indoor environments more broadly. It first proposes that a crucial task of a new transdisciplinary research agenda will be to redefine hygiene, not only in narrative, but in practice to encompass broader aspects of environmental health. It emphasises that the agents of harm considered to be of concern will need to be collaboratively and iteratively debated to ensure that dominant epistemological traditions do not continue to obscure important forms of agency and risk. It also explains why this 'definition work' should not only be the first task, but an ongoing process, of a new research program. It highlights the limitations of the research presented in this thesis, and discusses what other research areas could usefully be pursued. This is followed by a final section detailing three emerging areas of research that may usefully progress a transdisciplinary research agenda looking at

healthier indoor ecologies: digital citizen sensing, microbial mapping and practice-oriented design.

6.2.1 REDEFINING HYGIENE IN PRACTICE

This thesis has argued that conflicting techniques of definition within divergent epistemological traditions can result in important risks being ignored or exacerbated. To define something, particularly a social or environmental problem, involves an act of setting boundaries and categories, and of making certain attributes explicit and essential in relation to others. The work of definition is not just rhetorical; it involves making certain things clear through the use of scientific tools for measurement, and the setting of rules and parameters by institutions (Liboiron, 2012). I have also proposed that definitions are created and maintained through practice: practices continue to set the standards and expectations with regard to how things should be. Practices determine what is considered the ‘right’ way to conduct certain activities, and practices determine the parameters against which ‘right’ is measured.

This thesis has gone some way to making apparent these crucial definitional and epistemological disparities in relation to healthy indoor environments. However, if actions and interventions that break with existing categories are to be possible, ‘definition work’ must form part of an ongoing, collective, transdisciplinary effort to disentangle the complex, interactive, non-linear multitude of micro-interactions that influence health and disease in indoor environments. Crucially, this process requires close engagement with those who have experienced and been impacted by the problem. I do not propose a deconstruction of the multiple definitions of hygienic indoor environments on offer in an attempt to arrive at a more essential, factual notion. Rather, I argue that it is important to understand the multiple ways in which indoor environments are bounded and defined, and the various objects that are included and excluded, and that ultimately determine

what research questions are asked and through what instrumentation the world will be measured. Following Latour (2004: 232), I am proposing that this transdisciplinary process could assist the transition from believing that hygienic indoor environments are *matters of fact* to perceiving them as *matters of concern*. He states:

Reality is not defined by matters of fact. Matters of fact are not all that is given in experience. Matters of fact are only very partial and, I would argue, very polemical, very political renderings of matters of concern and only a subset of what could also be called *states of affairs*.

In attempting to redraw and expand the boundaries of the problem of unhygienic home environments in wealthy industrialised societies, I have implicated and invited researchers and other actors from diverse fields into an emerging agenda which addresses the question of how to define and develop a more inclusive approach to hygienic indoor ecologies. However, there are many actors and forces beyond the scope of this thesis that must also contribute to the definitions that will inform future research and intervention to create healthier indoor ecologies. The following section examines the limitations of this thesis. This is followed by an introduction to the final paper, which reports on an attempt to initiate a transdisciplinary dialogue to address some of these concerns.

6.2.2 RESEARCH LIMITATIONS AND FUTURE DIRECTIONS

The primary focus of this thesis has been the relationship between hygiene practices enacted by parents and the microecologies of homes in Australia. Although this investigation has provided useful insights into the composition and dynamics of practices that are contributing to sub-optimal indoor environments, a more comprehensive investigation of the interactive ‘nexus’ of practices that animate micro-species in the home will be required to develop effective interventions where they are needed. This investigation would include an analysis of other practices that take place in the home, such

as eating, leisure, entertaining and gardening, and an analysis of the ways in which these practices intersect with broader urban or rural settings, wider geopolitical landscapes, infrastructures, 'dynamic non-humans' and socio-political worlds. To do this would require the development of spaces, forums and modes of integrating knowledge, experience and expertise across fields.

The research presented in this thesis is bound, by the conventions of doctoral research as an independent endeavour, and by my own attempts to define and make sense of the problem that informed the inclusions and exclusions outlined in my 'boundary critique' in Chapter 1. It was also bound by my objective to present my findings to particular, but diverse, disciplinary audiences via my publications. However, there are other ways in which this work could be framed and translated for the benefit of other audiences, for example natural scientists, builders and lay citizens. To begin to expand these boundaries and make sense of how my research sits within and complements other research on indoor environments, I initiated a transdisciplinary special issue of the international peer-reviewed journal *Human Ecology Review* on indoor ecologies. In the following paper, which was the editorial for this special issue, I examine some of the key themes emerging within indoor environmental health research across disciplines, and how they relate to my own findings about hygiene practices. I also discuss the challenges and opportunities associated with gathering divergent methodologies, the conventions of writing and reviewing, values, and epistemologies into dialogue with one another.

PAPER 5: INITIATING A TRANSDISCIPLINARY CONVERSATION TO IMPROVE INDOOR ECOLOGIES (EDITORIAL)

JOURNAL: HUMAN ECOLOGY REVIEW

Wakefield-Rann, R., Fam, D., & Stewart, S. (2018). "Initiating a Transdisciplinary Conversation to Improve Indoor Ecologies. *Human Ecology Review*, 24(2), 61.

Abstract

Indoor spaces have not traditionally been considered the domain of human ecology. They have been the subject of cultural, architectural, and sociological inquiry, and more recently the site at which various pathogenic or toxic encounters may be studied; yet, these concerns have rarely been investigated as part of one unified and codependent ecology. This special issue aims to remedy this dislocation by beginning a conversation between a range of disciplinary perspectives concerned with the indoors. This ambition is not only linked to a desire to articulate and connect multiple interacting variables operative in indoor spaces, but also to address both a number of factors that are increasingly creating indoor environmental conditions that are suboptimal for human habitation, and the broader more-than-human ecosystems in which they are situated. Although certainly not exhaustive in scope, the research presented in this special issue provides an exemplary profile of situated knowledge that must form the basis of future, integrative, transdisciplinary research into indoor ecologies. Spanning design, architecture, social and human ecology, environmental psychology, sociology, mycology, biotechnology, spatial sciences, statistics, engineering, philosophy, and "lay" and experiential knowledge perspectives, this special issue uncovers a number of the challenges and fertile points of overlap across epistemological approaches and areas of concern within the indoors. The goal of this issue is to highlight the points of divergence, and, more crucially, the points of convergence from which a new transdisciplinary approach to indoor research can emerge.

Keywords: great indoors, human ecology, indoor ecology, knowledge integration, transdisciplinary research

Introduction: The Indoor Biome

The earth is comprised of multiple biomes, habitats that support different forms of life and ecosystems. Today, the most rapidly expanding biome on Earth is the indoor environment. As cities and buildings have expanded to cover the globe in both horizontal and vertical space, they have created new habitats for different species and ecosystems to thrive.

It has been estimated that people in many industrialized regions of the world now spend up to 90% of their lives indoors (Luongo, 2016). As a consequence, it is imperative that an integrated understanding of the composition of indoor environments, what affects them, and how they affect human and ecological health is sought. Yet, very little is known about the indoor ecosystems we inhabit. What is known tends to be confined within disciplinary silos, obfuscating the ways that objects, bodies, structures, and meanings interact and react to create indoor ecologies.

This lack of interaction between different bodies of knowledge is concerning, as research in multiple disciplines is revealing that the confluence of multiple materials in the indoors is central to the creation of suboptimal ecologies. For example, a particular combination of volatile organic compounds emitted from wall paint, antimicrobial chemicals in cleaning products, a dog, and minimal ventilation to ensure temperature control would together produce a very particular indoor biochemical environment that might affect occupants differently if any one of these elements was removed from the system. Consequently, the ways in which indoor environments can cause harm are complex, nonlinear, and relational. As a starting point, one must then recognize that the composition of the indoors depends not only on the entities that reside there, but how they interact and transform over time.

The traditional focus of human ecology has been to tackle complex, “wicked” problems that emerge out of socioecological entanglements (Brown et al., 2010). As Dyball and Newall (2014) proposed, human ecology “has a practical interest in how systems of production, distribution, and consumption might be redesigned, so that the reasonable

daily needs of people ... might be met without causing harmful impacts” (p. 7). This interest in moving away from the individualization of responsibility for systemic health and environmental sustainability issues to instead focus on how human needs can be met in less harmful ways will be crucial for improving indoor environments. Despite indoor health being central to the inception of human ecology, a focus on the constitution of indoor ecologies has largely been superseded by a focus on the consequences of everyday actions on more macro socioecological issues and planetary health. When Ellen Richards first proposed the concept of human ecology over 100 years ago as a “knowledge of right living,” she explicitly addressed the significance of how we live in our indoor environments, and went on to found Home Economics in the United States (US) (Dyball & Carlsson, 2017). In this special issue we propose a return to the micro and mesoscales of the indoors to ask how we might live well in this expanding biome.

Answering this question in a holistic way requires consideration of a range of perspectives on indoor ecologies, and a transdisciplinary approach to research that seeks to overcome the inherent divide between academic disciplinary knowledge and societal knowledge. While such integrative approaches to research are not mainstream in the academic system and remain an “intellectual, cognitive, communicative, and institutional challenge” (Vilsmaier et al., 2018, p. 170), the call for research that crosses disciplines and links knowledge production to the transformation of complex problems is not new. Influential scholars have addressed the challenge of integrative research over decades (e.g., Freire, 1996; Nicolescu, 2002; Piaget & Wells, 1972) and have provided the grounding for exploring relational thinking on indoor ecologies in this special issue. In particular, the central concern here regards the importance of presenting in-depth case studies and critical reflection on collaboration and collective learning, which often lack in transdisciplinary research (Fam et al., 2018).

Facilitating Transdisciplinary Interaction in this Special Issue

In the interest of initiating a much-needed exchange of knowledge to address suboptimal indoor biomes, this special issue sought to bring together scholars across the natural and social sciences to critically assess and learn from one another's work. Knowledge exchange between disciplines can be critically inhibited not only by exclusive information-sharing platforms, such as journals and conferences, but also by disciplinary conventions for presenting research and measuring the validity of data. Critical reflection on what constitutes "valid data" and whose perspective should be valued is a necessary process in transdisciplinary approaches to inquiry. The very term "data" suggests a positivist epistemology and a politics of evidence associated with "reliability and validity" (Denzin, 2013). A solely positivist perspective rejects intuitive and introspective forms of knowledge, such as interpretations of a comment in an interview, a fragment of a field note, or an anecdote (MacLure, 2013). In relation to transdisciplinary approaches to research into complex problems, Palmer et al. (2018) noted that data have also been attributed with an agency outside of a single methodological approach, standard, or method. This is especially evident in data obtained through interviews, in which the voice of an informant can sometimes speak across and beyond disciplinary theories to which it is assigned. In attempting to draw together a range of perspectives on indoor ecologies, this special issue includes reference to both qualitative and quantitative data to support the case for transdisciplinarity as a means of improving some of the complex problems emerging in indoor environments.

Transdisciplinary research requires a type of critical reflection in relation to one's own and others' perspectives, values, data, and methodological approaches that inevitably creates challenges. In cases when individuals working within different knowledge systems meet to collectively address an issue, uneven power relations have the potential to emerge. Often, power dynamics come to reflect the dominant modes of knowledge production and marginalization in broader culture; for example, voices of scientists may

be elevated above traditional knowledge holders or perspectives based on phenomenological accounts of a situation.

To explicate the transdisciplinary orientation of this special issue, the editors provided authors with detailed guidance for structuring their own contributions and for reviewing alternative disciplinary perspectives. From the outset, the call for papers requested contributions that recognize healthy and sustainable indoor ecosystems as a complex issue. To highlight and begin to transgress disciplinary distinctions, the editors also requested that authors make explicit several elements in their research based on principles of transdisciplinarity. Each author was requested to address the following questions:

- How does your paper offer a contribution to resolving a larger societal problem?
- How is your research participatory or collaborative?
- How does your research transgress disciplinary boundaries?
- How have multiple sources of knowledge from stakeholders and/or disciplinary perspectives sought to be included in your paper?

This protocol was intended to help each author reflect on how their own research might be positioned within knowledge communities beyond their own disciplinary field. In the process, it also provided an opportunity for mutual learning between contributors as well as collaborative research into suboptimal indoor environments. In an attempt to encourage knowledge sharing between contributors, the editors requested lead authors review another manuscript in the special issue from an unfamiliar disciplinary field. This process provided authors with an opportunity to gain insight into alternative perspectives on the problem of indoor ecosystems across fields of inquiry, and ensured that contributions were communicated in language accessible across fields of inquiry.

Moreover, this process was instructive in highlighting some of the disciplinary disparities in the framing of indoor environmental health issues, the normative intent of research, the

range of methodological approaches adopted, and what constitutes data across fields of inquiry.

To assist authors in reviewing manuscripts beyond their own disciplinary field and convention, they were provided 12 questions to guide their review. In addition to standard questions around the appropriateness of content and length, questions specific to the overarching goal of the special issue were included:

- Has the author included a description of what interdisciplinarity or transdisciplinarity means in the context of their contribution and how it contributes to theory in practice?
- Have authors sought broad societal outcomes in their contribution to new knowledge?
- Is the language used accessible and engaging to multiple audiences across disciplinary fields?

In reviewing the manuscripts, the editors were also aware of the need to respect disciplinary conventions and avoid elevating any method or format for presenting research above others, provided clarity and accessibility were achieved. As a result, papers appear in the conventional scientific format, with an Introduction, Methods, Results, Discussion, and Conclusion, as well as full provision of data from some contributors, where needed. Additionally, a range of social scientific and design- based conventions were included.

This approach to framing the special issue and guiding authors to contribute reflexive and accessible papers resulted in a rich and diverse array of scholarship. Despite the range of disciplinary foci and epistemological approaches presented, a number of salient shared themes emerged across the papers. An exploration of these themes provides an apt starting point to develop a more integrated and systemic understanding of indoor ecologies and indoor environmental health.

Emerging Themes in Indoor Ecology Research

The breadth of papers in this special issue reveal four distinct but intimately entangled themes: (1) the psychological, social, and biophysical health effects of living in polluted indoor spaces; (2) the adaptation of living practices and environments in response to urban planning; (3) the significance of both affective and molecular qualities of indoor air; and (4) climate change and emerging forms of vulnerability associated with decreasing indoor environmental quality. Although these themes certainly do not account for the complete array of current indoor environmental health issues, they cover a significant breadth and depth of some of the most pressing contemporary indoor environmental challenges.

The diversity of perspectives represented across the themes elevate a range of human and nonhuman actors not encapsulated by any single viewpoint—that is, creating a more complex and nuanced picture of the more-than-human ecology of indoor spaces (Whatmore, 2006). Through these themes, the articles also highlight the interplay between forces acting at micro, meso and macroscales, and the dynamic and potentially reinforcing linkages between them that are determining the composition of indoor environments.

Living in Polluted Indoor Ecosystems

Indoor environments become polluted through numerous sources both internal and external to the indoor space itself. The types of pollutants that amass indoors vary based on geographical factors; for example, urban indoor spaces generally accumulate more emissions from traffic than rural ones, and the types of fuel used in the home, such as smoke fires, produce high indoor emissions (Luongo, 2016). However, there are a number of concerning trends emerging across industrialized nations associated with the proliferation of certain types of consumer products. Notably, research from North American cities is showing that emission rates of certain air pollutants in personal care

products are comparable to that of benzene from motor vehicles throughout the day (Coggon et al., 2018), with similar patterns observed in China (Yang et al., 2018).

Often, sources of indoor pollution are invisible or obscured, and individuals must rely on external authorities and their prescribed forms of measurement and instrumentation to provide knowledge about their living spaces. This dependence on the methods currently employed by authorities to produce and certify the evidence of harm is often problematic, as many emerging indoor air pollutants are either not deemed harmful or not measured until well after they have taken effect, despite affected individuals often noticing their presence (Murphy, 2006; Shapiro, 2015). As a result, scientists and citizens are increasingly calling for greater community involvement in the measurement of pollutants to protect themselves and keep the industries behind the emissions accountable (Pritchard & Gabrys, 2016; Regalado, 2017). Accordingly, a number of papers in this special issue explore some of the physical and psychological effects of the uncertainty and lack of control associated with indoor pollution.

Pollution of indoor environments not only affects people through molecular interactions between bodies and toxicants, but also profoundly affects one's sense of existential security and mode of being in the world. Through their qualitative research with residents living in contaminated urban sites across Australia, Cannon et al.'s (this issue) paper provides compelling evidence of the extent to which a contaminated home can affect not only the bodies of individuals, but perceptions of security normally associated with home environments. In these cases, a sense of control over one's future is often replaced with "feelings of isolation, threat, insecurity and a sense of powerlessness." Through their attentiveness to the spatial dynamics of experiences of contamination, the paper reveals that participants altered their practices in numerous subtle yet significant ways to avoid the risk of contamination, some of which included stopping growing vegetables in their gardens, keeping their windows closed, and either stopping using tap water or boiling it for washing dishes, food preparation, and personal care.

Aligned to Connon et al., Wakefield-Rann et al.'s (this issue) paper also demonstrates how individuals change their practices in response to perceived indoor environmental health hazards to protect themselves and their families. Drawing on theories of social practice, this paper presents findings from a qualitative investigation of parents' attempts to create a safe and hygienic home environment for their children. The practices carried out by Sydney parents with children under the age of five reflects a deep sense of uncertainty about what types of household chemicals and "germs" represent the greatest risk to their families. The burden of responsibility for managing families' chemical "body burdens" (Mackendrick, 2014) and pathogenic exposures is compounded by the demands of other household practices that compete for time and, in most cases, fall to mothers to negotiate expediently.

Both Connon et al.'s and Wakefield-Rann et al.'s papers highlight the uncertainty that permeates the landscape of risk within home environments causes significant anxiety, and adds additional cognitive and psychological burdens to everyday life. Also central to both papers is the erosion of agency and control of those dwelling in particular indoor environments. In the case of Connon et al.'s paper, the indoor environments of residents' homes are subject to a history of land-use practices with toxic legacies, as well as the political and corporate will to remediate land. Similarly, the participants in Wakefield-Rann et al.'s paper are limited to acts of "precautionary consumption" (Mackendrick, 2015) to remove toxicants from their homes in the absence of sufficient precautionary regulation against harmful classes of chemicals.

Although the primary attention in these papers is to issues of disempowerment and the inability to control the environment in which one lives, this is not to say the research participants do not exercise agency and strategically adapt their lifestyle practices around the issues they confront. The ways in which individuals and groups make micro-adaptations in the face of systemic forces over which they have limited control is also central to the following theme of urban planning and adaptation.

Urban Planning and Adaptive Indoor Lifestyle Practices

The influence of broad urban landscape transformations on changes in indoor practices and environmental exposures is central to a number of articles in this special issue. As the global population increases and the middle classes grow, urban areas around the world are rapidly expanding and densifying (Desai & Kharas, 2017). The types of agents, priorities, values, and power dynamics that are guiding urban planning are determining, in large part, the form and constitution of indoor environments. For example, governments and planners influence indoor environments through decisions about vegetation cover, which consequently influences urban biodiversity, temperatures, perceived requirements for air-conditioning, and the types of allergens in the air (Douglas et al., this issue; Mellick Lopes et al., this issue; Stokols, this issue). They also guide decisions about where certain polluting industries can be situated, and subsequent decisions over whether to build residential dwellings on that land (Connon et al., this issue).

Central to questions of urban planning are considerations of who cities and regions are designed for. The way that different types of knowledge, experience, and data are captured and deemed valid plays a key role in shaping landscapes. Communities whose needs have not been considered in such designs must consequently adapt their lifestyle practices onto the structures they have been provided, often resulting in further marginalization (Dooling & Simon, 2012). Scholars such as Whatmore (2006), Franklin (2017), and Maller (2018) have argued that the framing of healthy urban areas in human-centric terms has had detrimental effects not only on the other organisms that occupy cities, but also the humans that rely on their “ecosystem services,” such as cooling and clean water from increased vegetation cover. In turn, they advocate for a conceptualization of healthy urban environments as more-than-human in research and policy, and for the importance of transcending disciplinary boundaries to achieve this. Similarly, the articles in this special issue highlight the often subtle transformations that are occurring to dominant styles of

dwelling in the modern world that may have been overlooked, but have a profound effect on everyday lives.

In his paper, Stokols presents a broad macropolitical and cultural context currently shaping indoor life in industrialized societies. In doing this, he prompts us to recognize the profound influence of the proliferation of cyber technologies, particularly since the 1980s, on the form and functioning of indoor ecosystems, as well as the urban environments that shape them. He notes that the spatial, temporal, and organizational boundaries associated with residential, educational, occupational, recreational, and commercial settings have become increasingly blurred. In this way, digital communications and virtual communities have since interwoven and coevolved with individuals' place-based environments. With reference to concepts from environmental psychology, Stokols explores how this shift has meant homes are no longer just a refuge from work and a space for family life. Rather, they function as electronic hubs and places where work and a multitude of entertainment options have intruded, or, as Stokols put it, "indoor environments have become increasingly polyfunctional, as their boundaries have been rendered more permeable and fluid by cyber technologies." The changing purposes of indoor environments are exerting pressure on the shape of cities, as cafes and homes become multifunctional offices, and the needs for convenient access to bank branches decreases as more transactions become digital. Similarly, changing use requirements for the indoors alter our expectations about the level of comfort and other amenities that are provided to enable us to reside inside for prolonged periods of time. Importantly, these additional amenities also often come at a significant cost in terms of the material and energy required to manufacture and run them. The role of city planning in the ways individuals attempt to create comfortable, protective, and livable home environments is also at the center of Mellick Lopes et al.'s (this issue) paper. The authors note that "[a]s the climate warms, indoor environments facilitated by technical infrastructures of cooling are fast becoming the condition around which urban life is shaped." These factors are compounded by rapidly densifying suburbs, based

around a model of urban living that promotes lifestyles carried out in discreet, climate-controlled atmospheres. The promise of air-conditioned indoor spaces has guided city planning and enabled other means of cooling the urban environment, such as increased vegetation cover and free water, to be deprioritized. The negative effects of these decisions are disproportionately experienced by those already economically marginalized, who cannot afford air-conditioning, and do not have the capacity to modify their home environments for cooling due either to poor design or because they do not own their property. These residents adopt practices of “thermal rationing” to balance the competing pressures of comfort and financial sustainability.

A similar set of pressures was felt in the community of the New Ngelepen dome settlement discussed by Yuliar et al. (this issue). Here, people were forcibly displaced by an earthquake near Yogyakarta, Indonesia, and relocated to a purpose-built community of “dome” houses in a style pioneered by the international Domes for the World group. Through their analysis of the settlement grounded in actor–network theory, the authors detail a significant clash between assumptions about interior and exterior lifestyle practices embedded in the building designs and traditional lifestyles, forcing residents to retrofit their domes and adapt their practices.

The analysis presented traces the implications of developing structures that do not respect traditional ways of living and interacting between the indoors and outdoors. The omission of a *tritisan*, an outdoor shelter from sun and rain, and a back doorway from the dome designs meant that important outdoor activities, such as plant cultivation and sheep breeding, which are demarcated and isolated from indoor activities, could not be maintained in a culturally appropriate way. The authors’ analysis also reveals that by valuing some actors and uses of space over others in the planning process, many residents’ experiences of being in the broader community were diminished. For example, decisions to paint the domes white to reflect sun and keep the indoors cool meant that a large

amount of glare was generated, as the close proximity of the buildings and lack of other colors or ornamentations on their white surfaces were not taken into account.

The implications of the values that are embedded in the form of buildings and indoor environments are further borne out in Lee and Wakefield-Rann's (this issue) paper, which examines subtle shifts in how people engage with risk according to archetypal modern apartment lifestyles. With reference to the philosopher Peter Sloterdijk (2016), they examine how from the comfort of an apartment one can achieve daily "resocialization and attainment of worldliness" through a choice of media, and control over the content and dosage of "reality influx" one wishes to absorb. An indoor apartment space allows for content from around the world to enter the apartment cell through various media, while still insulating and providing "immunity," comfort, and distance. As Sloterdijk (2016) argued, this mode of engaging with the world can create a state in which vast quantities of information about potential risks are communicated, which can elicit a type of psychocultural "autoimmune" response. This response may include mental stress that, if not adequately managed, has the potential for adverse effects on individual mental health and the politic as a whole.

In addition to their affective consequences, urban planning decisions also play an important role in the types of pollutants or other health-affecting particulates to which people are exposed indoors. The participants in Connon et al.'s (this issue) study of residents' responses to remediation of the contaminated land on which their homes sit links directly to the ways in which governments and planning authorities have historically restricted or allowed the use and disposal of certain contaminants on land and in water, the way the remediation technologies are selected and residents are engaged in the process (or not), and increasing demand for housing in rapidly densifying urban areas. These combined factors have led to a situation in which residents do not feel safe in their own homes.

Similarly, Wakefield-Rann et al. (this issue) discuss how decisions made by regulators and product manufacturers about the amount and types of chemicals that are allowed in consumer products contribute to both the levels of anxiety that parents feel in relation to their homes, and the actual degree of hazardous material to which they are exposed. Exposure to pollutants in the home is exacerbated by numerous factors that are encouraging people to spend more time indoors. As Stokols suggested, increased digital connectivity and the blurring of work and home spaces are encouraging people in many places to spend more time at home than ever before. Mellick Lopes et al. (this issue) also alerted us to the effects of cities that are designed around infrastructures of cooling that encourage people to spend time in climate-controlled indoor environments, rather than attempting to improve the outdoor thermal amenity.

The geography and design of cities is central to Douglas et al.'s (this issue) paper, which reports on the most comprehensive mapping of the spatial and temporal patterns of aeromycota (airborne fungi) across urban Sydney to date. Their approach of using geographic information system mapping techniques to predict the concentration and diversity of airborne fungi enables the relationships between building design, urban design, changing climate variables, and fungi exposure levels to be observed. The health effects of inhaled fungal particles can include exacerbation of asthma, allergic rhinitis or sinusitis, hypersensitivity pneumonitis, allergic respiratory ailments, and atopic dermatitis, depending on individual sensitivities and the differing pathogenic properties of the fungi. In drawing out both spatial and other variables that affect the distribution of aeromycota, Douglas et al. demonstrate how the exclusion of certain parameters in city planning can result in certain indoor (and other) health issues being exacerbated. How, and to what extent, indoor air is deemed unhealthy relates to the next theme, which examines more closely how properties of indoor air are defined, understood, and measured.

The Physical and Affective Properties of Indoor Air

Murphy (2006) in her text *Sick Building Syndrome* discussed how the design of office spaces and heating, ventilation, and air-conditioning (HVAC) systems have been informed by definitions of health and harm determined in relation to a narrow set of comfort indicators, such as temperature and humidity, for adult, white, male bodies. These indications and their materialization in office building design have established what she has termed a “regime of perceptibility,” which has disabled our capacity to see and measure how different bodies are affected by different elements of the indoor environment, such as chemicals off-gassing from paints and carpets. Murphy and other researchers such as Hoffman (2017) and Wylie et al. (2017) contended that the way we define and measure the properties of air need to be challenged to account for that all potential hazards to all potential bodies.

Mellick Lopes et al. (this issue) remind us that what we now understand as “air-conditioning” refers only to one way of “conditioning” the air based on a particular set of values. They highlight the public health debates in the early twentieth century in which approaches advocating for the circulation of “fresh air” in buildings were pitted against those arguing for the value of climate-control technologies that heated or cooled recirculated air. Like many aspects of home design, the features that are considered essential for human health at particular times directly reflect the way society understands the body, disease and its transmission, and living well, more broadly. For example, as “germ theory” gained cultural traction in Europe, bathrooms and kitchens transformed from being heavily ornamented, multicolored, fabric-adorned spaces, to white, hard, enameled surfaces that could reveal any germ-carrying dirt that may be present (Lupton & Miller, 1996).

Central to twentieth- and twenty-first-century air-conditioning, and design for the indoors more generally, is the emergence of comfort as an important guiding criterion. Shove (2003) argued in her seminal text *Comfort, Cleanliness and Convenience* that like cleanliness, standards of comfort have escalated and become standardized across much of

the industrialized world. Mellick Lopes et al. alert us to the consequences of creating cities in which the indoors is characterized by air-conditioning by emphasizing the implications for energy consumption and on bodies. They contend that air-conditioning is not only further contributing to the warming of the climate, but also creating bodies that are more “sedentary and passive,” as they no longer have to work to adjust and acclimatize in a state of air conditioned “thermal monotony” (Mellick Lopes et al., this issue).

Aside from its direct effects on the thermal comfort of occupants, the way indoor air is conditioned also determines what organisms it carries. Douglas et al. (this issue) sensitize us to the crucial relationship between the concentration and composition of indoor bioaerosols (microscopic organisms in the air), and building ventilation types (natural, mechanical, or mixed). The authors note that the interaction between these variables is largely influenced by temporal changes in the inflow of outdoor air, and ventilation requirements associated with thermal conditioning or other indoor environmental quality requirements.

Douglas et al. also highlight that only some aspects of air, such as certain chemical air pollutants and pollens, have been mapped for distribution and diversity in urban settings. Their research into aeromycota mapping adds another layer of insight to our understanding of urban air, which has been largely obscured. By articulating this additional dimension of air through the use of mapping techniques that encapsulate spatial and temporal variables, buildings and their ventilation systems can begin to be designed more appropriately for the requirements of the urban landscape in which they are situated. This addition of aeromycota to air mapping also has potentially significant implications for assisting individuals with self-management of allergies. If provided with readily available information (such as weather data) and an easy way to comprehend their own building ventilation systems, sensitive individuals could limit their exposure.

Aside from the intentional conditioning of indoor air for desirable qualities, such as temperature and freshness, the role of air as a vector of potential hazards was a prominent theme throughout the articles in this issue. Wakefield-Rann et al. (this issue) highlight how the way we are trained to see hazard, or the “regime of perceptibility” we inhabit, determines how we clean our home environments. Normative cleaning regimes were revealed in this paper to be guided by a set of sensory cues and culturally entrained habitual practices that disproportionately sensitize participants to the presence of “germs” over other hazards, such as aerosolized chemicals in cleaning products. The irony of this limiting conception of “clean” and “healthful” indoor atmospheres as germ free is that we add synthetic imitations of cleanliness and freshness in the form of “air fresheners,” which are known to contain some of the most hazardous chemicals used in indoor environments (Steinemann et al., 2017).

Lee and Wakefield-Rann’s paper provides an important context for the evolution of phenomenological and technoscientific understandings of what air is and how it is experienced in the broadly Western cannon of thought. With reference to Sloterdijk’s (2016) contention that air cannot be adequately understood without highlighting the technical changes inflicted on the atmosphere over the course of the last 200 years, readers are provided insight into some of the sociopolitical arrangements that have made certain properties of air culturally and scientifically explicit, and of concern. Sloterdijk (2016) traced developments in “atmospheric terrorism” from the initial uses of gas warfare in World War I, through the industrial-scale extermination camps used in World War II, to gas chambers used sporadically in the United States, and radioactive matter atmospherically experienced through nuclear power. These developments, he proposed, have resulted in a “reordering of ‘environmental’ awareness towards the invisible milieu of waves and rays” (Sloterdijk, 2016, p. 130). Similarly, Sloterdijk (2016) demonstrated how the understanding of air that underpins “atmotechnics” have provided the air-conditioning technology and associated practices that increasingly shape public and

private spaces of the twenty-first century. He suggested that various air-conditioning and climate-control technologies have both enabled and testify to the cultural preference for the indoors, in that spaces where identity is constructed and life's activities are carried out—what Sloterdijk (2016) termed “addiction to dwelling” (pp. 169–170)—subsequently extend beyond home to working, shopping, and spectating (i.e., sports and cinema), among other doings.

The negative effects of landscapes shaped according to a preference for comfortable indoor activities are most acutely felt by vulnerable populations. As discussed in the Urban Planning and Adaptive Indoor Lifestyle Practices section above, Mellick Lopes et al. (this issue) detailed how the amplification of “infrastructures of cooling,” particularly under a warming climate, have the greatest effect on communities without the means or capacity to access air-conditioning. The following section examines the relationship between climate change, indoor environments, and vulnerability in more detail.

Climate Change and Emerging Forms of Vulnerability

Many of the forms of vulnerability and harm to humans and the environment included in this special issue have been discussed in the literature under the term “slow disaster,” as they lack the spectacular, immediate, and explosive qualities that are typically associated with “typical” disasters (Joyner & Orgera, 2013; Morrison, 2017). However, Nixon (2011) and others (O’Lear, 2016) made the persuasive argument that where deliberate actions are taken that have known effects on human health or the environment, such as emitting large quantities of greenhouse gases or using chemicals that are persistent or bioaccumulative, “violence” is a more appropriate term than “disaster.” Note here, Nixon (2011) characterized slow violence as “a violence that occurs gradually and out of sight, a violence of delayed destruction that is dispersed across time and space, an attritional violence that is typically not viewed as violence at all” (p. 2). The papers under this theme in the special issue show how the slow violence of climate change is affecting the evolution

of indoor lifestyles in two key ways: first, to maintain comfort and safety in response to new thermal and climatic conditions, and, second, to reduce the effect buildings and lifestyle practices have on the environment.

Douglas et al. (this issue) reported that high average temperatures and high relative humidity favor microbiological growth, therefore, exacerbating urban bioaerosol proliferation, and, consequently, the vulnerability of those who experience allergies. At a far greater scale, Stokols reminds us that nearly half the world's population lives within 150 km (93 mi) of a coast and upwards of 200 million people reside near shorelines, the majority of which will be forced to endure involuntary migration caused by extreme weather events, depriving them of the physical and existential security offered by the indoors. Increased forced migration also raises questions about how people will be resettled and new indoor environments created, according to the physical, cultural, and economic needs of displaced populations.

Although not a climatic event, Yuliar et al.'s (this issue) study of post-earthquake community resettlement in Yogyakarta, Indonesia, provided an instructive example and cautionary tale of the implications of how indoor lifestyle needs and practices are considered in post-disaster resettlement. The particular agents that were engaged to contribute to the design of the new settlement intended to house displaced communities precipitated the creation of indoor and exterior spaces that failed to meet the needs of residents. The discussions between architects, funding bodies, and local government officials highlighted competing design priorities, with the desire for buildings that not only "respond to the physical environment," but also to the cultural needs and aesthetics of the community. The structures that emerged did not meet community needs in several important ways, requiring residents to retrofit, and ultimately abandon, previous aspects of their lifestyles. The politics around how settlements for displaced populations are structured for the perceived physical, cultural, and aesthetic needs of communities has endured in urban studies and geography since at least the 1950s (see Young & Wilmott,

1957; Zukin, 2009). However, this debate will take on new and potentially more urgent dimensions, as forced migration due to extreme climatic events increases. In this context, the tensions between the ways communities value and use indoor spaces, and the preferences of international engineers and architects could become more common. This example also reemphasizes the necessity of transdisciplinary approaches to research and intervention, which does not prioritize technical and scientific ways of knowing over traditional, or place-based, knowledge.

Simultaneously, ways of living indoors are changing in an attempt to reduce the emissions they also produce. Stokols notes that built environments generate a disproportionately high percentage of carbon emissions worldwide. Indoor ecosystems will consequently be challenged to adapt to prevent the exacerbation of climate change by adopting renewable materials and energy, and reducing resource consumption. As Mellick Lopes et al. (this issue) demonstrate, some individuals and communities have more constraints imposed by urban design and economic position to improve their own levels of thermal comfort or retrofit their dwellings to reduce their contribution to greenhouse gas emissions.

In cases when individuals and communities have been empowered to adapt their dwellings to enable low carbon lifestyles, one unforeseen consequence has been the alteration of the chemical and microbial environments within buildings. The sealing of doors and windows to reduce indoor–outdoor airflow and consequent energy loss can have the effect of trapping hazardous chemicals and pollutants indoors, as well as reducing the flow of outdoor microbes indoors; both of which are linked to a range of health conditions (Hamilton et al., 2015; Wakefield-Rann et al., 2018). A narrow framing of the desirable attributes of air around carbon can, therefore, mean that other crucial factors that affect human health and the environment have not only been excluded, but also exacerbated by their omission.

Importantly, the papers in this special issue have highlighted many of the ways that people become vulnerable as a result of the composition of, and forces acting on, indoor environments: Yuliar et al. illustrate how individuals can be forced to change their indoor lifestyle practices in undesirable ways if resettlement housing does not meet their cultural and physical needs, while Connon et al. show us how disempowering the contamination of one's home with hazardous pollutants can be, and how disruptions to supposedly safe and protective home spaces affect one's sense of being and security in the world. Similarly, Wakefield-Rann et al. demonstrate how the uncertainty that surrounds pathogens and toxicants in the home environment causes anxiety in parents and leads to maladaptive practices, which often make individuals more vulnerable to harmful exposures. In all of these cases, the ways in which indoor environmental health has been framed have influenced the actions that have, or have not, been taken. The following section draws on the different ways that papers in this special issue have understood the role of spatial arrangements, and metaphors in constructing indoor environments and certain modes of being within them.

A New Spatial Philosophy for Indoor Ecological Research

One of the most potentially transformative offerings from the papers in this special issue is an indication of how the psychological, cultural, and scientific conceptualizations of the indoor spaces in which we dwell shape both culture and broader ecological systems. Both Stokols, and Lee and Wakefield-Rann offer compelling characterizations of the implications of co-isolated living in modern societies, which are simultaneously hyperconnected and insulated. The metaphorical characterization of these connected yet isolated indoor worlds has been described respectively by Stokols as "cocoons," and by Lee and Wakefield-Rann (through Sloterdijk, 2016) as "foams." The analysis offered in both papers explores how one's relationship to dwelling mediates their relationships with the rest of the world. As Stokols notes, the way that digitized homes permit individuals to conduct all manner of activities from inside—from ordering groceries, to working,

banking, studying, receiving news updates, engaging with friends, and consuming entertainment—encourages a form of residential cocooning. Stokols aptly characterizes these spaces as “real–virtual mesosystems,” in which connections between a particular physical space, and the virtual places accessed from there, meet. He argues that this restructuring of indoor settings and our increased access to, and control over, the information one receives has altered the very fabric of society and daily life.

Lee and Wakefield-Rann trace a similar set of connections, with reference to Sloterdijk’s (2016) analysis of the key advent of the telephone for indoor life, which he proposed offered a two-way channel of connecting the apartment dweller linking the domestic interior with the “real” world outside, putting each into a “state of simultaneity” (p. 555) with the other. Essentially, he argued that modern apartment lifestyles, initially supported by the telephone, represent a significant shift from how communication was conducted within the home in the premodern era, where most interactions related to the immediate locality were generally private and with family, and where the sender of all interesting messages beyond these confines was God.

These insights into the transformation of indoor living experiences through telecommunication and cyber technologies is extended by Connon et al., who demonstrate how this spatial and conceptual alteration of dwelling is also changing our relationship with risk. Connon et al. employ the notion of “lifescape” to explore this intersection between individual psychological, physical, and socioeconomic states with the specific material and social environmental contexts in which they operate. Through their findings, they emphasize how the indoor environment is associated with a sense of personal control, as it provides a secure base for identity construction and freedom from public surveillance. Additionally, they stress the cultural significance of having a home in particular societies, and the form of existential security and “grounding” this brings, particularly in places with histories of colonialism.

These conceptualizations of space and dwelling, in terms of both what is and ought to be, have implications for how transdisciplinary research is conducted into the future, as the framing of a problem informs the conceptual frameworks and methodological approaches used to understand scientific and societal problems. In this case, framing not only refers to literal descriptions of problems, but also the metaphors we invoke to understand them. For example, Lee and Wakefield-Rann draw on Sloterdijk to demonstrate the power of spatial metaphors by contrasting a conception of our society as a “network” that brings to mind linear connections between nodes in simple geometric space, or as a “foam,” which describes the architectural and social situation of simultaneous enclosure and spatial extension. The authors propose Sloterdijk’s psychologically and architecturally informed interpretation of human psychosocial space as foam may allow for an account of the complex interweaving of physical and psychic space, which other spatial metaphors may not.

Moving Forward

The rapid growth of the indoor biome is a result of unprecedented material and atmospheric habitat engineering by humans, based on our perceived needs and desires. The papers in this special issue have demonstrated that, in addition to providing shelter and comfort, indoor environments can represent atmospheres permeated by hazard and insecurity for when human needs are miscalculated or inadequately provided for.

This special issue has started a conversation about what is, and ought to be, noticed, measured, and valued in indoor environments from different perspectives, including design, architecture, social ecology, environmental psychology, sociology, mycology, biotechnology, spatial sciences, statistics, engineering, philosophy, and lay or experiential viewpoints. In highlighting these diverse perspectives, values, and ways of knowing, the cases presented in this issue demonstrate how certain forms of action are made possible, or obfuscated, depending on how a problem is defined, and where the surrounding

boundaries are drawn. By bringing these diverse perspectives into conversation with one another, such margins of mutual understanding can begin to expand and become adequately nuanced to guide action across multiple social scales.

The exchange across heterogeneous and often disparate and disconnected disciplinary fields facilitated by this special issue has also drawn attention to an array of essential nonhuman participants in the construction and experience of the indoors as more-than-human environments. Some important nonhumans that exert agency in indoor ecologies include the air (as carrier of microbes, fungus, chemical toxicants, and heat, among other qualities), chemical toxicants (in consumer products and contaminated land and air), microbial and fungal life, natural disasters (e.g., earthquakes and climatic events), buildings and urban environments (such as homes, offices, and suburbs), furniture and other indoor products, and contaminated soil and water, among many others.

In addition to articulating some of the diversity of more-than-human indoor worlds, this special issue has provided insights into the challenges and value of transdisciplinary research and collaboration. The articles included represent often profoundly divergent epistemological approaches to research, yet many points of convergence could easily be found when presented together under the overarching theme of indoor environments. In addition, the research in the special issue traverses a range of cultural and geographic contexts across scales, from micro-interactions in the home, to macroclimatic events that affect all organisms and ecosystems.

By elevating the perspectives and experiences of those affected by the decision-making that shapes indoor ecosystems, the articles in this special issue have begun to give voice to some of the humans, and nonhumans, that have previously been excluded from planning, design, and research. This special issue has established a dialogue upon which researchers across disciplines can continue to reflexively build a shared language and shared understandings of the multiple actors, interests, and livelihoods at stake in indoor

environments. More importantly, this special issue represents a necessary first step for a transdisciplinary collaboration between researchers, policy-makers, and communities to begin to transform “the great indoors” into a biome that can sustain life into the future.

References

- Brown, V. A., Harris, J. A., & Russell, J. Y. (Eds.). (2010). *Tackling wicked problems through the transdisciplinary imagination*. London, UK: Earthscan.
- Coggon, M. M., McDonald, B. C., Vlasenko, A., Veres, P. R., Bernard, F., Koss, A. R., ... de Gouw, J. A. (2018). Diurnal variability and emission pattern of decamethylcyclopentasiloxane (D5) from the application of personal care products in two North American cities. *Environmental Science & Technology*, 52(10), 5610–5618. doi.org/10.1021/acs.est.8b00506
- Denzin, N. K. (2013). The death of data? *Cultural Studies ↔ Critical Methodologies*, 13(4), 353–356. doi.org/10.1177/1532708613487882
- Desai, R. M., & Kharas, H. (2017, July 13). Is a growing middle class good for the poor? Social policy in a time of globalization. *Brookings*. Retrieved from www.brookings.edu/research/is-a-growing-middle-class-good-for-the-poor-social-policy-in-a-time-of-globalization/
- Dooling, S., & Simon, G. (Eds.). (2012). Cities, nature and development: The politics and production of urban vulnerabilities. In S. Dooling & G. Simon (Eds.), *Cities, nature and development* (pp. 3–23). Surrey, UK: Ashgate.
- Dyball, R., & Carlsson, L. (2017). Ellen swallow Richards: Mother of human ecology? *Human Ecology Review*, 23(2), 17–29. doi.org/10.22459/HER.23.02.2017.03
- Dyball, R., & Newell, B. (2014). *Understanding human ecology: A systems approach to sustainability*. London, UK: Routledge.
- Fam, D., Neuhauser, L., & Gibbs, P. (Eds.). (2018). *Transdisciplinary theory, practice and education: The art of collaborative research and collective learning*. New York, NY: Springer.
- Franklin, A. (2017). The more-than-human city. *The Sociological Review*, 65(2), 202–217. doi.org/10.1111/1467-954X.12396
- Freire, P. (1996). *Pedagogy of the oppressed* (revised ed.). New York, NY: Continuum.

- Hamilton, I., Milner, J., Chalabi, Z., Das, P., Jones, B., & Shrubsole, C., ... Wilkinson, P. (2015). Health effects of home energy efficiency interventions in England: A modelling study. *BMJ Open*, 5(4), e007298. doi.org/10.1136/bmjopen-2014-007298
- Hoffman, K., Butt, C. M., Webster, T. F., Preston, E. V., Hammel, S. C., Makey, C., ... Meeker, J. D. (2017). Temporal trends in exposure to organophosphate flame retardants in the United States. *Environmental Science & Technology Letters*, 4(3), 112–118. doi.org/ 10.1021/acs.estlett.6b00475
- Joyner, T. A., & Orgera, R. (2013). Climate change hazard mitigation and disaster policy in south Louisiana: Planning and preparing for a “slow disaster”. *Risk, Hazards & Crisis in Public Policy*, 4(3), 198–214. doi.org/10.1002/rhc3.12034
- Luongo, J. C. (2016). *Towards defining healthy buildings: Investigating the effect of building characteristics and interventions on indoor air microbial exposures and energy efficiency* (PhD thesis). University of Colorado at Boulder, CO. Retrieved from scholar.colorado. edu/mcen_gradetds/120
- Lupton, E., & Miller, J. A. (1996). *Bathroom, the kitchen, and the aesthetics of waste: A process of elimination*. New York, NY: Princeton Architectural Press.
- Mackendrick, N. (2014). More work for mother: Chemical body burdens as a maternal responsibility. *Gender & Society*, 28(5), 705–728. doi.org/10.1177/0891243214529842
- Mackendrick, N. (2015). Protecting ourselves from chemicals: a study of gender and precautionary consumption. In D. N. Scott (Ed.), *Our chemical selves: Gender, toxics, and environmental health* (pp. 58–77). Vancouver, Canada: UBC Press.
- MacLure, M. (2013). The wonder of data. *Cultural Studies ↔ Critical Methodologies*, 13(4), 228–232. doi.org/10.1177/1532708613487863
- Maller, C. (2018). *Healthy urban environments: More-than-human theories*. Abingdon, UK: Routledge.
- Morrison, K. (2017). The role of traditional knowledge to frame understanding of migration as adaptation to the “slow disaster” of sea level rise in the South Pacific. In K. Sudmeier- Rieux, M. Fernández, I. Penna, M. Jaboyedoff, & J. Gaillard (Eds.), *Identifying emerging issues in disaster risk reduction, migration, climate change and sustainable development* (pp. 249–266). Cham, Switzerland: Springer.
- Murphy, M. (2006). *Sick building syndrome and the problem of uncertainty: Environmental politics, technoscience, and women workers*. Durham, NC: Duke University Press.

- Nicolescu, B. (2002). *Manifesto of transdisciplinarity* (K. C. Voss, Trans.). New York, NY: Suny Press.
- Nixon, R. (2011). *Slow violence and the environmentalism of the poor*. Cambridge, MA: Harvard University Press.
- O'Lear, S. (2016). Climate science and slow violence: A view from political geography and STS on mobilizing technoscientific ontologies of climate change. *Political Geography*, 52, 4–13. doi.org/10.1016/j.polgeo.2015.01.004
- Palmer, J., Fam, D., Smith, T. E., & Kent, J. (2018). Where's the data? Using data convincingly in transdisciplinary doctoral research. *International Journal of Doctoral Studies*, 13, 9–29. doi.org/10.28945/3941
- Piaget, J., & Wells, P. A. (1972). *Psychology and epistemology: Towards a theory of knowledge*. London, UK: Allen Lane.
- Pritchard, H., & Gabrys, J. (2016). From citizen sensing to collective monitoring: Working through the perceptive and affective problematics of environmental pollution. *GeoHumanities*, 2(2), 354–371. doi.org/10.1080/2373566X.2016.1234355
- Regalado, C. (2017). Getting out of their way: Do-it-yourselfers, sensing, and self-reliance. In V. Loreto (Ed.), *Participatory sensing, opinions and collective awareness* (pp. 273–298). Cham, Switzerland: Springer.
- Shapiro, N. (2015). Attuning to the chemosphere: Domestic formaldehyde, bodily reasoning, and the chemical sublime. *Cultural Anthropology*, 30(3), 368–393. doi.org/10.14506/ca30.3.02
- Shove, E. (2003). *Comfort, cleanliness and convenience: The social organization of normality*. Oxford, UK & New York, NY: Berg.
- Sloterdijk, P. (2016). *Foams, spheres volume III: Plural spherology* (W. Ho-ban, Trans.). Los Angeles, CA: Semiotext(e).
- Steinemann, A., Wargocki, P., & Rismanchi, B. (2017). Ten questions concerning green buildings and indoor air quality. *Building and Environment*, 112, 351–358. doi.org/10.1016/j.buildenv.2016.11.010
- Vilsmaier, U., Brandner, V., & Engbers, M. (2018). Research in-between: The constitutive role of cultural differences in transdisciplinarity. *Journal of Engineering & Science*, 8, 169–179. doi.org/10.22545/2017/00093

- Wakefield-Rann, R., Fam, D., & Stewart, S. (2018). Routine exposure: Social practices and environmental health risks in the home, *Social Theory and Health*, 1–18. doi.org/10.1057/s41285-018-00084-8
- Whatmore, S. (2006). Materialist returns: Practising cultural geography in and for a more-than-human world. *Cultural Geographies*, 13(4), 600–609. doi.org/10.1191/1474474006cgj377oa
- Wylie, S., Wilder, E., Vera, L., Thomas, D., & McLaughlin, M. (2017). Materializing exposure: Developing an indexical method to visualize health hazards related to fossil fuel extraction. *Engaging Science, Technology, and Society*, 3, 426–463. doi.org/10.17351/ests2017.123
- Yang, T., Xiong, J., Tang, X., & Misztal, P. K. (2018). Predicting indoor emissions of cyclic volatile methylsiloxanes (cVMS) from the use of personal care products by university students. *Environmental Science & Technology*. doi.org/10.1021/acs.est.8b00443
- Young, M. D., & Wilmott, P. (1957). *Family and kinship in East London*. London, UK: Routledge and Kegan Paul.
- Zukin, S. (2009). Changing landscapes of power: Opulence and the urge for authenticity. *International Journal of Urban and Regional Research*, 33(2), 543–553. doi.org/10.1111/j.1468-2427.2009.00867.x

6.3 BROADENING THE TRANSDISCIPLINARY DIALOGUE

Paper 5 provides an example of one type of forum and practice through which a transdisciplinary approach to addressing indoor environmental health can begin to be formulated. In addition to drawing out shared salient themes across indoor ecological research, the strengths of this particular process include: its capacity to highlight the tensions between different epistemological traditions, the collective recognition of certain issues that need to be addressed, and the sharing of tools that may be used to further knowledge.

Having espoused the value of this process, it is important to acknowledge that a transdisciplinary research agenda must also do much more to include experiential, 'lay', forms of knowledge that are often marginalised in academic research practices, and non-humans which may not have been given a voice, but must be protected and cared for. Underpinning my propositions about the requirements and possibilities of future research is a rejection of human exceptionalism, not only in terms of the research subjects interrogated, but also in terms of whose needs and responsibilities are considered. Most of this thesis has focused on the impacts of practices on human health. However, domestic practices, and the micro-species they mobilise, also have significant impacts on various non-human organisms, and broader ecosystems. For example, EDCs commonly used in the home have been found to have detrimental effects of the reproductive capacities and sex balance of wild populations of numerous marine species around the world (Vos et al., 2000). Even if one's primary concern was for human health, it cannot be denied that we live in a more-than-human world, and that our health is predicated on the health of other organisms and ecosystems. An investigation of these systems is beyond the scope of this thesis. However, I propose the further development of spaces in which a transdisciplinary dialogue can be progressed. This would enable us to re-evaluate the ways in which existing approaches to indoor environmental health exclude some subjects and entities.

Closely related to, and arguably a precondition for, redefining hygiene will be the development of a politics of evidence that makes currently obscured or misunderstood

micro-species more perceptible. The development of a new politics of evidence will depend on the acknowledgement that the current political economy enables and promotes the large-scale production of untested post-industrial chemicals, and their inclusion and dissemination in consumer products. It will need to address the unwillingness of governments around the world to create policy based upon the 'precautionary principle'. If this principle was adhered to, citizens would be protected from probable agents of harm, even when definitive proof of harm is not possible or practical. Although some national governments are making efforts to legislate some degree of precaution (see California, Europe), these protections have not been realised anywhere in practice. I contend that the questions and conclusions presented in this thesis would remain crucial even if government and industry supported the use of the precautionary principle. In other words, even if the precautionary principle were embedded in legislative and industrial practices around the world, the way that hygiene is defined and practised, and the micro-entities we populate our most intimate environments with, would still need to be better understood.

A key contention of this thesis has been that the material agency of important actors within everyday hygiene practices, particularly at the micro-scale, have been obfuscated or mischaracterised. I propose that a key task for future transdisciplinary research with the objective of defining and enabling healthy (hygienic) indoor environments, is to find new ways of making explicit the emergent agency of these actors in a way that enables the complexity of their everyday roles in the constitution of environments and bodies to be perceived. I contend that this is a precondition for success in the larger task at hand of determining how the molecular relations embedded in existing regimes of hygiene and chemical living, in Australia and other late industrial societies, can be disrupted to enable new practices to emerge. As discussed in the literature review chapter, this central objective is shared with advocates of a socio-exposome approach to researching human exposures more broadly. I detail below three modes of research that are giving voice to

micro-entities and acknowledging the constitutive role of social practices in indoor ecological composition, in ways that could be instructive for future research.

6.4 NEXT STEPS: RE-ORIENTING THE POLITICS OF EVIDENCE AND REGIMES OF PERCEPTIBILITY

This final section provides examples of three investigative approaches that I propose could be utilised to 1) make more explicit emergent forms of micro-species agency and disrupt current regimes of perceptibility, and 2) enable the creators of new products and infrastructures to account for the dynamics of practice in their designs.

The hybrid social practice/multispecies theoretical framework developed and utilised in this research has been instructive in highlighting the dynamism of micro-species in domestic hygiene practices, and some of the specific ways they manifest in both symbolic and physical registers that are contributing to sub-optimal indoor environments. In addition to creating transdisciplinary spaces and further dialogue to apprehend home environments more comprehensively, I propose that this research could be progressed through the cautious integration of technologies and design practices that are able to 1) provide additional ways for micro-species to be recognised, followed and understood that go beyond the sensory capacity of humans, and 2), to provide avenues for micro-species agency in everyday practices to be accounted for in design practices for healthy and sustainable domestic products and spaces. By turning new objects and processes into matters of concern, the integration of these approaches could elevate the status of previously ignored actors in the politics of evidence that currently determines what are considered safe or harmful conditions for human dwelling.

The first two approaches discussed below involve forms of sensing that incorporate techno-scientific methods: digital pollutant sensors and microbial swabbing and sequencing. The third pertains to the creation of new objects and services that are

sensitive to the dynamics of everyday practices and the forms of emergent agency that comprise and guide them. It is proposed that these approaches could be useful, if integrated into research that begins with the iterative and non-conclusive definition work in transdisciplinary congregations that I have referred to above.

6.4.1 APPREHENDING MICRO-SPECIES THROUGH CITIZEN SENSING

Citizen-sensing practices are related to citizen science but diverge in the ways in which they seek to engage the public through environmental practice and monitoring. The majority of citizen science can be classified as ‘downstream’ research, an approach that aims to collect large amounts of data while informing the public about science (Lorimer and Hodgetts, 2017). In downstream models, such as wildlife monitoring and much of the personal monitoring described in the section on exposure science in the Literature Review chapter, citizens are engaged to collect data with prescribed instruments and protocols, and do not generally have a say in the research design. In contrast, upstream approaches aim to actively involve the public in shaping the goals, design and practice of research from an early stage in the process. The two examples below represent upstream models of citizen sensing that could make a valuable contribution to a transdisciplinary research agenda with the aim of making micro-species perceptible in ways that direct interventions to create healthier indoor ecologies.

Even where citizens and broader communities work with scientists to frame the questions that guide research, sensor-based research must be approached cautiously. A number of scholars working with sensing devices to help communities have raised concerns, which do not disqualify their value, but point to essential considerations that should prefigure what they are considered to do for communities and how they are used. Shapiro et al. (2017: 575) usefully identify four reasons for caution in deploying enumerative practices for health and environmental justice:

1) projects engaged in the use of science for justice claims cannot fully escape reproducing hierarchies of knowledge-power, type, and knower; 2) the pursuit of science in these instances has the potential to foreclose imaginative horizons of ‘how’ and ‘why’ in favor of ‘how much’; 3) the pursuit of more data sets the stage for adversarial epistemological encounters that can lead to entrenchment rather than resolution; and 4) these practices have the resultant effect of defining and confining (democratic) participation to one in which data become an essential gateway to having a voice. Following from this, we ask: what are the approaches to apprehending the environment that might not so easily boil down to binaries of benevolence or harm...?

In the case of this research, a particular concern is that in attempting to enumerate the potential for harm, one risks reproducing the quest for thresholds for acceptable levels of exposure, and distilling risk based on calculations that will inevitably fall short of taking full account of the complexity of the situation.

The processes of questioning that lead to ways of apprehending the environment prior to the use of sensing devices are therefore essential in determining what is perceived and validated, and what remains obscured. The transdisciplinary definition work, and the creation of spaces in which it can occur, that I have referred to above, must therefore take place prior to and during any sensing practices. This definition work is similar to what Shapiro et al. (2017: 575) term the process of ‘inviting apprehension’, which they propose may ‘beckon further thought, illuminate radical alterities, or articulate the histories (supply chains, infrastructures, consumer demands, etc.) that lead to concerns of toxicity, while still leaving multiple meanings to exist simultaneously.’ Once these considerations are taken into account, the ways in which the practices that are detailed below can positively contribute may begin to be considered.

6.4.2 DIGITAL CITIZEN SENSING FOR INDOOR POLLUTANTS

One of the issues identified in this thesis is that at present, dominant hygiene regimes often enable potential germs to be perceived more effectively, and often inaccurately, relative to chemical toxicants. The use of digital sensors by those affected by pollutants which are not currently measured or deemed relevant by authorities is helping to reorient regimes of perceptibility in a number of contexts by creating new types of evidence. Compelling examples of this include: Citizen Sense (Citizen Sense, 2019) a project which employs digital sensing devices, primarily for air pollutants, to investigate how new modes of generating data can give rise to new forms of environmental awareness, politics and participation; and Public Lab, an open network of community organisers, educators and researchers who create low-cost technologies for monitoring air, water and land. Public Lab (Public Lab, 2019) formed in response to lack of community access to the tools and techniques required to participate in decisions being made about them, especially in relation to environmental hazards.

Jennifer Gabrys, the lead researcher in the Citizen Sense project, analyses the transformative potential of digital sensing devices, not just for their capacity to make particular non-humans explicit, but also for their capacity to engender new forms of relationality in the process (Gabrys et al., 2016). Writing with regard to sensing activities that use computational technologies such as smartphones and other mobile and low-cost electronic devices, she proposes that:

environmental sensors are not simply providing access to new registers of information for established subjects but are changing the *subjects of experience* as well as the sensing relationships in which subjects are entangled and through which they act (Gabrys, 2016: 22)

In this conception, sensing is not only about human sensing, but also distributed experiences across human and non-human (more-than-human) sensing subjects. This approach to sensing may enable an approach to investigating micro-species as they act

and transform within practices, and cumulatively and interactively effect indoor environments and their occupants. A crucial premise of this approach is that sensing is not just a process of generating information; it is also a way of informing experience and actively programming the environment. Sensors create new conditions that operationalise particular relationships within environments.

When these technologies are utilised non-reflexively, or considered to be ‘vessels’ through which what ‘is’ can be communicated, there is a risk that new regimes of perceptibility may become entrenched. However, they can also make possible powerful modes of inquiry that can enable ‘slow violence’ and other forms of currently invisible agency to become visible, and they can open up avenues for speculative engagements and careful interactions in which non-humans can be sensed and can express agency in new ways (Nixon, 2011).

If citizen sensing were used in conjunction with the combined methodology utilised in my research, a number of new research avenues may be possible. As discussed in Chapter 5, methods that focus on dialogical or text-based interactions afford limited access to embodied and material action occurring within practices. The integration of sensing methods into this type of methodological approach may serve to further decentre cognitive ways of knowing and representing practices, and further elevate material interactions. This approach involves the integration of sensing practices into a suite of methods that attend to the dynamic interactions between cultural, political, infrastructural and embodied processes that inform practices. This integration may help to direct attention away from the molecular register in these types of sensing studies by locating molecular relations within socio-material practices.

6.4.3 MAPPING MICROBIAL LANDSCAPES

In addition to sensing practices that are able to foreground material relations between bodies and chemical pollutants, projects are emerging that provide new ways of sensing microbes. The approach employed in projects such as the Oxford-based 'Good Germs Bad Germs' may assist in doing this in ways that prioritise co-design with the public, and may complement pollution-sensing practices, to give form to the most important health-related interactions occurring within indoor microecologies.

'Good Germs Bad Germs' explores the microbial ecologies of peoples' kitchens by engaging a small community of public participants. Although the project utilises recent developments in DNA sequencing, it focuses on addressing the questions and concerns people have about bacteria in their homes, and the potential value of interacting with scientists to find out more about them. The project's aim was to: (1) explore human-microbe relations in the domestic kitchen; and (2) develop scientific techniques for visualising the domestic microbiome that are accessible to non-expert publics through a form of 'participatory metagenomics'.

One of the researchers states that:

We examine how scientific knowledge and techniques are enrolled into lay practices of making microbes sensible; how these intersect with, reinforce or disrupt previous feelings for microorganisms; and how new ways of relating with microbial others emerge (Greenhough et al., 2018: 1)

Unlike other downstream citizen science projects, such as those mentioned in the Literature Review chapter, which invited people to swab various ecological niches inside their houses (shower heads, door frames, air conditioning units etc), researchers in the 'Good Germs Bad Germs' project asked participants to help design the experiments. Results of the microbial analysis were also presented and discussed at group meetings in the community centre, at which the group decided what they would like to explore in the next experiment. The researchers state that in each successive round of experiments, the

participant group took greater ownership of the experimental design, with the academic team shifting into a 'consulting role'. This type of engaged sensing practice and experimental approach has the capacity to provide important insights about: what micro-species shape hygiene practices, how they relate to actual micro-species behaviours, how that knowledge is able to transform the hygiene regimes that govern how homes are built, and how people attempt to manage micro-species in them.

Sensing micro-species through digital and genomic practices has the potential to contribute to improved understandings of the macro forces that led them to be (or not be) there. However, this will only happen if we are able to resist the temptation to render them visible as calculable data points. By resisting this trap, we can begin to see these micro-species as part of the toxic infrastructures, or impoverished microbial landscapes, that have emerged through widespread cultural, political and industry practices that produce harm across multiple registers, beyond those which are sensed at the molecular level in the home. Moreover, by focusing on individuated micro-species and their designations as harmful or benevolent, we risk perpetuating the mindset that led to regrettable substitution. According to this mindset, if we can just identify the toxic molecules and replace them, we will be fine. Rather, what is required is a deeper consideration of how our needs and desires are constituted and serviced through particular interdependent systems of materials (Roberts, 2010). As a way of beginning to grapple with the larger practices that produce the material infrastructures, products and services, I turn to practice-oriented design in the next section.

6.4.4 PRACTICE-ORIENTED DESIGN FOR HYGIENIC INDOOR ENVIRONMENTS

In moving beyond attempts to define and apprehend the forces contributing to sub-optimal home environments, effective modes of intervention must also be considered. The findings in this thesis have implications for public policy, and for architectural and

commercial agents that are perpetuating existing notions of hygienic indoor environments or contributing the pollutants that are making them harmful. As discussed in Paper 4, designers exert a considerable influence on the construction of our sensory and affective relationships with hygiene, and on what we are ultimately exposed to. Whether driven by changes in policy or corporate responsibility, designers will be responsible for developing the products and services needed to enable a required shift in hygiene practices. This section discusses an emerging approach to practice-oriented design. If it were incorporated into a transdisciplinary program of research, this approach could make a significant positive difference in the way that hygiene and hygienic indoor environments are enacted.

Shove et al. (2007) proposed the term practice-oriented design in response to what they characterise as two dominant modes of engagement currently pursued in design: product-centred design (based on the idea that designers can embed values in objects, and that these objects meet pre-existing needs) and user-centred design (which conceives of value in terms of the relations between people and things, rather than belonging to things alone). Alternatively, practice-oriented design based on the premise that, if materials help to configure what users experience, and to some extent their needs and desires, then designers who give them form play a significant role in transforming social practices (Kuijer and De Jong, 2011, Kuijer, 2014, Lackner, 2014). On this basis, practice-oriented design is reoriented away from attempts to understand and meet self-identified user needs. Instead, it aims at understanding how particular material needs evolve from practices. In this way, designers are seen to add value, not to individual products, but to the perpetuation or reorientation of practices of which objects are a part.

A practice-oriented design approach has now been adopted by a number of design researchers with a view to intervening in existing hygiene-related practices to make them less resource intensive (in terms of energy and water) (Scott et al., 2012). Examples include: examinations of bathing (Kuijer and De Jong, 2011, Kuijer, 2014, Scott et al., 2009)

hair care (Hielscher et al., 2008) and laundering (Pettersen, 2009). These studies have demonstrated the value of this approach in unpacking what individuals consider to be inevitable and essential objects or resources needed to achieve the basic requirements of everyday life. For example, it is assumed that immersion in water is essential to hygienic bathing. A significant part of this approach is figuring out the 'stickiness' of certain sensory and aesthetic requirements of existing practices, and the more flexible elements which are more readily open to adaptation.

None of the practice-oriented design research projects examined in this thesis account for the role of chemical pollutants or microorganisms in domestic hygiene practices. A practice-oriented design approach may have a great deal to offer in terms of improving the state of indoor environments, and the more-than-human environments they are situated in, if they are guided by a framework that is interested in the roles of both macro-materials, and emergent forms of micro-species agency that influence the health and ecological impacts of practices. The omission of toxicants and microbial communities from existing practice-oriented design research into hygiene highlights the importance of including designers and their skills as part of a broader transdisciplinary approach in which problem definitions can be iteratively and carefully formulated. In this context, the inclusion of practice-oriented design could potentially play a transformative role in reimagining and intervening in the material and sensory engagements that underpin how hygiene is defined in practice. By articulating how needs and expectations are materialised, and how these could be transformed, practice-oriented design could also contribute to public health, health communications and policy to create the socio-material environments required to enable people to enact healthy practices.

6.5 FINAL REFLECTIONS

I began this research journey with an interest in the ecologically transformative role of the habitual acts that make up everyday life. This developed into a deep fascination and concern with forms of micro-ecological activity that are transforming ecosystems and bodies in unprecedented ways, but have been made imperceptible via regimes of hygiene and chemical living.

The research presented in this thesis has contributed: some theoretical tools for apprehending the emergent agency of micro-species in practices; insights into the ways that hygiene and chemical regimes are enacted and reproduced in the home; and an appreciation of the value of combining social practice theories and multispecies ethnographic approaches to interrogate the specific character of ongoing more-than-human entanglements and practices involving agencies at the micro-scale.

My hope is that I have begun to transform the ‘matters of fact’ that currently ground understandings of hygiene and environmental health within disciplinary frameworks into ‘matters of concern’.

In saying this, I return to Latour’s provocation that if you designate something as ‘designed’,

you are not only authorized but forced to ask whether it has been well or badly designed. The spread of design to the inner definitions of things carries with it, not only meaning and hermeneutics, but also morality. More exactly, it is as if materiality and morality were finally coalescing (Latour, 2008: 5).

By showing some of the workings behind the meanings and materials that comprise not only hygiene practices, but also categories such as dirty and clean, toxic and non-toxic and living and non-living species, one is able to begin to unpack and comprehend how these systems have been ‘designed’ – in this expanded sense of the term – and thus how they could be cautiously and reflexively redesigned. This is important because, as Latour continues:

if you begin to redesign cities, landscapes, natural parks, societies, as well as genes, brains and chips, no designer will be allowed to hide behind the old protection of matters of fact (Latour, 2008: 5).

My wish for the future trajectory of this work is that it will provide a foundation stone and some wayfinding points to help guide the knowledge integration required to reconsider and redesign indoor ecologies in relation to emerging risks, and emerging knowledge about bodies, species, and ecosystems.

REFERENCES

- ABRAHAMSSON, S., BERTONI, F., MOL, A. & MARTÍN, R. I. 2015. Living with Omega-3: New Materialism and Enduring Concerns. *Environment and Planning D: Society and Space*, 33, 4-19.
- ADAMS, R. I., BHANGAR, S., DANNEMILLER, K. C., EISEN, J. A., FIERER, N., GILBERT, J. A., GREEN, J. L., MARR, L. C., MILLER, S. L. & SIEGEL, J. A. 2016. Ten questions concerning the microbiomes of buildings. *Building and Environment*, 109, 224-234.
- ADAMS, R. I., MILETTO, M., TAYLOR, J. W. & BRUNS, T. D. 2013. The diversity and distribution of fungi on residential surfaces. *PloS one*, 8, e78866.
- ADIBI, J. J., WHYATT, R. M., WILLIAMS, P. L., CALAFAT, A. M., CAMANN, D., HERRICK, R., NELSON, H., BHAT, H. K., PERERA, F. P. & SILVA, M. J. J. E. H. P. 2008. Characterization of phthalate exposure among pregnant women assessed by repeat air and urine samples. 116, 467.
- AIELLO, A. E. & LARSON, E. 2003. Antibacterial cleaning and hygiene products as an emerging risk factor for antibiotic resistance in the community. *The Lancet Infectious Diseases*, 3, 501-506.
- ALEXANDRE-SILVA, G. M., BRITO-SOUZA, P. A., OLIVEIRA, A. C., CERNI, F. A., ZOTTICH, U. & PUCCA, M. B. 2018. The hygiene hypothesis at a glance: early exposures, immune mechanism and novel therapies. *Acta tropica*.
- ALTMAN, R. G., MORELLO-FROSCH, R., BRODY, J. G., RUDEL, R., BROWN, P. & AVERICK, M. 2008. Pollution comes home and gets personal: women's experience of household chemical exposure. *Journal of health and social behavior*, 49, 417-435.
- AMEDEI, A. & BOEM, F. 2018. I've Gut A Feeling: Microbiota Impacting the Conceptual and Experimental Perspectives of Personalized Medicine. *International Journal of Molecular Sciences*, 19, 3756.
- ANDERSON, V. D. 2006. *Creatures of empire: How domestic animals transformed early America*, Oxford University Press, USA.
- ATIIM, G. A. & ELLIOTT, S. J. 2016. The global epidemiologic transition: Noncommunicable diseases and emerging health risk of allergic disease in sub-Saharan Africa. *Health Education Behavior*, 43, 37S-55S.
- AUSTRALIAN BUREAU OF STATISTICS 2011. Information Paper: Measures of Socioeconomic Status. Australian Federal Government
- AYLWARD, J. 2018. Defence's toxic legacy. *Precedent*, 4.
- BACHMANN, J., DAMBERG, R., CALDWELL, J., EDWARDS, C. & KOMAN, P. 1996. Review of the national ambient air quality standards for particulate matter: Policy assessment of scientific and technical information. OAQPS staff paper. Final report. Environmental Protection Agency, Research Triangle Park, NC, United States.
- BARAD, K. 2003. Posthumanist performativity: Toward an understanding of how matter comes to matter. *Signs: Journal of women in culture*, 28, 801-831.
- BARAD, K. 2007. *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*, duke university Press.

- BARNETT, C., CLOKE, P., CLARKE, N. & MALPASS, A. 2010. *Globalizing responsibility: The political rationalities of ethical consumption*, John Wiley & Sons.
- BARNETT, R. 2014. *The Sick Rose: Or; Disease and the Art of Medical Illustration*, Thames & Hudson.
- BASHFORD, A. 2003. *Imperial hygiene: a critical history of colonialism, nationalism and public health*, Springer.
- BAUMANN, S., ENGMAN, A. & JOHNSTON, J. 2015. Political consumption, conventional politics, and high cultural capital. *International Journal of Consumer Studies*, 39, 413-421.
- BENN, C. S., MELBYE, M., WOHLFAHRT, J., BJÖRKSTÉN, B. & AABY, P. J. B. 2004. Cohort study of sibling effect, infectious diseases, and risk of atopic dermatitis during first 18 months of life. *British Medical Journal*, 328, 1223.
- BENNETT, J. 2009. *Vibrant matter: A political ecology of things*, Duke University Press.
- BENSON, E. 2010. Review: Animal Encounters by Tom Tyler, Manuela Rossini *JAC*, 30, 3-4.
- BERGMAN, Å., HEINDEL, J. J., JOBLING, S., KIDD, K. & ZOELLER, T. R. 2013. State of the science of endocrine disrupting chemicals 2012: summary for decision-makers. *World Health Organization*.
- BIESTERBOS, J. W., DUDZINA, T., DELMAAR, C. J., BAKKER, M. I., RUSSEL, F. G., VON GOETZ, N., SCHEEPERS, P. T. & ROELEVELD, N. 2013. Usage patterns of personal care products: important factors for exposure assessment. *Food and Chemical Toxicology*, 55, 8-17.
- BIOLOGY AND THE BUILT ENVIRONMENT. 2019. Available: <https://biobe.uoregon.edu/> [Accessed 20 August 2018].
- BIRCH, G. F. 2011. Contaminated soil and sediments in a highly developed catchment-estuary system (Sydney estuary, Australia): an innovative stormwater remediation strategy. *Journal of Soils & Sediments*, 11, 194-208.
- BLOOMFIELD, S., STANWELL-SMITH, R., CREVEL, R. & PICKUP, J. 2006. Too clean, or not too clean: the hygiene hypothesis and home hygiene. *Clinical & Experimental Allergy*, 36, 402-425.
- BLOOMFIELD, S. F., ROOK, G. A., SCOTT, E. A., SHANAHAN, F., STANWELL-SMITH, R. & TURNER, P. 2016. Time to abandon the hygiene hypothesis: new perspectives on allergic disease, the human microbiome, infectious disease prevention and the role of targeted hygiene. *Perspectives in public health*, 136, 213-224.
- BLUE, S. 2013. *Scheduling routine: An analysis of the spatio-temporal rhythms of practice in everyday life*. PhD, University of Lancaster.
- BOHME, S. R. 2014. *Toxic injustice: a transnational history of exposure and struggle*, Univ of California Press.
- BOUDIA, S. & JAS, N. 2014. *Powerless Science? Science and Politics in a Toxic World*, Berghahn Books.
- BOUDIA, S. & JAS, N. 2016. *Powerless Science? The Making of the Toxic World in the Twentieth Century*.
- BOURDIEU, P. 1977. Towards a theory of practice. *Cambridge Univ. Press*.
- BRAUN, B. 2007. Biopolitics and the molecularization of life. *Cultural Geographies*, 14, 6-28.

- BRODY, J. G., MORELLO-FROSCH, R., ZOTA, A., BROWN, P., PÉREZ, C. & RUDEL, R. A. 2009. Linking exposure assessment science with policy objectives for environmental justice and breast cancer advocacy: the Northern California Household Exposure Study. *American Journal of Public Health*, 99, S600-S609.
- BROOKS, C., PEARCE, N. & DOUWES, J. 2013. The hygiene hypothesis in allergy and asthma: an update. *Current opinion in allergy and clinical immunology*, 13, 70-77.
- BROWN, N. & NETTLETON, S. 2017. Bugs in the blog: Immunitary moralism in antimicrobial resistance (AMR). *Social Theory & Health*, 15, 302-322.
- BROWN, P. 1997. Popular epidemiology revisited. *Current Sociology*, 45, 137-156.
- BROWN, V. A., HARRIS, J. A. & RUSSELL, J. Y. 2010. *Tackling Wicked Problems Through the Transdisciplinary Imagination*, Earthscan.
- BROWNE, A. L. 2016. Can people talk together about their practices? Focus groups, humour and the sensitive dynamics of everyday life. *Area*, 48 198-205.
- BUCHWALTER, C. 2007. Living A LUSH Life With LUSH Fresh Handmade Cosmetics http://carriebuchwalter.weebly.com/uploads/2/7/6/6/2766408/cb_lush_paper.pdf.
- BUSHNIK, T., HAINES, D., LEVALLOIS, P., LEVESQUE, J., VAN OOSTDAM, J. & VIAU, C. 2010. Lead and bisphenol A concentrations in the Canadian population. *Health Reports*, 21, 7.
- CAMPBELL, C. 2013. A critique of the consumption as communication thesis. *Buy this book: Studies in advertising and consumption*, 340.
- CAMPKIN, B. & COX, R. 2012. *Dirt: New geographies of cleanliness and contamination*, IB Tauris.
- CARBAJO, J. B., PERDIGÓN-MELÓN, J. A., PETRE, A. L., ROSAL, R., LETÓN, P. & GARCÍA-CALVO, E. 2015. Personal care product preservatives: Risk assessment and mixture toxicities with an industrial wastewater. *Water research*, 72, 174-185.
- CASELLI, E., D'ACCOLTI, M., VANDINI, A., LANZONI, L., CAMERADA, M. T., COCCAGNA, M., BRANCHINI, A., ANTONIOLI, P., BALBONI, P. G. & DI LUCA, D. 2016. Impact of a probiotic-based cleaning intervention on the microbiota ecosystem of the hospital surfaces: focus on the resistome remodulation. *PloS one*, 11, e0148857.
- CAVALEIRO RUFO, J., MADUREIRA, J., PACIÊNCIA, I., AGUIAR, L., PEREIRA, C., SILVA, D., PADRÃO, P., MOREIRA, P., DELGADO, L. & ANNESI-MAESANO, I. 2017. Indoor fungal diversity in primary schools may differently influence allergic sensitization and asthma in children. *Pediatric Allergy Immunology*, 28, 332-339.
- CHEN, M. Y. 2012. *Animacies: Biopolitics, racial mattering, and queer affect*, Duke University Press.
- CITIZEN SENSE. 2019. Available: <https://citizensense.net/> [Accessed 20 December 2018].
- CLASSEN, C., HOWES, D. & SYNNOTT, A. 1994. *Aroma: The cultural history of smell*, Taylor & Francis.
- CLAYTON, E. M. R., TODD, M., DOWD, J. B. & AIELLO, A. E. 2011. The impact of bisphenol A and triclosan on immune parameters in the US population, NHANES 2003-2006. *Environmental health perspectives*, 119, 390.
- COLLIER, J. 1995. Photography and Visual Anthropology. *Principles of Visual Anthropology*, 2, 235-254.

- COLLIER, J. & COLLIER, M. 1986. *Visual anthropology: Photography as a research method*, UNM Press.
- COMISKEY, D., API, A., BARRETT, C., ELLIS, G., MCNAMARA, C., O'MAHONY, C., ROBISON, S., ROSE, J., SAFFORD, B. & SMITH, B. 2017. Integrating habits and practices data for soaps, cosmetics and air care products into an existing aggregate exposure model. *Regulatory Toxicology Pharmacology*, 88, 144-156.
- CONNON, I., PRIOR, J. & FAM, D. 2018. Danger From the Outside in: Resident Perceptions of Environmental Contamination in Home Environments. *Human Ecology Review* 24.
- COOLE, D. & FROST, S. 2010. Introducing the new materialisms. *New Materialisms: Ontology, Agency, Politics*, 1-43.
- CORBIN, A. 1986. *The foul and the fragrant: odor and the French social imagination*, Harvard University Press.
- COWAN, R. S. 1983. *More work for mother: The ironies of household technology from the open hearth to the microwave*, London, Basic Books.
- CRESPI, B. J. 2001. Response from Crespi: The evolution of social behavior in microorganisms. *Trends in Ecology and Evolution*, 16, 607.
- CRESWELL, J. W. 1998. Quality inquiry and research design: Choosing among five traditions. *Sage Publications*
- CRIGHTON, E., BROWN, C., BAXTER, J., LEMYRE, L., MASUDA, J. & URSITTI, F. 2013. Perceptions and experiences of environmental health risks among new mothers: a qualitative study in Ontario, Canada. *Health, risk & society*, 15, 295-312.
- DANT, T. & BOWLES, D. 2003. Dealing with dirt: servicing and repairing cars. *Sociological Research Online*, 8, 1-17.
- DARLING, K. W., ACKERMAN, S. L., HIATT, R. H., LEE, S. S.-J. & SHIM, J. K. 2016. Enacting the molecular imperative: How gene-environment interaction research links bodies and environments in the post-genomic age. *J Social Science & Medicine*, 155, 51-60.
- DAVIS, F. R. 2014. *Banned: A history of pesticides and the science of toxicology*, Yale University Press.
- DAVISON, G. 2008. Down the gurgler: historical influences on Australian domestic water consumption. *Troubled waters: Confronting the water crisis in Australia's cities*. Australian National University Press: Canberra, Australia.
- DELORMIER, T., FROHLICH, K. L. & POTVIN, L. 2009. Food and eating as social practice—understanding eating patterns as social phenomena and implications for public health. *Sociology of Health and Illness*, 31, 215-228.
- DI RENZO, G. C., CONRY, J. A., BLAKE, J., DEFRANCESCO, M. S., DENICOLA, N., MARTIN, J. N., MCCUE, K. A., RICHMOND, D., SHAH, A. & SUTTON, P. 2015. International federation of gynecology and obstetrics opinion on reproductive health impacts of exposure to toxic environmental chemicals. *International Journal of Gynecology & Obstetrics*, 131, 219-225.
- DIAMANTI-KANDARAKIS, E., BOURGUIGNON, J.-P., GIUDICE, L. C., HAUSER, R., PRINS, G. S., SOTO, A. M., ZOELLER, R. T. & GORE, A. C. 2009. Endocrine-disrupting chemicals: an Endocrine Society scientific statement. *Endocrine Reviews*, 30, 293-342.
- DIBLEY, L. 2011. Analysing narrative data using McCormack's Lenses. *Nurse Researcher*, 18.

- DOLEJSOVA, M. & KERA, D. 2017. The Fermentation GutHub Project and the Internet of Microbes. *Enriching Urban Spaces with Ambient Computing, the Internet of Things, and Smart City Design*. IGI Global.
- DOUGLAS, M. 1966. *Purity and danger*, London and New York, Routledge & Keegan Paul
- DUNN, R. R., FIERER, N., HENLEY, J. B., LEFF, J. W. & MENNINGER, H. L. 2013. Home life: factors structuring the bacterial diversity found within and between homes. *PloS one*, 8, e64133.
- DYBALL, R. 2011. Human Ecology as open transdisciplinary inquiry. *Human Ecology*, 24.
- ERCOLINI, A. & MILLER, S. 2009. The role of infections in autoimmune disease. *Clinical Experimental Immunology*, 155, 1-15.
- EVANS, D. 2012. Beyond the throwaway society: ordinary domestic practice and a sociological approach to household food waste. *Sociology*, 46, 41-56.
- EVANS, D., WELCH, D. & SWAFFIELD, J. 2017. Constructing and mobilizing 'the consumer': Responsibility, consumption and the politics of sustainability. *Environment and Planning A*, 49, 1396-1412.
- EWG 2003. Body Burden: The Pollution in People. *Washington, DC: Environmental Working Group*, <http://www.ewg.org/reports/bodyburden1/dynam-contams.php>.
- FAHIMIPOUR, A. K., MAMAAR, S. B., MCFARLAND, A. G., BLAUSTEIN, R. A., CHEN, J., GLAWE, A. J., KLINE, J., GREEN, J. L., HALDEN, R. U. & VAN DEN WYMELENBERG, K. 2018. Antimicrobial Chemicals Associate with Microbial Function and Antibiotic Resistance Indoors. *mSystems*, 3, e00200-18.
- FALL, T., LUNDHOLM, C., ÖRTQVIST, A. K., FALL, K., FANG, F., HEDHAMMAR, Å., KÄMPE, O., INGELSSON, E. & ALMQVIST, C. 2015. Early exposure to dogs and farm animals and the risk of childhood asthma. *JAMA pediatrics*, 169, e153219-e153219.
- FAM, D., LOPES, A., WILLETTS, J. & MITCHELL, C. 2009. The challenge of system change: an historical analysis of Sydney's sewer systems. *Design Philosophy Papers*, 7, 195-208.
- FAM, D., PALMER, J., RIEDY, C. & MITCHELL, C. 2017. *Transdisciplinary research and practice for sustainability outcomes*, Taylor & Francis.
- FAN, X., KUBWABO, C., RASMUSSEN, P. & JONES-OTAZO, H. 2010. Simultaneous quantitation of parabens, triclosan, and methyl triclosan in indoor house dust using solid phase extraction and gas chromatography-mass spectrometry. *Journal of Environmental Monitoring*, 12, 1891-1897.
- FASULO, A., LOYD, H. & PADIGLIONE, V. 2007. Children's socialization into cleaning practices: A cross-cultural perspective. *Discourse & Society*, 18, 11-33.
- FIERER-LAB. 2019. Available: <http://fiererlab.org/> [Accessed 20 December 2018].
- FORTY, A. & CAMERON, I. 1995. *Objects of desire: design and society since 1750*, Thames and Hudson London.
- FOTOPOULOU, M., IORDANIDOU, M., VASILEIOU, E., TRYPSIANIS, G., CHATZIMICHAEL, A. & PARASKAKIS, E. 2018. A short period of breastfeeding in infancy, excessive house cleaning, absence of older sibling, and passive smoking are related to more severe atopic dermatitis in children. *European Journal of Dermatology*, 28, 56-63.
- FUJIMURA, K. E., JOHNSON, C. C., OWNBY, D. R., COX, M. J., BRODIE, E. L., HAVSTAD, S. L., ZORATTI, E. M., WOODCROFT, K. J., BOBBITT, K. R. & WEGIENKA, G. 2010. Man's best friend? The effect of pet ownership on house dust microbial communities. *The Journal of allergy and clinical immunology*, 126, 410.

- GABRYS, J. 2016. *Program earth: Environmental sensing technology and the making of a computational planet*, U of Minnesota Press.
- GABRYS, J., PRITCHARD, H. & BARRATT, B. 2016. Just good enough data: Figuring data citizenships through air pollution sensing and data stories. *Big Data & Society*, 3, 2053951716679677.
- GEBERT, M. J., DELGADO-BAQUERIZO, M., OLIVERIO, A. M., WEBSTER, T. M., NICHOLS, L. M., HONDA, J. R., CHAN, E. D., ADJEMIAN, J., DUNN, R. R. & FIERER, N. 2018. Ecological analyses of mycobacteria in showerhead biofilms and their relevance to human health. *Mbio*, 9, e01614-18.
- GEENS, T., ROOSENS, L., NEELS, H. & COVACI, A. 2009. Assessment of human exposure to Bisphenol-A, Triclosan and Tetrabromobisphenol-A through indoor dust intake in Belgium. *Chemosphere*, 76, 755-760.
- GEERTZ, C. 1973. Thick description. *The interpretation of cultures*, 3-30.
- GELL, A. 1995. The language of the forest: landscape and phonological iconism in Umeda . In: HIRSCH, E. & O'HANLON, M. (eds.) *The anthropology of landscape: Perspectives on place and space*.
- GIDDENS, A. 1984. *The Constitution of Society: Outline of the Theory of Structuration*, Cambridge, Polity Press.
- GOSENS, I., DELMAAR, C. J., TER BURG, W., DE HEER, C. & SCHUUR, A. G. 2014. Aggregate exposure approaches for parabens in personal care products: a case assessment for children between 0 and 3 years old. *Journal of Exposure Science and Environmental Epidemiology*, 24, 208-214.
- GRAM-HANSEN, K. 2007. Teenage consumption of cleanliness: how to make it sustainable? *Sustainability: Science, Practice Policy*, 3, 15-23.
- GRAM-HANSEN, K. 2014. New needs for better understanding of household's energy consumption-behaviour, lifestyle or practices? *J Architectural Engineering and Design Management*, 10, 91-107.
- GRANJOU, C. & PHILLIPS, C. 2018. Living and labouring soils: metagenomic ecology and a new agricultural revolution? *BioSocieties*, 1-23.
- GREAVES, M. 2018. A causal mechanism for childhood acute lymphoblastic leukaemia. *Nature Reviews Cancer*, 1.
- GREEN, J. L. 2014. Can bioinformed design promote healthy indoor ecosystems? *Indoor Air*, 24, 113-115.
- GREENHOUGH, B., DWYER, A., GRENYER, R., HODGETTS, T., MCLEOD, C. & LORIMER, J. 2018. Unsettling antibiotics: how might interdisciplinary researchers generate a feeling for the microbiome and to what effect? *Nature*, 4, 149.
- GRÜN, F. & BLUMBERG, B. 2009. Endocrine disruptors as obesogens. *Molecular and cellular endocrinology*, 304, 19-29.
- GSPI. 2016. *Six Classes* [Online]. Available: <http://greensciencepolicy.org/topics/six-classes/> [Accessed 20 February 2016].
- GUPTA, R. S., SINGH, A. M., WALKNER, M., CARUSO, D., BRYCE, P. J., WANG, X., PONGRACIC, J. A. & SMITH, B. M. Hygiene factors associated with childhood food allergy and asthma. Allergy and Asthma Conference proceedings, 2016. OceanSide Publications, e140.

- HA, S., SEIDLE, T. & LIM, K.-M. 2016. Act on the Registration and Evaluation of Chemicals (K-REACH) and replacement, reduction or refinement best practices. *Environmental health and toxicology*, 31.
- HAAHTELA, T., HOLGATE, S., PAWANKAR, R., AKDIS, C. A., BENJAPONPITAK, S., CARABALLO, L., DEMAINE, J., PORTNOY, J. & VON HERTZEN, L. 2013. The biodiversity hypothesis and allergic disease: world allergy organization position statement. *World Allergy Organization Journal*, 6, 1.
- HALEEM, A. M., HASSAN, D. M. A. & AL-HIYALY, S. A. 2013. Comparative Assessment of Microbial Contamination from Swabs Collected within University Facilities. *Journal of Health Science*, 3, 25-28.
- HAMILTON, L. & TAYLOR, N. 2017. *Ethnography after Humanism*. London: Palgrave Macmillan.
- HAMMERSLEY, M. & ATKINSON, P. 2007. *Ethnography: Principles in practice*, Routledge.
- HAND, M. & SHOVE, E. 2004. Orchestrating concepts: kitchen dynamics and regime change in Good Housekeeping and Ideal Home, 1922–2002. *Home Cultures*, 1, 235-256.
- HARAWAY, D. J. 2008. *When species meet*, U of Minnesota Press.
- HARPER, D. 1987. The visual ethnographic narrative. *Visual Anthropology*, 1, 1-19.
- HARTMANN, E. M., HICKEY, R., HSU, T., BETANCOURT ROMÁN, C. M., CHEN, J., SCHWAGER, R., KLINE, J., BROWN, G., HALDEN, R. U. & HUTTENHOWER, C. 2016. Antimicrobial chemicals are associated with elevated antibiotic resistance genes in the indoor dust microbiome. *Environmental science & technology*, 50, 9807-9815.
- HARVEY, M., MCMEEKIN, A., RANGLES, S., SOUTHERTON, D., TETHER, B. & WARDE, A. 2001. Between demand and consumption: A framework for research. *Centre for Research on Innovation Competition Discussion Paper*, 40.
- HAYWARD, E. 2010. Fingeryeyes: Impressions of cup corals. *Cultural Anthropology*, 25, 577-599.
- HEALS. 2019. *Health and Environment-wide Associations based on Large population Surveys* [Online]. Available: <http://www.heals-eu.eu/> [Accessed 20 December 2018].
- HEEDERIK, D. & VON MUTIUS, E. 2012. Does diversity of environmental microbial exposure matter for the occurrence of allergy and asthma? *Journal of Allergy and Clinical Immunology*, 130, 44-50.
- HELIX: BUILDING THE EARLY-LIFE EXPOSOME. 2019. Instituto de Salud Global de Barcelona (ISGlobal). Available: <http://www.projecthelix.eu/> [Accessed 20 December 2018].
- HELMREICH, S. 2009. *Alien ocean: Anthropological voyages in microbial seas*, Univ of California Press.
- HENNINK, M., HUTTER, I. & BAILEY, A. 2010. *Qualitative research methods*, Sage.
- HIELSCHER, S., FISHER, T. & COOPER, T. The return of the beehives, brylcreem and botanical! An historical review of hair care practices with a view to opportunities for sustainable design. Undisciplined! Design Research Society Conference 2008 Proceedings, 2008.
- HIRD, M. 2010. Meeting with the microcosmos. *Environment Planning D: Society Space*, 28, 36-39.
- HITCHINGS, R. 2012. People can talk about their practices. *Area*, 44, 61-67.

- HOLST, G., HØST, A., DOEKES, G., MEYER, H., MADSEN, A., PLESNER, K. & SIGSGAARD, T. 2016. Allergy and respiratory health effects of dampness and dampness-related agents in schools and homes: a cross-sectional study in Danish pupils. *Indoor Air*, 26, 880-891.
- HOOKE, R. L., MARTÍN-DUQUE, J. F. & PEDRAZA, J. 2012. Land transformation by humans: a review. *GSA Today*, 22, 4-10.
- HOOKS, K. B. & O'MALLEY, M. A. 2017. Dysbiosis and its Discontents. *MBio*, 8, e01492-17.
- HOOVER, E., RENAULD, M., EDELSTEIN, M. R. & BROWN, P. 2015. Social science collaboration with environmental health. *Environmental health perspectives*, 123, 1100.
- HOPWOOD, N. 2017. *Enhancing 1:1 research interviews: the secret power of the third thing* [Online]. Available: <https://nickhop.wordpress.com/2017/08/01/enhancing-11-research-interviews-the-secret-power-of-the-third-thing/> [Accessed 15/8/2018 2018].
- HOSPODSKY, D., QIAN, J., NAZAROFF, W. W., YAMAMOTO, N., BIBBY, K., RISMANI-YAZDI, H. & PECCIA, J. 2012. Human occupancy as a source of indoor airborne bacteria. *PloS one*, 7, e34867.
- HUI, A., SCHATZKI, T. & SHOVE, E. (eds.) 2017. *The nexus of practices: Connections, constellations, practitioners*, London: Routledge.
- INGOLD, T. 2000. *The perception of the environment: essays on livelihood, dwelling skill*, London, Routledge.
- INGOLD, T. 2007. Materials against materiality. *Archaeological dialogues*, 14, 1-16.
- INGOLD, T. 2015. *The life of lines*, London, Routledge.
- INGOLD, T. 2016. *Evolution and social life*, London, Routledge.
- INGRAM, M. 2011. Fermentation, rot, and other human-microbial performances. *Knowing nature: Conversations at the intersection of political ecology and science studies*, 99-112.
- IRWIN, A. 2014. Risk, science and public communication. *J Routledge handbook of public communication of science technology*, 160-172.
- ISGLOBAL: BARCELONA INSTITUTE FOR GLOBAL HEALTH. 2019. *EXPOsOMICS* [Online]. Available: <https://www.isglobal.org/en/-/exposomics> [Accessed].
- ISOLAURI, E., HUURRE, A., SALMINEN, S. & IMPIVAARA, O. 2004. The allergy epidemic extends beyond the past few decades. *Clinical Experimental Allergy*, 34, 1007-1010.
- JACK, T. 2013a. Laundry routine and resource consumption in Australia. *International Journal of Consumer Studies*, 37, 666-674.
- JACK, T. 2013b. Nobody was dirty: Intervening in inconspicuous consumption of laundry routines. *Journal of Consumer Culture*, 13, 406-421.
- JACK, T. 2017. Cleanliness and consumption: exploring material and social structuring of domestic cleaning practices. *International Journal of Consumer Studies*, 41, 70-78.
- JAIN, S. L. 2013. *Malignant: How cancer becomes us*, Univ of California Press.
- JAMES, A. L., KNUIMAN, M. W., DIVITINI, M. L., HUI, J., HUNTER, M., PALMER, L., MAIER, G. & MUSK, A. 2010. Changes in the prevalence of asthma in adults since 1966: the Busselton health study. *European Respiratory Journal*, 35, 273-278.

- JONES, S. E. & LEBARON, C. D. 2002. Research on the relationship between verbal and nonverbal communication: Emerging integrations. *Journal of Communication*, 52, 499-521.
- JUAREZ, P., MATTHEWS-JUAREZ, P., HOOD, D., IM, W., LEVINE, R., KILBOURNE, B., LANGSTON, M., AL-HAMDAN, M., CROSSON, W. & ESTES, M. 2014. The public health exposome: a population-based, exposure science approach to health disparities research. *International journal of environmental research public health*, 11, 12866-12895.
- JUAREZ, P. D. 2019. The Public Health Exposome. *Unraveling the Exposome*. Springer.
- KANSTRUP, A. M. 2002. Picture the Practice—Using Photography to Explore Use of Technology Within Teachers' Work Practices. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, 3.
- KAYE-SMITH, H. W. 2017. *Doing laundry more sustainably: Disrupting everyday practices through media conversations*. Western Sydney University (Australia).
- KEHILY, M. J., MARTENS, L., BURNINGHAM, K., VENN, S., CHRISTIE, I., JACKSON, T. & GATERSLEBEN, B. 2014. New motherhood: a moment of change in everyday shopping practices? *Young Consumers*, 15, 211-226.
- KELLER, M. & RUUS, R. 2014. Pre-schoolers, parents and supermarkets: co-shopping as a social practice. *International Journal of Consumer Studies*, 38, 119-126.
- KELLEY, S. T. & GILBERT, J. A. 2013. Studying the microbiology of the indoor environment. *Genome biology*, 14, 202.
- KEMBEL, S. W., JONES, E., KLINE, J., NORTHCUTT, D., STENSON, J., WOMACK, A. M., BOHANNAN, B. J., BROWN, G. & GREEN, J. L. 2012. Architectural design influences the diversity and structure of the built environment microbiome. *The ISME journal*, 6, 1469.
- KESSLER, R. 2015. More than cosmetic changes: taking stock of personal care product safety. *Environmental health perspectives*, 123, A120.
- KIRKSEY, E. 2015. Species: a praxiographic study. *Journal of the Royal Anthropological Institute*, 21, 758-780.
- KIRKSEY, S. E. & HELMREICH, S. 2010. The emergence of multispecies ethnography. *Cultural anthropology*, 25, 545-576.
- KOCH, H. M. & CALAFAT, A. M. 2009. Human body burdens of chemicals used in plastic manufacture. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364, 2063-2078.
- KOO, H. 2016. The Global Middle Class: How Is It Made, What Does It Represent? *Globalizations*, 13, 440-453.
- KUIJER, L. & DE JONG, A. M. 2011. Practice theory and human-centered design: A sustainable bathing example. *Nordes*.
- KUIJER, S. 2014. Implications of social practice theory for sustainable design.
- LA GUARDIA, M., SCHREDER, E., UDING, N. & HALE, R. 2017. Human indoor exposure to airborne halogenated flame retardants: influence of airborne particle size. *International journal of environmental research public health*, 14, 507.
- LACKNER, C. 2014. Human Practice Centered Design: Service Designing Practice Transition-Community Supported Agriculture as a Case Study.

- LAKIND, J. S., WILKINS, A. A. & BERLIN JR, C. M. 2004. Environmental chemicals in human milk: a review of levels, infant exposures and health, and guidance for future research. *Toxicology & Applied Pharmacology*, 198, 184-208.
- LANDECKER, H. 2011. Food as exposure: Nutritional epigenetics and the new metabolism. *BioSocieties*, 6, 167-194.
- LANGLITZ, N. 2013. *Neuropsychedelica: the revival of hallucinogen research since the decade of the brain*, Univ of California Press.
- LATOUR, B. 1988. *The Pasteurization of France*. Translated by Sheridan, Alan, and John Law. Cambridge, MA, The Harvard University Press.
- LATOUR, B. 1992. Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts. In: BIJKER, W. E. & LAW, J. (eds.) *Shaping technology/building society: studies in sociotechnical change*. Cambridge, Mass: MIT Press.
- LATOUR, B. 2004. Why has critique run out of steam? From matters of fact to matters of concern. *Critical inquiry*, 30, 225-248.
- LATOUR, B. A cautious Prometheus? A few steps toward a philosophy of design (with special attention to Peter Sloterdijk). Proceedings of the 2008 annual international conference of the design history society, 2008. 2-10.
- LAW, J. & URRY, J. 2004. Enacting the social. *Economy and society*, 33, 390-410.
- LIBOIRON, M. 2012. *Redefining Pollution: Plastics in the Wild*. Doctor of Philosophy, New York University.
- LIBOIRON, M. 2015. Redefining pollution and action: The matter of plastics. *Journal of Material Culture*, 21, 87-110.
- LIBOIRON, M., TIRONI, M. & CALVILLO, N. 2018. Toxic politics: Acting in a permanently polluted world. *Social studies of science*, 48, 331-349.
- LILJENQUIST, K., ZHONG, C.-B. & GALINSKY, A. D. 2010. The smell of virtue clean scents promote reciprocity and charity. *Psychological Science*, 21, 381-383.
- LIOY, P. 2010. Exposure science: a view of the past and milestones for the future. *J Environmental health perspectives*, 118, 1081-1090.
- LIPPMANN, M. 2013. Exposure science in the 21st century: A vision and a strategy. Nature Publishing Group.
- LORENZEN, J. A. 2012. Going Green: The Process of Lifestyle Change¹. *Sociological Forum*, 27, 94-116.
- LORETZ, L., API, A., BABCOCK, L., BARRAJ, L., BURDICK, J., CATER, K., JARRETT, G., MANN, S., PAN, Y. & RE, T. 2008. Exposure data for cosmetic products: Facial cleanser, hair conditioner, and eye shadow. *Food and chemical Toxicology*, 46, 1516-1524.
- LORIMER, J. 2017. Probiotic environmentalities: Rewilding with wolves and worms. *Theory, Culture, Society*, 34, 27-48.
- LORIMER, J., HODGETTS, T., GRENYER, R., GREENHOUGH, B., MCLEOD, C. & DWYER, A. 2019. Making the microbiome public: Participatory experiments with DNA sequencing in domestic kitchens. *Transactions of the Institute of British Geographers*.
- LORIMER, J. & HODGETTS, T. J. B. 2017. Good germs, bad germs: Citizen science and microbiology. 39.
- LU, X., CHEN, M., ZHANG, X., SUN, Y., ZHU, D., ZHANG, Q., WANG, B. & ZHANG, Z. J. A. M. 2013. Simultaneous quantification of five phenols in settled house dust using

- ultra-high performance liquid chromatography-tandem mass spectrometry. 5, 5339-5344.
- LUONGO, J. C. 2016. *Towards Defining Healthy Buildings: Investigating the Effect of Building Characteristics and Interventions on Indoor Air Microbial Exposures and Energy Efficiency*. University of Colorado at Boulder.
- LUPTON, E. & MILLER, J. A. 1996. *Bathroom, the Kitchen, and the Aesthetics of Waste*, Princeton Architectural Press.
- LUSH. 2016. *Liquid Soap vs. Solid Soap* [Online]. Available: https://www.lushusa.com/Liquid-Soap-vs.-Solid-Soap/Article_Liquid-Soap-Vs-Solid-Soap.en_US.pg.html?fid=tips-tricks [Accessed 23 March 2016].
- LYNCH, S. V., WOOD, R. A., BOUSHEY, H., BACHARIER, L. B., BLOOMBERG, G. R., KATTAN, M., O'CONNOR, G. T., SANDEL, M. T., CALATRONI, A. & MATSUI, E. 2014. Effects of early-life exposure to allergens and bacteria on recurrent wheeze and atopy in urban children. *Journal of Allergy and Clinical Immunology*, 134, 593-601. e12.
- MAANTAY, J. 2002. Mapping environmental injustices: pitfalls and potential of geographic information systems in assessing environmental health and equity. *Environmental Health Perspectives*, 110, 161-171.
- MACKENDRICK, N. 2014. More work for mother: Chemical body burdens as a maternal responsibility. *Gender & Society*, 28, 705-728.
- MACKENDRICK, N. 2018. *Better Safe Than Sorry: How Consumers Navigate Exposure to Everyday Toxics*, Univ of California Press.
- MACKENDRICK, N. & STEVENS, L. M. 2016. "Taking Back a Little Bit of Control": Managing the Contaminated Body Through Consumption. *Sociological Forum*, 31.
- MACKENDRICK, N. A. 2010. Media framing of body burdens: precautionary consumption and the individualization of risk. *Sociological Inquiry*, 80, 126-149.
- MACKOWIAK, P. A. 2013. Recycling Metchnikoff: probiotics, the intestinal microbiome and the quest for long life. *Frontiers in Public Health*, 1, 52.
- MAIZELS, R. M. 2005. Infections and allergy—helminths, hygiene and host immune regulation. *Current Opinion in Immunology*, 17, 656-661.
- MALLER, C. 2011. *Practices involving energy and water consumption in migrant households*, CSIRO Publishing: Melbourne, Australia.
- MALLER, C. 2018. *Healthy Urban Environments: More-Than-Human Theories*, Routledge.
- MALLER, C. & STRENGERS, Y. 2013. The global migration of everyday life: Investigating the practice memories of Australian migrants. *Geoforum*, 44, 243-252.
- MALTERUD, K., SIERSMA, V. D. & GUASSORA, A. D. 2016. Sample size in qualitative interview studies: guided by information power. *Qualitative Health Research*, 26, 1753-1760.
- MARMOT, M., FRIEL, S., BELL, R., HOUWELING, T. A. & TAYLOR, S. 2008. Closing the gap in a generation: health equity through action on the social determinants of health. *Commission on Social Determinants of Health: The Lancet*, 372, 1661-1669.
- MARTENS, L. 2012. Practice 'in talk' and talk 'as practice': Dish washing and the reach of language. *Sociological Research Online*, 17, 1-11.
- MARTENS, L. & SCOTT, S. 2005. "The unbearable lightness of cleaning": Representations of domestic practice and products in Good Housekeeping Magazine (UK): 1951–2001. *Consumption, Markets and Culture*, 8, 379-401.

- MARTIN, L. J., ADAMS, R. I., BATEMAN, A., BIK, H. M., HAWKS, J., HIRD, S. M., HUGHES, D., KEMBEL, S. W., KINNEY, K. & KOLOKOTRONIS, S.-O. 2015. Evolution of the indoor biome. *Trends in Ecology Evolution*, 30, 223-232.
- MAZZEI, L. A. 2013. A voice without organs: Interviewing in posthumanist research. *International Journal of Qualitative Studies in Education*, 26, 732-740.
- MCCALMAN, J. & SPADINGER, E. 1984. *Struggletown: public and private life in Richmond, 1900-1965*, Melbourne University Press Carlton.
- MCDONALD, B. C., DE GOUW, J. A., GILMAN, J. B., JATHAR, S. H., AKHERATI, A., CAPPA, C. D., JIMENEZ, J. L., LEE-TAYLOR, J., HAYES, P. L. & MCKEEN, S. A. 2018. Volatile chemical products emerging as largest petrochemical source of urban organic emissions. *Science*, 359, 760-764.
- MEADOW, J. F., ALTRICHTER, A. E., BATEMAN, A. C., STENSON, J., BROWN, G., GREEN, J. L. & BOHANNAN, B. J. 2015. Humans differ in their personal microbial cloud. *PeerJ*, 3, e1258.
- MEADOW, J. F., ALTRICHTER, A. E., KEMBEL, S. W., KLINE, J., MHUIREACH, G., MORIYAMA, M., NORTHCUTT, D., O'CONNOR, T. K., WOMACK, A. M. & BROWN, G. 2014. Indoor airborne bacterial communities are influenced by ventilation, occupancy, and outdoor air source. *Indoor Air*, 24, 41-48.
- MEEKER, J. D., SATHYANARAYANA, S. & SWAN, S. H. 2009. Phthalates and other additives in plastics: human exposure and associated health outcomes. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 364, 2097-2113.
- MELOSI, M. V. 2008. *The sanitary city: Environmental services in urban America from colonial times to the present*, University of Pittsburgh Pre.
- MIDGLEY, G., MUNLO, I. & BROWN, M. 1998. The theory and practice of boundary critique: developing housing services for older people. *Journal of the Operational Research Society*, 49, 467-478.
- MILLER, D. 2010. *Stuff*, Polity.
- MILLS, J. G., WEINSTEIN, P., GELLIE, N. J., WEYRICH, L. S., LOWE, A. J. & BREED, M. F. 2017. Urban habitat restoration provides a human health benefit through microbiome rewilding: the Microbiome Rewilding Hypothesis. *Restoration Ecology*, 25, 866-872.
- MITCHELL, C., CORDELL, D. & FAM, D. 2015. Beginning at the end: The outcome spaces framework to guide purposive transdisciplinary research. *Futures*, 65, 86-96.
- MITRO, S. D., DODSON, R. E., SINGLA, V., ADAMKIEWICZ, G., ELMI, A. F., TILLY, M. K. & ZOTA, A. R. 2016. Consumer product chemicals in indoor dust: a quantitative meta-analysis of US studies. *Environmental science and technology*, 50, 10661-10672.
- MOL, A. 2002. *The body multiple: Ontology in medical practice*, Duke University Press.
- MONCURE, K. P. 2016. *Inverted Quarantine: Individual Response to Collective Fear*. Oberlin College.
- MORSE, J. M. 1994. Designing funded qualitative research. In: DENZIN, N. K. & LINCOLN, Y. S. (eds.) *Handbook of qualitative research*. Thousand Oaks, CA, US: Sage Publications, Inc.
- .
- MULLIN, M. 2002. Animals and anthropology. *Society and Animals*, 10, 387-394.

- MUNCKE, J. 2011. Endocrine disrupting chemicals and other substances of concern in food contact materials: An updated review of exposure, effect and risk assessment. *The Journal of Steroid Biochemistry and Molecular Biology*, 127, 118-127.
- MÜNSTER, D. 2017. Zero Budget Natural Farming and Bovine Entanglements in South India. *RCC Perspectives*, 25-32.
- MURPHY, M. 2006. *Sick building syndrome and the problem of uncertainty: Environmental politics, technoscience, and women workers*, Duke University Press.
- MURPHY, M. 2008. Chemical regimes of living. *Environmental History*, 13, 695-703.
- MURPHY, M. 2015. Unsettling care: Troubling transnational itineraries of care in feminist health practices. *Social Studies of Science*, 45, 717-737.
- MYERS, N. 2015. *Rendering life molecular: Models, modelers, and excitable matter*, Duke University Press.
- MYLAN, J. & SOUTHERTON, D. 2017. The social ordering of an everyday practice: The case of laundry. *Sociology*, 52, 1134-1151.
- NATIONAL ACADEMIES OF SCIENCES, E., & MEDICINE 2017. The value of social, behavioral, and economic sciences to national priorities: A report for the National Science Foundation. Retrieved from The National Academies Press website: <https://www.nap.edu/catalog/24790/the-value-of-social-behavioral-and-economic-sciences-to-national-priorities>.
- NATIONAL ACADEMIES OF SCIENCES ENGINEERING & MEDICINE 2017. *Microbiomes of the built environment: a research agenda for indoor microbiology, human health, and buildings*, National Academies Press.
- NAZAROFF, W. W. & WESCHLER, C. J. 2004. Cleaning products and air fresheners: exposure to primary and secondary air pollutants. *Atmospheric Environment*, 38, 2841-2865.
- NICOLINI, D. 2016. Is small the only beautiful? Making sense of 'large phenomena' from a practice-based perspective. *The nexus of practices*. Routledge.
- NIEWÖHNER, J. 2011. Epigenetics: Embedded bodies and the molecularisation of biography and milieu. *BioSocieties*, 6, 279-298.
- NIXON, R. 2011. *Slow Violence and the Environmentalism of the Poor*, Harvard University Press.
- O'HARA, A. M. & SHANAHAN, F. J. E. R. 2006. The gut flora as a forgotten organ. 7, 688-693.
- O'MALLEY, M. A. 2016. Microbiology, philosophy and education. *FEMS microbiology letters*, 363.
- O'MALLEY, M. A. & DUPRÉ, J. 2007. Size doesn't matter: towards a more inclusive philosophy of biology. *J Biology & Philosophy*, 22, 155-191.
- O'MALLEY, M. A. & SKILLINGS, D. 2018. Methodological Strategies in Microbiome Research and their Explanatory Implications. *Perspectives on Science*, 26, 239-265.
- OED. 2016. *Hygiene* [Online]. Available: <http://www.oxforddictionaries.com/definition/english/hygiene> [Accessed 31 March 2016].
- OGLE, M. 1996. *All the modern conveniences: American household plumbing, 1840-1890*, Johns Hopkins University Press.
- OKADA, H., KUHN, C., FEILLET, H., BACH, J. F. J. C. & IMMUNOLOGY, E. 2010. The 'hygiene hypothesis' for autoimmune and allergic diseases: an update. 160, 1-9.

- OLIVEIRA, S. M. D., GOMIDES, A. P. M., MOTA, L. M. H. D., LIMA, C. M. B. L. & ROCHA, F. A. C. 2017. Intestinal parasites infection: protective effect in rheumatoid arthritis? *Revista brasileira de reumatologia*, 57, 461-465.
- OLSSON, M. 2014. *The Cost of Inaction: A Socioeconomic analysis of costs linked to effects of endocrine disrupting substances on male reproductive health*, Nordic Council of Ministers.
- OTT, W. R., STEINEMANN, A. C. & WALLACE, L. A. 2006. *Exposure analysis*, CRC Press.
- OUIMETTE, M. Y. 2011. *Cleaning house: Considerations of ecological health and sustainability in the selection of household cleaning products*. Boston College.
- PARK, M. 2016. Defying obsolescence. *Longer Lasting Products*. Routledge.
- PARKER, W. 2014. The “hygiene hypothesis” for allergic disease is a misnomer. *BMJ*, 349, g5267.
- PATTERSON, M. & JOHNSTON, J. 2012. Theorizing the obesity epidemic: Health crisis, moral panic and emerging hybrids. *Social Theory & Health*, 10, 265-291.
- PAXSON, H. 2008. Post-Pasteurian cultures: the microbiopolitics of raw-milk cheese in the United States. *Cultural Anthropology*, 23, 15-47.
- PAXSON, H. 2014. Microbiopolitics. In: KIRKSEY, E. (ed.) *The Multispecies Salon*. Duke University Press.
- PAXSON, H. & HELMREICH, S. 2014. The perils and promises of microbial abundance: Novel natures and model ecosystems, from artisanal cheese to alien seas. *Social Studies of Science*, 44, 165-193.
- PENDERS, J., GERHOLD, K., STOBBERINGH, E. E., THIJS, C., ZIMMERMANN, K., LAU, S. & HAMELMANN, E. 2013. Establishment of the intestinal microbiota and its role for atopic dermatitis in early childhood. *Journal of Allergy Clinical Immunology*, 132, 601-607. e8.
- PERLROTH, N. H. & BRANCO, C. W. C. 2017. Current knowledge of environmental exposure in children during the sensitive developmental periods. *Jornal de pediatria*, 93, 17-27.
- PETERSEN, A. R. 1996. Risk and the regulated self: the discourse of health promotion as politics of uncertainty. *The Australian and New Zealand Journal of Sociology*, 32, 44-57.
- PETERSON, C., SHARMA, V., ELMÉN, L. & PETERSON, S. 2015. Immune homeostasis, dysbiosis and therapeutic modulation of the gut microbiota. *Clinical Experimental Immunology*, 179, 363-377.
- PETTERSEN, I. N. Framing the role of technology in transformation of consumption practices: Beyond user-product interaction. Proceedings of the Conference on Joint Actions on Climate Change, 2009. 42.
- PHILLIPS, C. 2014. Following beekeeping: more-than-human practice in agrifood. *Journal of Rural Studies*, 36, 149-159.
- PICKERILL, J. 2015. Cold comfort? Reconceiving the practices of bathing in British self-build eco-homes. *Annals of the Association of American Geographers*, 105, 1061-1077.
- PICKERING, A. 1993. The mangle of practice: Agency and emergence in the sociology of science. *American Journal of Sociology*, 99, 559-589.

- PINK, S. 2014. Digital-visual-sensory-design anthropology: Ethnography, imagination and intervention. *Arts Humanities in Higher education*, 13, 412-427.
- PINK, S. 2015. *Doing sensory ethnography*, Sage.
- PINK, S. & MACKLEY, K. L. 2015. Social science, design and everyday life: refiguring showering through anthropological ethnography. *Journal of Design Research*, 13, 278-292.
- PUBLIC LAB. 2019. Available: <https://publiclab.org/> [Accessed 20 December 2018].
- PULLINGER, M., BROWNE, A., ANDERSON, B. & MEDD, W. 2013. *Patterns of water: The water related practices of households in southern England, and their influence on water consumption and demand management*, Lancaster, GB. University of Lancaster 177pp.
- QIAN, J., HOSPODSKY, D., YAMAMOTO, N., NAZAROFF, W. W. & PECCIA, J. 2012. Size-resolved emission rates of airborne bacteria and fungi in an occupied classroom. *Indoor air*, 22, 339-351.
- QUITZAU, M.-B. 2004. Changing ideas of bodily cleanliness. *Urban infrastructure in Transition: What can we learn from history?. 6th International Summer Academy on Technology Studies*, . Deutschlandsberg, Austria, 05/11/2004.
- QUITZAU, M.-B. & RØPKE, I. 2009. Bathroom transformation: from hygiene to Well-Being? *Home Cultures*, 6, 219-242.
- RAPPAPORT, S. M. & SMITH, M. T. J. S. 2010. Environment and disease risks. *Science*, 330, 460-461.
- RECKWITZ, A. 2002a. Toward a theory of social practices a development in culturalist theorizing. *European journal of social theory*, 5, 243-263.
- RECKWITZ, A. 2002b. Toward a theory of social practices: A development in culturalist theorizing. *European journal of social theory*, 5, 243-263.
- REEVES, S., KUPER, A. & HODGES, B. D. 2008. Qualitative research methodologies: ethnography. *BMJ*, 337, a1020.
- REINECKE, J. & ANSARI, S. 2016. Taming wicked problems: The role of framing in the construction of corporate social responsibility. *Journal of Management Studies*, 53, 299-329.
- REUBEN, S. 2010. Reducing Environmental Cancer Risk: What We Can Do Now. President's Cancer Panel, Annual Report 2008-2009.
- RITTEL, H. W. & WEBBER, M. M. 1973. Dilemmas in a general theory of planning. *Policy sciences*, 4, 155-169.
- RITTVO, H. 1989. *The Animal Estate*, Harvard University Press.
- ROB DUNN LAB. 2019. Available: <http://robdunnlab.com/> [Accessed 20 December 2018].
- ROBERTS, J. A., LANGSTON, N., EGAN, M., FRICKEL, S., NASH, L., ALLEN, B., VOGEL, S. A., FREDERICK ROWE, D., DAEMMRICH, A. & MURPHY, M. 2008. Toxic bodies/toxic environments: An interdisciplinary forum. *Environmental History*, 13, 629-703.
- ROCHESTER, J. R. & BOLDEN, A. L. 2015. Bisphenol S and F: a systematic review and comparison of the hormonal activity of bisphenol A substitutes. *Environmental Health Perspectives (Online)*, 123, 643.
- ROGAWANSAMY, S., GASKIN, S., TAYLOR, M. & PISANIELLO, D. 2015. An evaluation of antifungal agents for the treatment of fungal contamination in indoor air

- environments. *International journal of environmental research Public Health Nutrition*, 12, 6319-6332.
- ROOK, G. & KNIGHT, R. 2015. Environmental microbial diversity and noncommunicable diseases. In: ORGANIZATION, W. H. (ed.) *Connecting global priorities: biodiversity and human health*. World Health Organization and Secretariat of the Convention on Biological Sciences.
- ROOK, G. A. 2012. Hygiene hypothesis and autoimmune diseases. *Clinical reviews in allergy & immunology*, 42, 5-15.
- ROOK, G. A., ADAMS, V., HUNT, J., PALMER, R., MARTINELLI, R. & BRUNET, L. R. Mycobacteria and other environmental organisms as immunomodulators for immunoregulatory disorders. Springer seminars in immunopathology, 2004. Springer, 237-255.
- ROOK, G. A. & BRUNET, L. R. 2005. Old friends for breakfast. *Clin Exp Allergy*, 35, 841-842.
- ROSE, N. 1990. *Governing the soul: the shaping of the private self*, Taylor & Frances/Routledge.
- ROSE, N. 2007. Molecular biopolitics, somatic ethics and the spirit of biocapital. *Social Theory and Health*, 5, 3-29.
- RUDEL, R. A. & PEROVICH, L. J. 2009. Endocrine disrupting chemicals in indoor and outdoor air. *Atmospheric Environment*, 43, 170-181.
- RYGHAUG, M. & TOFTAKER, M. 2014. A transformative practice? Meaning, competence, and material aspects of driving electric cars in Norway. *Nature and Culture*, 9, 146-163.
- SAHAKIAN, M. & WILHITE, H. 2014. Making practice theory practicable: Towards more sustainable forms of consumption. *Journal of Consumer Culture*, 14, 25-44.
- SAHLBERG, B., WIESLANDER, G. & NORBÄCK, D. 2010. Sick building syndrome in relation to domestic exposure in Sweden-A cohort study from 1991 to 2001. *Scandinavian journal of public health*, 38, 232-238.
- SARANTIS, H. 2010. *Not so sexy: The health risks of secret chemicals in fragrance* [Online]. Available: <https://www.safecosmetics.org/wp-content/uploads/2015/02/Not-So-Sexy-report.pdf> [Accessed].
- SARATHY, B., HAMILTON, V. & BRODIE, J. F. 2018. *Inevitably Toxic: Historical Perspectives on Contamination, Exposure, and Expertise*, University of Pittsburgh Press.
- SAVAGE, A. M., HILLS, J., DRISCOLL, K., FERGUS, D. J., GRUNDEN, A. M. & DUNN, R. R. 2016. Microbial diversity of extreme habitats in human homes. *Peer J*, 4, e2376.
- SCHATZKI, T. 2010. Materiality and social life. *Nature and Culture*, 5, 123-149.
- SCHATZKI, T. 2016. Practice theory as flat ontology. *Practice Theory and Research*. Routledge.
- SCHATZKI, T. R. 1996. *Social practices: A Wittgensteinian approach to human activity and the social*, Cambridge Univ Press.
- SCHATZKI, T. R. 2002. *The site of the social: A philosophical account of the constitution of social life and change*, Penn State Press.
- SCHATZKI, T. R., KNORR-CETINA, K. & VON SAVIGNY, E. 2001. *The practice turn in contemporary theory*, Psychology Press.

- SCHRADER, A. 2010. Responding to *pfiesteria piscicida* (the fish killer) phantomatic ontologies, indeterminacy, and responsibility in toxic microbiology. *Social Studies of Science*, 40, 275-306.
- SCHUG, T., ABAGYAN, R., BLUMBERG, B., COLLINS, T., CREWS, D., DEFUR, P., DICKERSON, S., EDWARDS, T., GORE, A. & GUILLETTE, L. 2013. Designing endocrine disruption out of the next generation of chemicals. *Green Chemistry*, 15, 181-198.
- SCOTT, D. N., HAW, J. & LEE, R. 2017. 'Wannabe Toxic-Free?' From precautionary consumption to corporeal citizenship. *Environmental Politics*, 26, 322-342.
- SCOTT, K., BAKKER, C. & QUIST, J. 2012. Designing change by living change. *Design Studies*, 33, 279-297.
- SCOTT, K., QUIST, J. & BAKKER, C. Co-design, social practices and sustainable innovation: involving users in a living lab exploratory study on bathing. Proceedings of Paper for the "Joint Actions on Climate Change" Conference, Aalborg, Denmark, 2009. 8-9.
- SCRUGGS, C. E., ORTOLANO, L., SCHWARZMAN, M. R. & WILSON, M. P. 2014. The role of chemical policy in improving supply chain knowledge and product safety. *Journal of Environmental Studies and Sciences*, 4, 132-141.
- SENIER, L., BROWN, P., SHOSTAK, S. & HANNA, B. 2017. The socio-exposome: advancing exposure science and environmental justice in a postgenomic era. *Environmental Sociology*, 3, 107-121.
- SHAPIRO, J. A. & DWORKIN, M. 1997. *Bacteria as multicellular organisms*, Oxford University Press.
- SHAPIRO, N. 2015. Attuning to the chemosphere: Domestic formaldehyde, bodily reasoning, and the chemical sublime. *Cultural Anthropology*, 30, 368-393.
- SHAPIRO, N. & KIRKSEY, E. 2017. CHEMO-ETHNOGRAPHY: An Introduction. *Cultural Anthropology*, 32, 481-493.
- SHAPIRO, N., ZAKARIYA, N. & ROBERTS, J. 2017. A wary alliance: From enumerating the environment to inviting apprehension. *Engaging Science, Technology, Society and Animals*, 3, 575-602.
- SHARMA, A. & GILBERT, J. A. 2018. Microbial exposure and human health. *Current Opinion in Microbiology*, 44, 79-87.
- SHOTWELL, A. 2016. *Against purity: Living ethically in compromised times*, U of Minnesota Press.
- SHOVE, E. 2003. *Comfort, cleanliness and convenience: The social organization of normality*, Berg Oxford.
- SHOVE, E. 2004. Sustainability, system innovation and the laundry. *System innovation and the transition to sustainability: theory, evidence and policy*, 76-94.
- SHOVE, E. 2007a. *The design of everyday life*, Berg.
- SHOVE, E. 2007b. The Materials of Material Culture: Plastic. *The design of everyday life*. Berg.
- SHOVE, E. 2011. On the difference between chalk and cheese—a response to Whitmarsh et al's comments on "Beyond the ABC: climate change policy and theories of social change". *Environment & Planning A*, 43, 262-264.
- SHOVE, E. 2017a. Matters of practice. *The nexus of practices: Connections, constellations, practitioners*.

- SHOVE, E. 2017b. *Practice theory methodologies do not exist* [Online]. Available: <https://practicetheorymethodologies.wordpress.com/2017/02/15/elizabeth-shove-practice-theory-methodologies-do-not-exist/#more-668> [Accessed].
- SHOVE, E. & PANTZAR, M. 2005. Consumers, producers and practices: Understanding the invention and reinvention of Nordic walking. *Journal of Consumer Culture*, 5, 43-64.
- SHOVE, E., PANTZAR, M. & WATSON, M. 2012. *The dynamics of social practice: Everyday life and how it changes*, Sage Publications.
- SHOVE, E. & SOUTHERTON, D. 2000. Defrosting the freezer: from novelty to convenience: a narrative of normalization. *Journal of Material Culture*, 5, 301-319.
- SHOVE, E. & WARDE, A. 2002a. Inconspicuous consumption: the sociology of consumption, lifestyles and the environment. *Sociological theory the environment: classical foundations, contemporary insights*, 230, 51.
- SHOVE, E. & WARDE, A. 2002b. Inconspicuous consumption: the sociology of consumption, lifestyles and the environment. *Sociological theory and the environment: classical foundations, contemporary insights*, 230, 51.
- SIDNELL, J. 2006. Coordinating gesture, talk, and gaze in reenactments. *Research on Language Social Interaction*, 39, 377-409.
- SILBERGELD, E. K., MANDRIOLI, D. & CRANOR, C. F. 2015. Regulating chemicals: law, science, and the unbearable burdens of regulation. *Annual Review of Public Health*, 36, 175-191.
- SKILLINGS, D. 2016. Holobionts and the ecology of organisms: Multi-species communities or integrated individuals? *Biology and Philosophy*, 31, 875-892.
- SMITH, D., ALVERDY, J., AN, G., COLEMAN, M., GARCIA-HOUCHINS, S., GREEN, J., KEEGAN, K., KELLEY, S. T., KIRKUP, B. C. & KOCIOLEK, L. 2013. The Hospital Microbiome Project: Meeting Report for the 1st Hospital Microbiome Project Workshop on sampling design and building science measurements, Chicago, USA, June 7th-8th 2012. *Standards in Genomic Sciences*, 8, 112.
- SMITH, V. 2007. *Clean: A History of Personal Hygiene and Purity*, OUP Oxford.
- SNOW, D. A., DELLA PORTA, D., KLANDERMANS, P. & MCADAM, D. 2013. *The Wiley-Blackwell Encyclopedia of Social & Political Movements*. The Wiley-Blackwell
- SOFLOULIS, Z. 2005. Big water, everyday water: a sociotechnical perspective. *Continuum*, 19, 445-463.
- SPURLING, N. J., MCMEEKIN, A., SOUTHERTON, D., SHOVE, E. A. & WELCH, D. 2013. Interventions in practice: reframing policy approaches to consumer behaviour. Sustainable Practices Research Group.
- STAMATIAN, F. & GOIDESCU, I. 2016. Side effects of endocrine disruptors on the human reproductive function. *Obstet si Ginecol*, 64, 205-214.
- STEIN, M. M., HRUSCH, C. L., GOZDZ, J., IGARTUA, C., PIVNIOUK, V., MURRAY, S. E., LEDFORD, J. G., MARQUES DOS SANTOS, M., ANDERSON, R. L. & METWALI, N. 2016. Innate immunity and asthma risk in Amish and Hutterite farm children. *New England Journal of Medicine*, 375, 411-421.
- STEINEMANN, A., WARGOCKI, P. & RISMANCHI, B. 2017. Ten questions concerning green buildings and indoor air quality. *Building and Environment*, 112, 351-358.
- STOKOLS, D. 2014. Training the next generation of transdisciplinary researchers. *Enhancing communication & collaboration in interdisciplinary research*, 56-81.

- STOKOLS, D. 2018. *Social ecology in the digital age: Solving complex problems in a globalized world*, Academic Press.
- STRACHAN, D. P. 1989. Hay fever, hygiene, and household size. *British Medical Journal*, 299, 1259.
- STRENGERS, Y. 2010a. Conceptualising everyday practices: composition, reproduction and change. *Carbon Neutral Communities Working Paper*.
- STRENGERS, Y. 2010b. Conceptualising everyday practices: composition, reproduction and change. *Carbon Neutral Communities Centre for Design, RMIT University. Working papers*.
- STRENGERS, Y. 2011a. Beyond demand management: co-managing energy and water practices with Australian households. *Policy Studies*, 32, 35-58.
- STRENGERS, Y. 2011b. Negotiating everyday life: The role of energy and water consumption feedback. *Journal of Consumer Culture*, 11, 319-338.
- STRENGERS, Y. & MALLER, C. 2012. Materialising energy and water resources in everyday practices: Insights for securing supply systems. *Global Environmental Change*, 22, 754-763.
- STRENGERS, Y. & MALLER, C. 2014. *Social practices, intervention and sustainability: beyond behaviour change*, Routledge.
- STRENGERS, Y. & MALLER, C. 2019. Dynamic Non-humans in a Changing World. In: MALLER, C. & STRENGERS, Y. (eds.) *Social Practices and Dynamic Non-Humans*. Springer.
- STRENGERS, Y., NICHOLLS, L. & MALLER, C. 2016. Curious energy consumers: Humans and nonhumans in assemblages of household practice. *Journal of Consumer Culture*, 16, 761-780.
- STROM, E. 2018. Brownfield Redevelopment: Recycling the Urban Environment. *The Palgrave Handbook of Sustainability*. Springer.
- SUTTON, P., WALLINGA, D., PERRON, J., GOTTLIEB, M., SAYRE, L. & WOODRUFF, T. 2011. Reproductive health and the industrialized food system: a point of intervention for health policy. *Health Affairs*, 30, 888-897.
- SZASZ, A. 2007. *Shopping Our Way to Safety*
How We Changed from Protecting the Environment to Protecting Ourselves, University of Minnesota Press.
- TAYLOR, J., SYMONDS, P., MAVROGIANNI, A., DAVIES, M., SHRUBSOLE, C., HAMILTON, I., CHALABI, Z. & WILKINSON, P. 2016. Estimating Current and Future Indoor Air Pollution and Temperatures in England. *Indoor Air*.
- THE HUMAN EXPOSOME PROJECT. 2019. Available: <https://humanexposomeproject.com/> [Accessed 20 December 2018].
- THRIFT, N. 2008. *Non-representational theory: Space, politics, affect*, Routledge.
- TOMES, N. 1999. *The gospel of germs: men, women, and the microbe in American life*, Harvard University Press.
- TOUSIGNANT, N. 2013. Broken tempos: of means and memory in a Senegalese university laboratory. *Social Studies of Science*, 43, 729-753.
- TSING, A. 2012. Unruly Edges: Mushrooms as Companion Species For Donna Haraway. *Environmental humanities*, 1, 141-154.

- TURNBAUGH, P. J., LEY, R. E., HAMADY, M., FRASER-LIGGETT, C. M., KNIGHT, R. & GORDON, J. I. 2007. The human microbiome project. *Nature*, 449, 804.
- TUTT, D. & HINDMARSH, J. 2011. Reenactments at work: Demonstrating conduct in data sessions. *Research on Language Social Interaction*, 44, 211-236.
- VANDENBERG, L. N., COLBORN, T., HAYES, T. B., HEINDEL, J. J., JACOBS JR, D. R., LEE, D.-H., SHIODA, T., SOTO, A. M., VOM SAAL, F. S. & WELSHONS, W. V. 2012. Hormones and endocrine-disrupting chemicals: low-dose effects and nonmonotonic dose responses. *Endocrine Reviews*, 33, 378-455.
- VERBEEK, D. & MOMMAAS, H. 2008. Transitions to sustainable tourism mobility: The social practices approach. *Journal of Sustainable Tourism*, 16, 629-644.
- VON GOETZ, N., WORMUTH, M., SCHERINGER, M. & HUNGERBÜHLER, K. 2010. Bisphenol A: how the most relevant exposure sources contribute to total consumer exposure. *Risk Analysis*, 30, 473-487.
- VON WINTERSDORFF, C. J., PENDERS, J., VAN NIEKERK, J. M., MILLS, N. D., MAJUMDER, S., VAN ALPHEN, L. B., SAVELKOUL, P. H. & WOLFFS, P. F. 2016. Dissemination of antimicrobial resistance in microbial ecosystems through horizontal gene transfer. *Frontiers in microbiology*, 7, 173.
- VOS, J. G., DYBING, E., GREIM, H. A., LADEFOGED, O., LAMBRÉ, C., TARAZONA, J. V., BRANDT, I. & VETHAAK, A. D. 2000. Health effects of endocrine-disrupting chemicals on wildlife, with special reference to the European situation. *Critical Reviews in Toxicology*, 30, 71-133.
- WAHLEN, S. 2011. The routinely forgotten routine character of domestic practices. *International Journal of Consumer Studies*, 35, 507-513.
- WAKEFIELD-RANN, R. 2017. More Than Skin Deep: A Service Design Approach to Making the Luxury Personal Care Industry More Sustainable. *Sustainable Management of Luxury*. Springer.
- WAKEFIELD-RANN, R. & FAM, D. 2018. Initiating a Transdisciplinary Conversation to Improve Indoor Ecologies. *HUMAN ECOLOGY REVIEW*, 24, 3-23.
- WANG, H., EDWARDS, M. A., FALKINHAM III, J. O. & PRUDEN, A. 2013. Probiotic approach to pathogen control in premise plumbing systems? A review. *Environmental science and technology*, 47, 10117-10128.
- WARDE, A. 2005. Consumption and theories of practice. *Journal of consumer culture*, 5, 131-153.
- WARNER, J. 1999. Worldwide variations in the prevalence of atopic symptoms: what does it all mean? *Thorax*, 54, S46.
- WATERTON, C. & TSOUVALIS, J. 2015. On the political nature of cyanobacteria: intra-active collective politics in Loweswater, the English Lake District. *Environment and Planning D: Society and Space*, 33, 477-493.
- WATSON, M. & MEAH, A. 2012. Food, waste and safety: negotiating conflicting social anxieties into the practices of domestic provisioning. *The Sociological Review*, 60, 102-120.
- WEATHERLY, L. M. & GOSSE, J. A. 2017. Triclosan exposure, transformation, and human health effects. *Journal of Toxicology and Environmental Health, Part B*, 20, 447-469.
- WEBB, J. S., GIVSKOV, M. & KJELLEBERG, S. 2003. Bacterial biofilms: prokaryotic adventures in multicellularity. *Current Opinion in Microbiology*, 6, 578-585.

- WESCHLER, C. J. 2009. Changes in indoor pollutants since the 1950s. *Atmospheric Environment*, 43, 153-169.
- WHATMORE, S. 2002. *Hybrid geographies: Natures cultures spaces*, London, SAGE Publications.
- WHATMORE, S. 2006. Materialist returns: practising cultural geography in and for a more-than-human world. *Cultural Geographies*, 13, 600-609.
- WILD, C. P. 2012. The exposome: from concept to utility. *International Journal of Epidemiology*, 41, 24-32.
- WILLIAMS, G. H. 2003. The determinants of health: structure, context and agency. *Sociology of Health & Illness*, 25, 131-154.
- WILSON, N. K., CHUANG, J. C., LYU, C., MENTON, R. & MORGAN, M. K. 2003. Aggregate exposures of nine preschool children to persistent organic pollutants at day care and at home. *Journal of Exposure Science and Environmental Epidemiology*, 13, 187-202.
- WOOLGAR, S. & LEZAUN, J. 2013. The wrong bin bag: A turn to ontology in science and technology studies? *Social Studies of Science*, 43, 321-340.
- WYNNE, B. 2006. Public engagement as a means of restoring public trust in science—hitting the notes, but missing the music? *J Public Health Genomics*, 9, 211-220.
- YANG, C. Z., YANIGER, S. I., JORDAN, V. C., KLEIN, D. J. & BITTNER, G. D. 2011. Most plastic products release estrogenic chemicals: a potential health problem that can be solved. *Environmental Health Perspectives*, 119, 989.
- YANG, T., XIONG, J., TANG, X. & MISZTAL, P. K. 2018. Predicting indoor emissions of cyclic volatile methylsiloxanes from the use of personal care products by university students. *Environmental Science Technology*, 52, 14208-14215.
- YAZDANBAKHSH, M., KREMSNER, P. G. & VAN REE, R. 2002. Allergy, parasites, and the hygiene hypothesis. *Science*, 296, 490-494.
- ZAHARA, A. 2018. *Against Risk Perception* [Online]. Available: <https://discardstudies.com/2018/10/01/against-risk-perception-the-deficit-model-and-public-understandings-of-risk/> [Accessed 1/2/2018].
- ŽALMANOVÁ, T., HOŠKOVÁ, K., NEVORAL, J., PROKEŠOVÁ, Š., ZÁMOSTNÁ, K., KOTT, T. & PETR, J. 2016. Bisphenol S instead of bisphenol A: a story of reproductive disruption by regrettable substitution—a review. *Czech Journal of Animal Science*, 61, 433-449.
- ZENG, M. Y., CISALPINO, D., VARADARAJAN, S., HELLMAN, J., WARREN, H. S., CASCALHO, M., INOHARA, N. & NÚÑEZ, G. 2016. Gut microbiota-induced immunoglobulin G controls systemic infection by symbiotic bacteria and pathogens. *Immunity*, 44, 647-658.
- ZIMMERMAN, J. B. & ANASTAS, P. T. 2015. Toward substitution with no regrets. *Science*, 347, 1198-1199.
- ZOELLER, R. T., BROWN, T., DOAN, L., GORE, A., SKAKKEBAEK, N., SOTO, A., WOODRUFF, T. & VOM SAAL, F. 2012. Endocrine-disrupting chemicals and public health protection: a statement of principles from The Endocrine Society. *Endocrinology*, 153, 4097-4110.
- ZOTA, A. R., RUDEL, R. A., MORELLO-FROSCH, R. A. & BRODY, J. G. 2008. Elevated house dust and serum concentrations of PBDEs in California: unintended consequences of furniture flammability standards? *Environmental Science and Technology*, 42, 8158-8164.

APPENDICES

A: PARTICIPANT INFORMATION SHEET 338

B: PARTICIPANT CONSENT FORM 340

C: RECRUITMENT FLYER 341

D: ACTIVITY DIARIES 342

E: DISSGREGATED CODED IN ALPHABETICAL ORDER 345

APPENDIX A: PARTICIPANT INFORMATION SHEET



Participant information sheet

Project Title: *'Designing for more sustainable cleaning practices in Australian households'*

Investigator: Rachael Wakefield-Rann (School of Design, University of Technology, Sydney)

Who is doing the research?

My name is Rachael Wakefield-Rann and I am a PhD Candidate at the University of Technology Sydney (UTS). My supervisors are Dr Susan Stewart and Dr Dena Fam.

What is the research about?

There is research showing how common ways of cleaning the home to create a suitable environment for children are unsustainable. These cleaning practices are conducted by the majority of Australians, and alternative ways of cleaning can be hard to learn about and implement. With your help, this research seeks to discover some of the challenges faced by Australian families that make it difficult to find out about and adopt more sustainable cleaning practices, and what types of alternative products and services would work for you in your daily lives.

If I say yes, what will it involve?

I will ask you to provide approximately 5 minutes of your time each day for 1 week writing down, drawing or photographing things relating to cleaning your home for your children. You will be provided with specific questions and also space to add your own thoughts. I will deliver the diaries to a location that suits you at the beginning of the week.

The diary activity will be followed by a 60 minute interview in your house where you will be asked more about the types of cleaning practices you perform to create a clean environment for your children, how you learned them, the products you buy and the challenges you face when trying to create a clean environment, for example: time, money, help from other family members and others.

You will be asked to sign a consent form and to give permission for the interview to be audio recorded and for non-identifying photographs to be taken.

Are there any risks or inconveniences?

There are very few risks due to the careful research design. All information gathered in the interview and diary will be de-identified and at any time you may withdraw your involvement without needing to give a reason.

Why have I been asked?

As the parent of a child under five in Australia, you are able to provide valuable insight into the challenges and opportunities of changing domestic cleaning routines for children to make them more sustainable.

THINK.CHANGE.DO

Do I have to say yes?

No, you don't have to say yes.

What will happen if I say no?

Nothing. I will thank you for your time so far and won't contact you about this research again.

If I say yes, can I change my mind later?

You can change your mind at any time and you don't have to say why. I will thank you for your time so far and won't contact you about this research again.

What if I have concerns or a complaint?

If you have concerns about the research that you think I or my supervisor can help you with, please feel free to contact me on Rachael.C.Wakefield-Rann@student.uts.edu.au or Ph: [REDACTED], or my supervisor Dena Fam, at Dena.Fam@uts.edu.au.

If you would like to talk to someone who is not connected with the research, you may contact the Research Ethics Officer on 02 9514 9772, and quote this code – ETH160739.

Yours sincerely,

Rachael Wakefield-Rann
PhD Candidate
Faculty of Design, Architecture and Building
University of Technology, Sydney
Peter Johnson Building, Building 6 (CB06)
702-730 Harris Street, Broadway, NSW 2007
Mobile +61 [REDACTED]
Rachael.C.Wakefield-Rann@student.uts.edu.au

Dr Dena Fam (supervisor)
Institute for Sustainable Futures
University of Technology, Sydney
Level 11, Building 10, 235 Jones Street Ultimo 2007
tel +61 2 9514 4950 | mobile +61 [REDACTED]
www.isf.uts.edu.au | Dena.Fam@uts.edu.au

APPENDIX B: PARTICIPANT CONSENT FORM



INFORMED CONSENT FORM

I _____ agree to participate in the research on *'Designing for more sustainable cleaning practices in Australian households'* being conducted by Rachael Wakefield-Rann (room CB06.06.49 of the University of Technology, Sydney for her degree Doctor of Philosophy (Design), ph: +61 _____ mail: Rachael.C.Wakefield-Rann@student.uts.edu.au)

I understand that the purpose of this study is to examine common everyday cleaning practices performed for children, and how a new system for cleaning could be designed that is more sustainable.

I understand that I will be participating in one or more of the following activities. Please tick the box/s corresponding to the activity/ies you will be participating in:

☐ **Activity diary**

This will involve recording cleaning actions performed for your child in a paper diary provided to you over a period of 1 week. This will take between 5 and 10 minutes per day. The researcher will collect the diary at the interview or from you at a convenient location at the end of this period.

☐ **Semi-structured interview**

This will involve answering questions from Rachael in your home for 40 minutes to 60 minutes, and may also involve follow-up phone or email contact with Rachael. I also understand that the interview audio will be electronically recorded and non-identifying photographs will be taken.

If you agree to participate in the semi-structured interview, please indicate by ticking the box below if you consent to photographs taken within your house being published in academic journals and books. You will not be identifiable in the photographs, or any other data. No images showing your face will be published.

☐ **I consent to de-identified photographs being published**

I am aware that I can contact Rachael Wakefield-Rann, or her supervisor Dr Dena Fam, if I have any concerns about the research. I also understand that I am free to withdraw my participation from this research project at any time I wish, without consequences, and without giving a reason.

I agree that Rachael Wakefield-Rann has answered all my questions fully and clearly.

I agree that the research data gathered from the interviews and activity diaries may be published in a form that does not identify me in any way.

Signature (participant)

____/____/____

Signature (researcher or delegate)

____/____/____

APPENDIX C: RECRUITMENT FLYER

This flyer reflects the direction of the research in the second year of my project. It also reflects the competing demands of framing the project in such a way that parents are not scared by risks that are made explicit, making the project sound appealing and interesting enough to respond, and to accurately represent the project.



**Are you interested helping create more healthy
and sustainable cleaning products for children?**

We are conducting a new research study across Sydney to better understand how cleaning and personal care products and services could better meet the needs of young families.

Who are we looking for? Parents with a child under 5 who would be happy to spend 5 minutes a day for a week filling out an activity diary, followed by one 60 minute interview.

Purpose: this study is part of Rachael Wakefield-Rann's doctoral research at the School of Design, University of Technology, Sydney, into how cleaning products can be made more sustainable and healthy for children. With your help, this research seeks to discover some of the challenges faced by Australian families that make it difficult to adopt sustainable cleaning practices. It aims to discover what types of alternative products and services would remove these barriers and work for you in your daily lives.

Where will the interview be held? If agreed, interviews will be held in participant's homes to determine how people's homes might influence cleaning practices.

Will the results of this research be available to me? The findings of the research will be made available for all participants upon request.

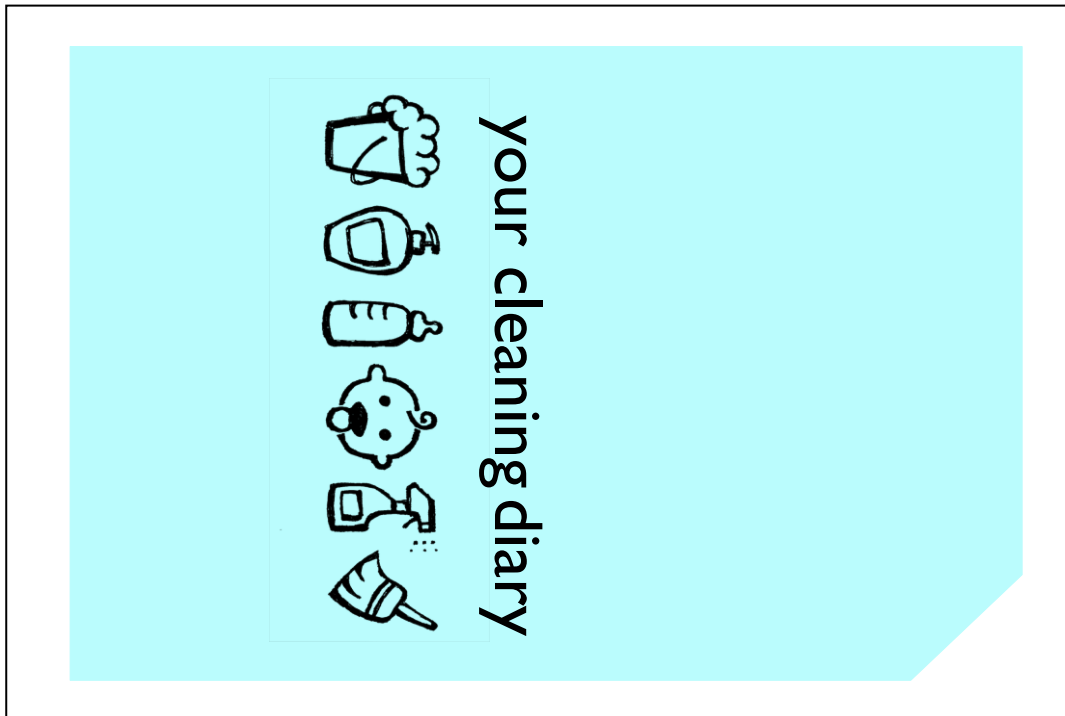
Will my privacy be protected? Your identity will be protected and your contribution will be entirely anonymous in all published data.

To find out more about the research please call the lead researcher, Rachael Wakefield-Rann, on [redacted] or email at Rachael.C.WakefieldRann@student.uts.edu.au

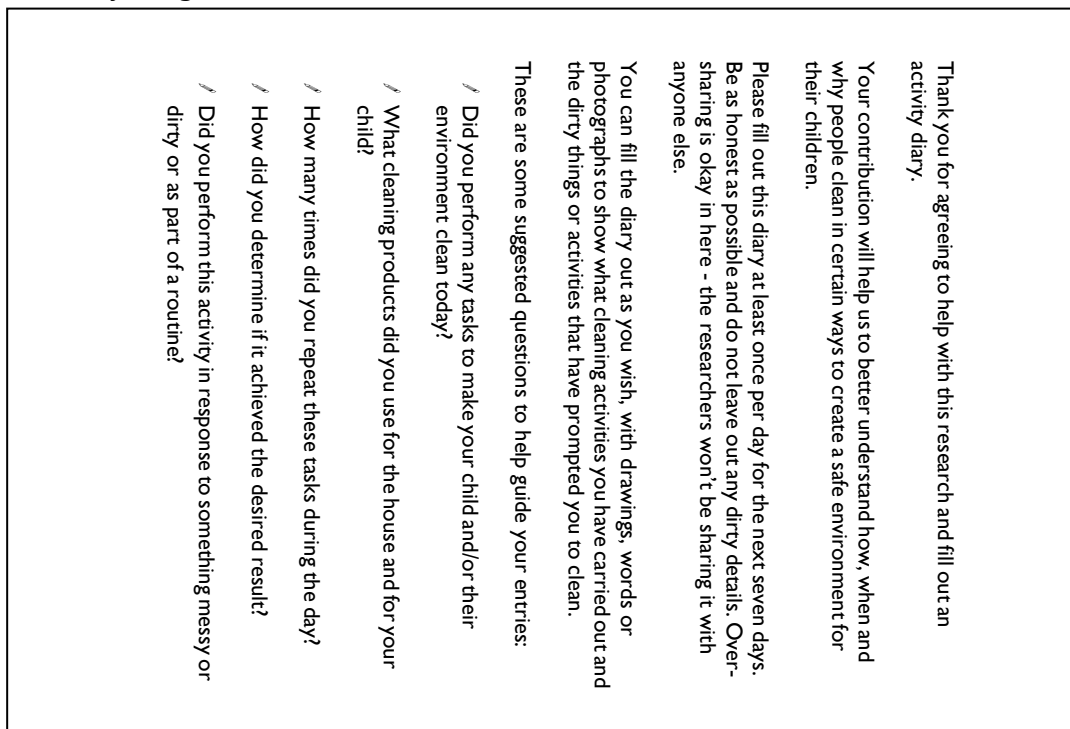


APPENDIX D: ACTIVITY DIARIES

The images below show the design of the diaries given to participants. The diaries filled in by participants were not included as part of the appendices because of the extremely sensitive nature of the contents and the difficulty associated with adequately deidentifying much of the sensitive information.



Diary image 1: front cover



Diary image 2: inside cover instructions to participants

APPENDIX E: DISAGGREGATED NVIVO CODES IN ALPHABETICAL ORDER

1. Acknowledgement that hazard may be psychological
2. Appropriation of objects for other tasks
3. Animal agency
 - a. Fleas
 - b. Germs
 - c. Microbial agency (action)
 - d. Microbial agency (belief)
 - e. Mosquitoes
 - f. Mould
 - g. Non-human agency (action)
 - h. Perceptions re pet hygiene
 - i. Pet influence on practice
4. Place described as 'appearing clean'
5. Awareness of environmental impact
6. Beliefs
7. Bodily movements
 - a. Gestures
 - b. Visceral reaction
8. Bundle of practices
9. Perceived boundaries of contamination
10. Chemical agency
 - a. Chemical agency (action)
 - b. Chemical agency (beliefs)
11. Child Vulnerability
 - a. Child health concerns
 - b. Child resilience
 - c. Children's skin
12. Childcare centre
13. Children's particular actions
14. Children's personal hygiene products
 - a. Child bathing
15. Cleaning frequency
 - a. Cleaning priority
 - b. Daily tasks
 - c. Reactionary tasks
- d. Routine tasks
16. Complex of practices
17. Use of home compost
18. Conflicting information
19. Convenience
20. Cost motivation
21. Critical periods of concern
22. Developmental stage practice influence
23. Division of labour
 - a. Hired cleaner
 - b. Husband's tasks
24. Don't want to appear too concerned
25. Claim that "I don't clean"
26. Dust in the environment
27. Employment status
28. Expression of enjoying cleaning
29. External environmental influence
30. Familial disagreement
31. Fastidiousness
32. Environment 'feels good'
33. Food and drink preparation
34. Use of phrase 'Germaphobe'
35. Feelings of guilt
36. Home more often now than before
37. House attributes
 - a. Carpet
 - b. Designated 'dirty' space
 - c. Dirt revealing surfaces
 - d. Floorboards
 - e. Garden
 - f. Inside-outside
 - g. Renovation
38. Hygiene concern
 - a. Chemical avoidance
 - b. Chemicals of concern
 - c. Food mess
 - d. Health concern
 - i. Allergies
 - ii. Health problem
 - iii. Plastic concern
39. Hygiene indicators
40. Hygiene metaphors
41. Implicit external pressure

- 42. Inconsistency in execution of values
- 43. Inconsistent results from cleaning product
- 44. Mental impacts of cleaning
- 45. Not being listened to
- 46. Reasons for product selection
- 47. Outside dirt
- 48. Overwhelming information
- 49. Claims about 'Parenting style'
- 50. Perception does not match bodily action
- 51. Practices
 - a. Bathroom cleaning
 - b. Bedroom cleaning
 - c. Floor cleaning
 - d. Kitchen cleaning
 - e. Laundry cleaning
 - f. Personal hygiene
 - g. Soaking
 - h. Travel hygiene practices
 - i. Unappealing practice
 - j. Vacuuming
 - k. Ventilation
 - l. Washing hands
 - m. Washing toys
 - n. Washing up
 - o. Wiping
- 52. Practice persistence and change
 - a. Abandoned attempt at new practice
 - b. Generational practice change
 - c. Inducting children into practice
 - d. Post-children practice shift
 - e. Potential practice innovations
 - f. Practice change between children
 - g. Practice disruption
 - h. Practice persistence
 - i. Practice transfer
 - j. Speed of practice shift
- 53. Products
 - a. Gifts
 - b. Have products but don't use them
 - c. Important products
 - d. Interdependent products
 - e. Label reading
 - f. Mixing of products
 - g. Natural products
 - h. Organic food
 - i. Price of products
 - j. Product attributes
 - i. Lather
 - ii. 'Purity'
 - iii. Scent
 - k. Product availability
 - l. Product consistency
 - m. Product loyalty
 - n. Product types
 - i. Cleaning products
 - ii. Detergent
 - iii. Disinfectant
 - iv. Air freshener
 - v. Anti-bacterial products
 - 1. Anti-bacterial wipes
 - 2. Hand sanitiser
 - vi. Bleach
 - vii. Insect repellent
 - viii. Nail polish
 - ix. Nappies
 - x. Soap
 - xi. Spray and wipe
 - xii. Sunscreen
 - xiii. Vinegar and bicarb
 - xiv. Window-glass cleaner
 - o. Products that work well
- 54. Recommendation sources
- 55. Reference to 'rituals'
- 56. Seasonal change
- 57. Sensitisation factors
- 58. Person described as 'sensitive'
- 59. Takes shoes off in the house
- 60. Shops where products are bought
- 61. Claim they 'Should do...' something
- 62. Some avoidance of perceived contaminant
- 63. Claim that some 'grime' or 'dirt' is good
- 64. Sources of information
- 65. They play sports
- 66. Subject's tasks (vs other members of household)
- 67. Suspicion of ideas or claims
- 68. 'Tidy' description of places
- 69. Time spent in current house
- 70. Time pressures on participant

71. 'Too extreme' description of action
72. 'Too much to clean' claim about house
73. Toys referenced
74. Trade off between different priorities
75. Trial and error approach to practices
76. Uncertainty about the best thing to do
77. Unfastidious claim
78. Unhygienic synonyms used
79. Willingness to try new ways of cleaning
80. Younger children perceived to be more vulnerable