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Convergence of the water & waste sectors: risks, opportunities & future trends

Discussion Paper

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ABOUT THE AUTHORS

The Institute for Sustainable Futures (ISF) was established by the University of Technology, Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human wellbeing and social equity. For further information visit: **www.isf.uts.edu.au**

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EXECUTIVE SUMMARY

This discussion paper has been developed by the Institute for Sustainable Futures (ISF), University of Technology Sydney, on behalf of the Australian Government, Department of the Environment and Energy (DoEE). It has collated knowledge from individuals within the project team including several experienced ISF researchers, Geoff Latimer (Ascend Waste and Environment) and Paul Starr (DoEE) with experience in both the water/wastewater and solid/hazardous waste sectors.

The aim of this discussion paper is to bring to light the increasing convergence of the water and waste sectors and the associated risks, benefits, and future trends already on the horizon. Current examples of convergence in managing coal seam gas (CSG), food waste, fats, oils and grease (FOG) and biosolids, provide insights into not only the risks to public and environmental health of waste streams that cross sectoral boundaries but also potential opportunities for the water and waste sectors to seize as business opportunities.

What is clear is that convergence between these sectors is already happening and in some cases there are adverse environmental consequences and associated health impacts. A key message from this research is the need to take an integrated and coordinated approach to planning and regulating the convergence of the water and waste sectors.

Key recommendations to manage the risks associated with cross sector convergence of the water and waste sectors include facilitating: (1) increased engagement between regulators of each sector, (2) greater communication across sectors (3) a co-ordinated approach and plan to managing waste streams, (4) the development of monitoring and evaluation frameworks that cross sectors and (5) a coordinated approach to the assessment of research needs.

CONTENTS

1 INTRODUCTION

Traditionally water/wastewater and solid waste have been managed using a linear approach to collection, transport and disposal. These systems were originally developed to protect public health and subsequently the environment. However, such systems are now no longer perceived as an appropriate or effective way of managing waste streams in modern society. And indeed, increasingly these ‘waste streams’ are being considered as potential ‘resources’ for reuse or recycling which in turn, requires a new approach to understanding risks and benefits.

The changing nature of the water and waste sectors is driven in part by rapid population growth, urbanization, industrial development and changing consumption patterns. The ever-increasing volumes of wastewater and waste generated means the traditional linear disposal methods (i.e. primary, secondary and tertiary treatment of wastewater and release to receiving waters and disposal of solid waste to landfill) are reaching system-constraint limits and raising important economic, social and environmental concerns. In addition, natural resource scarcity, changing hydrological conditions, and increasing costs of energy to transport, treat and manage waste streams is driving the need for innovative solutions in both the water and waste sectors to ‘do things differently’.

It is within this backdrop that a trend toward the commodification of waste streams (i.e. food waste, biosolids and trade waste streams) that the subsequent convergence of the water and waste sectors has emerged. This convergence offers both significant opportunities but also potential risks, which in many cases may have not yet been clearly identified or articulated.

This paper does not aim to provide a comprehensive overview of the convergence between these traditionally siloed and very separately managed sectors. Rather it aims to raise awareness and highlight the potential opportunities and risks of emerging current trends with the view of informing debate and bringing to light areas requiring further investigation and potential collaboration.

2 CHANGING CHARACTERISTICS AND DRIVERS

The demand for 'green alternatives' by customers across the water and waste sectors reflects a change in perception of 'waste' needing to be 'disposed of' to waste being perceived as a potential 'resource' to be utilised for beneficial reuse. The concept of sustainability has become more prevalent in Australian and international water and waste sectors. For example, growing pressure for wastewater infrastructure to respond to new challenges (e.g. population growth, drought, climate change impacts and changing living standards) has meant increasing awareness of the potential of closed loop water cycles, leading to a national focus on recycling and reuse of wastewater within most Australian cities. Figure 1 shows the significant increase in recycling in recent years in Sydney alone.

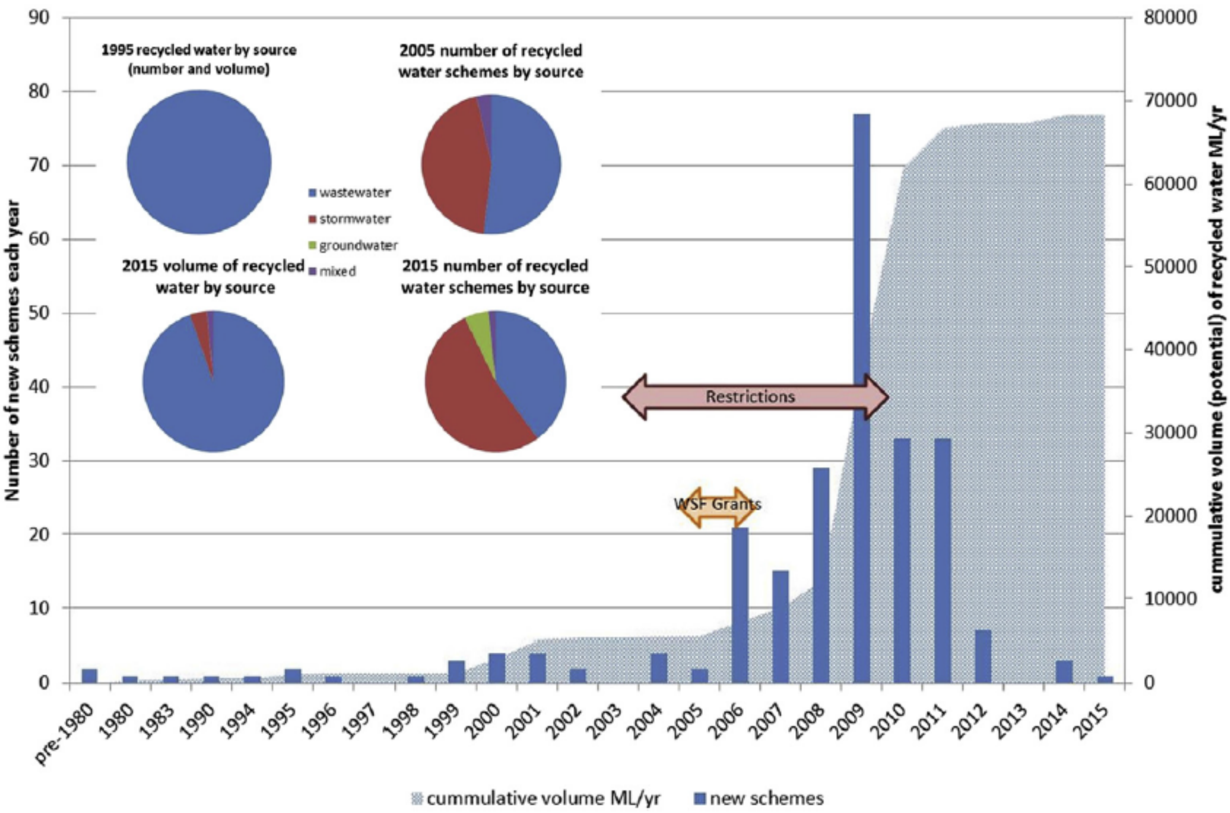

Figure 1: Increase in water recycling in Sydney in recent years[1]

Attitudinal shifts, to thinking of wastewater as a resource which can include 'valuable constituents to be recycled' rather than 'a pollutant to be disposed of', has driven a range of projects/installations of resource recovery and reuse systems Australia wide. These projects have been focused not only on water recovery and reuse but also nutrient recovery and reuse.

[1] Watson, R., Mukheibir, P., Mitchell, M., 2017 Local recycled water in Sydney: A policy and regulatory tug-of-war, Journal of Cleaner Production, 148 (2017) 583-594

Population growth in Australia and the trend towards urban densification in our cities has had flow-on effects for both the water and waste sectors, with for example wastewater treatment plants (WWTP) and landfill sites servicing Sydney heading toward capacity. In response to these emerging trends, the water and waste sectors in NSW have introduced economic incentives, both carrots and sticks, to help drive innovation to reduce waste streams. This has included the NSW EPA increasing landfill levies and 'gate fees' in recent years, currently the highest in the country, and Sydney Water Corporation (SWC) setting trade waste levies to incentivise more sustainable practices in managing organics waste streams. These and other economic incentives such as the major 'waste less recycle more' funding by the NSW EPA[2] are helping to drive innovation, incentivising industry to manage waste streams differently through new business models. This drive to incentivise reduction in waste is occurring to a lesser extent in other jurisdictions.

[2] http://www.epa.nsw.gov.au/wastestrategy/waste-less-recycle-more.htm (accessed 6.02.17)

3 THE CURRENT STATE OF CONVERGENCE OF THE WATER & WASTE SECTORS

There are increasing intersections and overlaps between the water and waste sectors, however, this emerging situation is yet to be reflected in integrated policy settings, oversight and regulations across the sectors. Water and waste sectors have traditionally been highly siloed with regulators of both sectors often oblivious to developments of the other, as they have to a large extent been managed as separate systems and waste streams. Therefore while there are current and future benefits of convergence between sectors, there is also the potential for associated risks, not to mention conflict with increasing encroachment on each sector's traditional 'turf'. Examples of waste streams with the potential to benefit multiple sectors are food waste and fats, oils and grease (FOG), where food waste streams are increasingly being sought as raw feed stocks by water utilities for energy generation through anaerobic digestion at their WWTPs (see Box 2 Sydney Cronulla trial in Section 4.6) and waste contractors identifying alternative business opportunities in managing FOG more efficiently (refer to Section 4.7).

While the water and waste sectors are aware of overlaps emerging, and in some cases deciding how to manage adverse outcomes from these overlaps (e.g. wet wipes, persistent organic pollutants (POPs), and micro plastics – refer to Section 4), there are likely many additional risks that are as yet not obvious and will require both foresight and vigilance to limit any adverse effects.

4 ILLUSTRATIVE CASE STUDIES

The follow case studies present brief illustrative examples of how the water and waste sectors are converging and the associated risks, opportunities and future trends to consider.

4.1 COAL SEAM GAS & THE WATER SECTOR

Coal Seam Gas (CSG) is a case in point illustrating an important tension that exists between the water and waste industries. The CSG industry produces large amounts of waste, in the form of water extracted from coal seams, drilling fluids or 'muds', hydraulic fracturing fluids and highly saline wastewaters. The industry has seen controversy over 'hydraulic fracturing', the process of fracturing deep rock strata in order to get to gas in coal seams, and the resulting waste, although hydraulic fracturing is not commonly practised in Australia because the coal seams are shallower and more accessible by more conventional means.

Managing what is termed 'produced' or 'co-produced' water as a result of CSG operations is a major issue for the CSG industry since it is usually of poor quality, containing potentially harmful levels of salt, radionuclides, metals and other contaminants.[3] The available options – each of which carry technical challenges and risks – include treatment and reuse for irrigation or industry, re-injection underground, or release into waterways following treatment. Treatment typically involves reverse osmosis, which concentrates contaminants in brine which itself requires safe disposal.

Concerns relating to CSG include (a) depletion of groundwater resources and its impacts on the environment and other water users; (b) contamination and interaction of groundwater resources; (c) the use of chemicals, especially contamination from drilling or hydraulic fracturing fluids; (d) cumulative impacts from multiple CSG developments; and (e) treatment, disposal and use of CSG water.[4]

Recent reported incidents illustrate the reality of concerns at the intersection of the CSG water and waste industries. In March 2014, a CSG project in the Pilliga Forest NSW operated by energy company Santos was found to have contaminated a nearby aquifer, with uranium at levels 20 times higher than safe drinking water guidelines.[5] Then in late 2014, concerns also arose regarding AGL's CSG pilot operation in Gloucester NSW, which was reported to have involved Transpacific discharging a prohibited substance into the Hunter Valley sewer system from its treatment site on Newcastle's Kooragang Island.[6]

[3] http://theconversation.com/coal-seam-gas-water-leaks-could-be-a-problem-for-decades-24718 (accessed 6.02.17)
[4] http://theconversation.com/coal-seam-gas-water-leaks-could-be-a-problem-for-decades-24718 (accessed 6.02.17)
[5] http://www.smh.com.au/environment/santos-coal-seam-gas-project-contaminates-aquifer-20140307-34csb.html (accessed 6.02.17)
[6] http://www.abc.net.au/news/2014-12-19/company-fined-for-dumping-csg-fracking-water-from-agl-site-in-n/5978776 (accessed 6.02.17)

4.2 THE LEGACY OF 'TRADITIONALLY' CONTAMINATED BIOSOLIDS STOCKPILES

The majority of biosolids produced in Australia come from WWTPs and are applied to land, mostly for agriculture but also for land rehabilitation purposes. Those biosolids contaminated above guideline levels (typically in heavy metals) cannot be used for this purpose and may be stockpiled awaiting an alternative fate. Such has been the case historically at Melbourne's Western (sewage) Treatment Plant, where approximately 1,500,000 'dry tonnes' of biosolids (equivalent to 7,500,000 tonnes on an average dewatered basis of 21% solids) are stockpiled, known to be contaminated with heavy metals such as mercury, cadmium and lead, 'traditionally' recognised and well-regulated pollutants. If this stockpile were managed in a similar fashion to contaminated soil, it would exceed Victoria's fill material upper limits and be classified as Category C contaminated soil. Similarly if it were managed in Victoria's solid waste framework, it would be classified as probably Category C prescribed industrial waste (PIW), with some potential for Category B depending on leach-ability testing. Either categorisation brings biosolids contaminated above guideline levels into the realm of the waste (and potentially hazardous waste) industry, a type of convergence not necessarily solicited by the water industry nor driven by market demand for recovery of the material.

4.3 EMERGING CONTAMINANTS IN BIOSOLIDS

There are a number of emerging pollutants of concern that are likely to be present in Australian biosolids, due to concerns about the 'pollutant sink' properties of biosolids, particularly from organic chemical residues. These include:

- *Persistent organic pollutants (POPs) such as perfluorooctane sulfonic acid (PFOS)* due to its tendency (compared to the other POPs) for high water-mobility and extreme water-species ecotoxicity – 0.00023 µg/L is the environmental water guideline value for 99% species protection[7] which is close to limits of laboratory detection.
- Other persistent organic chemicals used in personal care and household products including:
    - *chlorophenols such as triclosan*, used as a bactericide in personal hygiene products
    - *'polycyclic musks' such as galaxolide*, a commonly used ingredient found in household cleaning products, cosmetics and perfumes that is responsible for 'musky' odours.
    - Endocrine disrupting chemicals (EDCs)
- Dioxins and furans and polycyclic aromatic hydrocarbons (PAHs) such as Benzo[a]pyrene (B(a)P)
- A long list of pharmaceuticals and steroid hormones (via human excretion) also have the potential to be hazardous when applied to land.

Many of the above pollutants are EDCs.

[7] Australian Government Department of the Environment and Energy, DoEE (2016), *Commonwealth Environmental Management Guidance on Perfluorooctane Sulfonic Acid (PFOS) and Perfluorooctanoic Acid (PFOA) draft*, available from: https://www.environment.gov.au/system/files/pages/dfb876c5-581e-48b7-868c-242fe69dad68/files/draft-environmental-mgt-guidance-pfos-pfoa.pdf (accessed 6.02.17)

There are existing guidelines for contaminants in biosolids but they are not effective for emerging hazards and pollutants of concern which are likely to be present, typically persistent, bioaccumulative, toxic (often to aquatic environments) and either known or suspected of containing EDCs. This makes for a vastly wider set of contaminant questions for regulators to consider, that current biosolids management guidelines do not, given their focus on a narrow list of 'mainstream' contaminants such as heavy metals and some historically relevant organochlorine pesticides.

4.3.1 POPs in biosolids & wastewater

Several new chemicals were added to the Stockholm Convention on POPs in 2013. Amongst these were: polybrominated diphenyl ethers (PBDEs), also known as POP-BDEs, hexabromocyclododecane (HBCD) and perfluorooctane sulfonate & perfluorooctane sulfonic acid (PFOS).

POPs are hazardous and environmentally persistent substances which can be transported between countries by the earth's oceans and atmosphere. Their use has typically been in high-concentration applications such as flame retardancy of plastics, foams and building materials, and fire fighting foams. Both in use and end of life, these substances can find their way into soil and water environments via leakage from landfill, via domestic sewer input, from sewage treatment effluents and, potentially, through land application of biosolids. McGrath *et al*. (2016)[8] sampled surface soil from 30 sites across Melbourne and analysed them for various PBDEs, finding "widespread contamination of the urban environment, including locations where direct sources to soil are not clear." The Australian Government is yet to ratify these new additions to the Stockholm Convention, but ratification assessment processes are well-progressed.

While data on Australian biosolids concentrations of these contaminants is very limited, Gallen *et al*. (2016)[9] shows that PFOS (as a minimum) could be present in Australian biosolids above levels of concern, noting that if maximum allowable concentration regulatory limits similar to the UK or Germany were adopted in Australia in the future, as many as 7 out of the 16 sites assessed would have biosolids sufficiently contaminated as to be unfit for management by land application. For the most contaminated material, such a scenario could turn a current water industry resource into a future hazardous waste, with strict limitations on the nature of infrastructure that could manage it.

4.4 FLUSHABLE WET WIPES & THE WATER SECTOR

Adding solid waste to the wastewater system is problematic. An issue currently gaining significant attention, not just in Australia but internationally, are the detrimental effects of 'flushable' wet wipes on the sewer system and WWTPs as well as their effects on sewage overflows into properties and local waterways with unpleasant and costly damage and detrimental environmental impacts.

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[8] McGrath T.J., Morrison P.D., Sandiford C.J., Ball A.S., Clarke B.O. (2016), *Widespread polybrominated diphenyl ether (PBDE) contamination of urban soils in Melbourne, Australia*, Chemosphere 164 (2016) 225-232.

[9] Gallen C *et al.* (2016), *Occurrence and distribution of brominated flame retardants and perfluoroalkyl substances in Australian landfill leachate and biosolids*, Journal of Hazardous Materials 312 (2016) 55–64.

In recent years there has been an explosion in the wet wipe industry catering for a broad spectrum of age groups and uses. In North America alone wet wipe sales reached an estimated USD 2.2 billion in 2015[10]. Sydney Water Corporation (SWC) research indicates 1 in 4 people now use 'flushable' wet wipes in Sydney[11]. However, according the Water Services Association of Australia (WSAA) and utilities internationally, wet wipes should not be flushed as they do not break down in the same way as toilet paper and are not subject to the same levels of testing.

According to SWC, 75% of sewer blockages in Sydney involve wet wipes. In Australia alone the damage costs the industry $15 million p.a. New York City has spent over $23 million over the last 5 years dealing with issues associated with wet wipes and Thames Water (UK) spends GBP 23 million p.a. in London[12] including the removal of a 10 tonnes mass (the size of a double decker bus) from the sewer system at a cost of GBP 0.4 million[13]. Such masses often include a proportion of solidified fats, oils and greases creating 'fatbergs' as shown below.

'Fatberg' removed from a domestic sewer system

The problem has reached such proportions that: WSAA together with 300 international water utilities have signed a joint international statement to provide an industry position on non-flushable and flushable labelled products[14]; the Australian Competition and Consumer Commission (ACCC) is in the process of taking court action against the leading suppliers for making false and misleading claims about flushable products[15]; leading wet wipe manufacturers are beginning to modifying packaging and products in response to the backlash; and WSAA

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[10] https://www.theatlantic.com/science/archive/2016/10/are-wet-wipes-wrecking-the-worlds-sewers/504098/ (accessed 6.02.17).

[11] https://www.sydneywatertalk.com.au/wet-wipes/faqs (accessed 6.02.2017).

[12] http://www.ipwea.org/blogs/intouch/2016/04/14/hopes-international-standard-will-tackle-global-wet-wipe-scourge (accessed 6.02.17).

[13] https://www.theatlantic.com/science/archive/2016/10/are-wet-wipes-wrecking-the-worlds-sewers/504098/ (accessed 6.02.17).

[14] https://www.wsaa.asn.au/sites/default/files/paragraphs/attachments/International%20flushability%20statement%207%20Dec%202016.pdf (accessed 6.02.17).

[15] https://www.choice.com.au/health-and-body/beauty-and-personal-care/skin-care-and-cosmetics/articles/flushable-wipes (accessed 6.02.17).

together with associations representing wipe manufacturers are involved in the development of new international standards for flushable products[16].

4.5 MICROBEADS & PLASTICS CONTAMINATING WATERBODIES & SOILS

Flushable wet wipes are also involved in the ongoing issues associated with 'micro plastics' generally classified as plastics >1nm and <5mm in size[17]. Over 5 trillion pieces of plastic weighing an estimated 269,000 tons are thought to be spread throughout the world's oceans. These plastics decay slowly and distribute widely[18]. Over time larger plastics tend to break down into smaller pieces and become 'secondary' micro plastics. 'Primary' micro plastic, including micro beads are manufactured deliberately and can be found in personal care products such as exfoliating scrubs, toothpaste and soaps. Micro beads/plastics including by-products of wet wipes and fibres from clothes end up in fresh and marine environments as they are not intercepted by current WWTP systems. Unlike larger plastics micro plastics tend to settle in deep ocean sediment thereby potentially affecting deep-sea organisms as well as marine life in shallower waters[19]. Humans can ingest micro plastics from ingesting seafood. One study estimated that 90 plastic particles can be consumed in an average 250g serve of mussels and 50 particles in an average serve of 6 oysters although this is dependent on the marine environment from which they are sourced. It is possible that such particles may move from the gastrointestinal tract to other parts of the body especially microscopic particles, creating a risk of toxin exposure (Cauwenberghe and Janssen, 2014[20]).

[16] https://www.wsaa.asn.au/news/wsaa-welcomes-new-product-and-packaging-initiatives-wipes-manufacturer (accessed 6.02.2017).

[17] http://www.gesamp.org/data/gesamp/files/media/Publications/Reports_and_studies_90/gallery_2230/object_2500_large.pdf (accessed 6.02.17)

[18] http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/FlagPost/2016/June/Marine_microplastics (accessed 6.02.17)

[19] http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/FlagPost/2016/June/Marine_microplastics (accessed 6.02.17)

[20] Cauwenberghe, L., and Janssen, C., 2014 Microplastics in bivalves cultured for human consumption. Environmental Pollution, Vol 193, pp 65-70, October 2014 - http://www.sciencedirect.com/science/article/pii/S0269749114002425 (accessed 6.02.17)

An area that has received limited attention so far is the effects of micro plastics in agricultural soils due to the application of sewage sludge. Whilst sludge is heavily regulated, the micro plastic component is not. Sewage sludge used in agriculture varies between countries. In Europe and North America approximately 50 % of sludge is reused as fertilizer whilst in Norway, about two thirds of sludge is reused[21]. In Australia the majority of biosolids are either applied to land in agricultural production or used in land remediation. It is estimated that between 110,000 and 730,000 tons p.a. of micro plastics are transferred to agricultural soils in Europe and North America, more than the estimated total micro plastics currently present in the ocean. These figures are of concern since the effects of micro plastics accumulating in agricultural soils are currently unknown[22]. It is also important to note that POPs can bind to microbeads making them a potential secondary source of contamination.

Due to the well documented concerns of micro plastics entering the marine environment, state, territory and federal ministers announced a voluntary removal of micro beads from personal care, cosmetic and cleaning products sold in Australia by July 2018[23], strengthened by the former federal Environment Minister Greg Hunt announcing that a legal ban will be implemented by July 2017 if the voluntary ban is not effective[24]. Australia's product stewardship legislations may be used to enforce the ban. Countries such as the US and Canada have already moved to such a ban. Some cosmetic manufacturers have already voluntarily started phasing out micro beads and Australian supermarket chains have committed to banning micro beads in their own-brand personal care products by the end of 2017[25].

4.6 EMERGENCE OF FOOD WASTE MARKETS

Australia is currently the fifth largest municipal waste producer per capita of OECD members, behind Denmark, the US, Switzerland and Luxembourg (OECD, 2015[26]). Organic waste forms a significant component of the waste stream generated by industry and households, currently around 25% (ABS 2013[27]). In residential households an average bin contains 60% organics with typically a split of 2:1 food to garden waste (Ritchie 2016[28]).

Australian federal and state targets have been put in place in many jurisdictions in recent years to increase recycling and reduce organics sent to landfill. In some states landfill levies have increased significantly to drive economic incentives with NSW having the highest levy (refer to Figure 2). This has assisted in driving both avoidance of food waste and recycling rates.

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[21] Norwegian Institute for Water Research (NIVA). "Microplastics in agricultural soils: A reason to worry?." ScienceDaily. ScienceDaily, 28 October 2016. - https://www.sciencedaily.com/releases/2016/10/161028085827.htm (accessed 6.02.17)

[22] Norwegian Institute for Water Research (NIVA). "Microplastics in agricultural soils: A reason to worry?." ScienceDaily. ScienceDaily, 28 October 2016. - https://www.sciencedaily.com/releases/2016/10/161028085827.htm (accessed 6.02.17)

[23] https://www.environment.gov.au/system/files/pages/4f59b654-53aa-43df-b9d1-b21f9caa500c/files/mem-meeting4-statement.pdf (accessed 6.02.17)

[24] http://parlinfo.aph.gov.au/parlInfo/download/media/pressrel/4399792/upload_binary/4399792.pdf;fileType=application%2Fpdf#search=%22media/pressrel/4399792%22 (accessed 6.02.17)

[25] http://www.smh.com.au/business/consumer-affairs/aldi-joins-coles-and-woolies-in-microbead-ban-20160113-gm5hwk.html (accessed 6.02.17)

[26] http://www.oecd-ilibrary.org/docserver/download/9715091ec014.pdf?expires=1491454041&id=id&accname=guest&checksum=CAE7BBF301929631BB4ECF7FFC95C19B (accessed 6.02.17)

[27] ABS 2013, Waste Account, Australia, Experimental Estimates, 4602.0.55.005

[28] Ritchie, M., 2016 State of Waste 2016 – current and future Australian trends, MRA Consulting https://blog.mraconsulting.com.au/2016/04/20/state-of-waste-2016-current-and-future-australian-trends/ (accessed 6.02.17)

However, levies differ considerably, with QLD for example not currently having a landfill levy, likely a significant influential factor for their lower recycling rates compared to other states[29].

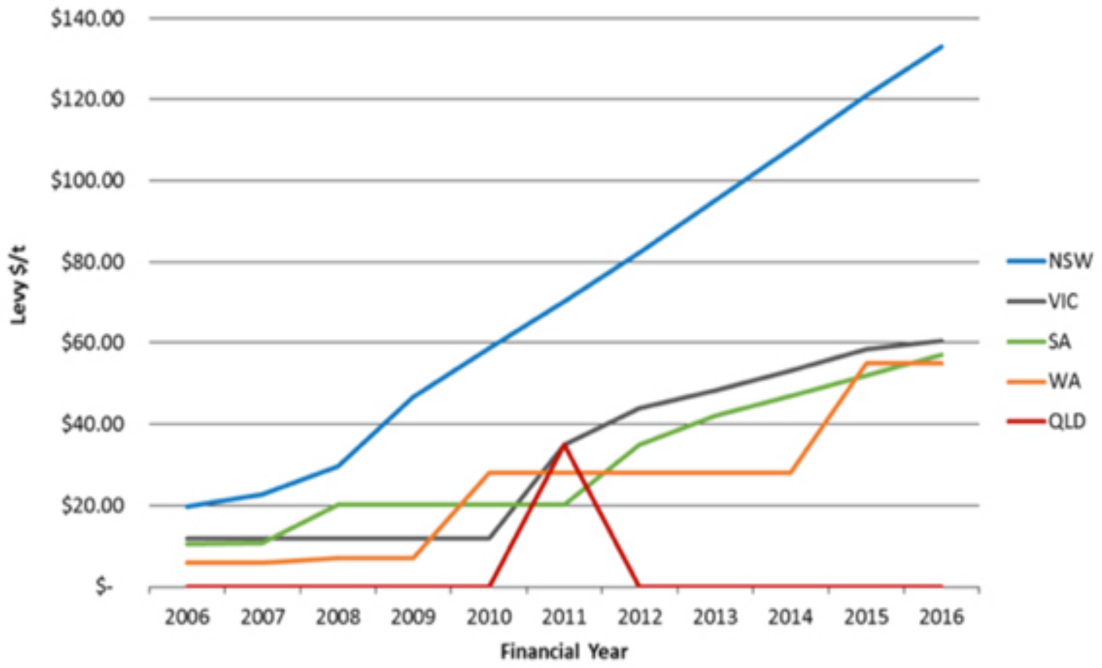

Figure 2: Change in landfill levies for major states over the last decade[30]

QLD's low cost landfills have had a perverse effect where waste from NSW and VIC has been transported to QLD's landfill sites. In 2014 the NSW government implemented a proximity principle to limit transporting waste more than 150 km from point of generation in an attempt to curb such practices[31].

The emergence of new markets and technological systems of food waste management especially in NSW have been driven by a combination of higher waste management charges and incentives.

[29] Ritchie, M., 2016 State of Waste 2016 – current and future Australian trends, MRA Consulting https://blog.mraconsulting.com.au/2016/04/20/state-of-waste-2016-current-and-future-australian-trends/ (accessed 6.02.17)
[30] Ritchie, M., 2016 State of Waste 2016 – current and future Australian trends, MRA Consulting https://blog.mraconsulting.com.au/2016/04/20/state-of-waste-2016-current-and-future-australian-trends/ (accessed 6.02.17)
[31] Qld government 2015, State of Waste and Recycling in Queensland 2015 https://www.ehp.qld.gov.au/waste/pdf/state-of-waste-report-2015.pdf (accessed 29.03.17)

Some of the emerging systems (i.e. waste to water) provide technological solutions that macerate food waste and discharge it to the sewer, reducing customer waste/landfill charges but in the process adding biochemical oxygen demand (BOD) to sewers (as a result of a regulatory loophole). Other technologies (i.e. Pulpmaster[32]) provide water utilities with the opportunity to collect pulped commercial food waste and add it to anaerobic digestion at WWTPs to generate energy, offset WWTP energy costs and potentially create a symbiotic biogas market in co-located sites. The ethical dilemma of water utilities actively seeking large volumes of organics (i.e. food waste for energy capture and profit) could potentially impact on profits for existing small scale waste contractors.

NSW's commitment to recycling and avoidance targets has been supported by significant funding commitments, which have begun to drive waste management innovation at both a large and, as can be seen in Box 1, local scale for organics waste management.

BOX 1 - Waste Less, Recycle More: Food waste dehydration[33]

The NSW Government has announced the extension of the Waste Less, Recycle More initiative with a further $337 million over 4 years from 2017-2021 (NSW EPA, 2017). This investment has driven technological innovation in the sector with 'rapid decomposing food waste' systems emerging as one way to manage large volumes of food waste. These systems dehydrate food waste within 24 hours with the original material reduced by up to 90% in volume with the potential to be used in application to land (under strict EPA guidelines – Resource Recovery Exemption). There is little doubt that dehydrators have the potential to play a significantly role in reducing food waste from landfill.

UTS accessed NSW EPA funding to install a rapid food waste dehydrator in two UTS buildings with the aim of managing 100% of the food waste produced onsite. The project separates and processes all uncontaminated food waste collected from 22 staff/student kitchens, servicing 34,500 fulltime students, 11 cafes and 1 concourse café housing 5 separate food outlets. Food waste is currently being processed and transported to EarthPower to generate energy and fertiliser with the ultimate goal to productively use the processed food waste on local parks and gardens, with the potential to process approximately 50-60 tonnes of raw organics per year to produce 5-6 tonnes of soil conditioner per year.

Dehydrated food waste processed onsite at UTS

[32] http://pulpmaster.com.au (accessed 6.02.17)
[33] http://www.epa.nsw.gov.au/wastestrategy/waste-less-recycle-more.htm (accessed 6.02.17)

Not driven by waste recycling or avoidance targets, SWC have begun to source commercial food waste streams (see Box 2). This has the potential to not only significantly reduce organic waste streams going to landfill but also provide opportunities for nutrient recovery and energy generation. The drivers for entering the food-waste nexus for SWC have been to offset energy costs through anaerobic digestion, investing in renewable energy as well as the intangible benefits of social acceptance of business models supporting sustainable development within SWC.

BOX 2 - Waste-to-energy trial using food waste to power Cronulla WWTP[34].

This three-year project is jointly funded by SWC and the Office of Environment and Heritage's Sustainability Advantage Program as part of a strategy by the NSW Government to lower energy costs and customers' bills.

SWC had an existing anaerobic digester on-site to process sewage sludge and a co-generator engine to generate power at the Cronulla WWTP. By building another tank to take liquefied food waste, this boosts the microbes creating methane and in the process generates the power required for operations at the Cronulla plant. SWC has partnered with Pulpmaster to bring the liquefied food waste from its clients to the Cronulla WWTP. Pulpmaster supplies equipment to commercial kitchens and markets to turn the food waste produced into a slurry, and then collects it for use at the Cronulla WWTP. The project not only diverts food waste from landfill but has the potential to generate more than 60% of the energy the plant needs to operate, which is equivalent to powering a third of homes in the Cronulla area per year.

Co-generation engine at Cronulla WWTP to process commercial food waste for energy production

[34] http://wastemanagementreview.com.au/utility-first-food-waste-to-energy-plant/ (accessed 6.02.17)

4.7 FATS, OILS & GREASE (FOG)

FOG provides a specific water and waste industry problem. Water utilities in Australia and internationally incur significant costs in the treatment of wastewater containing FOG discharged to sewer from commercial and industrial premises. FOG degrades in sewers creating noxious gases (hydrogen sulphide) that can erode steel and concrete. It is expensive to remove at WWTPs and even after treatment, large quantities are still released to the environment. For example SWC alone discharges 70,000 metric tonnes of FOG and suspended solids into the ocean every year.

Pre treatment systems and grease traps, managed through trade waste agreements with wastewater service providers in each jurisdiction are used to capture vast quantities of materials before they enter the wastewater system in order to reduce the detrimental effects on the wastewater infrastructure and environment. SWC for example requires that all food retailers have a trade waste agreement. Such premises are categorised according to their activities, a risk factor and size (i.e. number of seats per retail site). This assists in identifying the size of grease trap and the frequency of collection of FOG.

The FOG collected from grease traps and pre treatment systems is managed by authorised contractors. In Sydney there are over 25 SWC approved "wastesafe" transporters. These materials are treated at a number of large and small processing plants around Sydney including liquid waste, composting and anaerobic digester facilities producing an array of bi-products.

Historically FOG has been considered a waste stream with the potential to cause significant damage to wastewater infrastructure and environmental harm. However, more recently some public water and wastewater service providers and private businesses have identified the benefits of FOG and actively seek opportunities to collect the materials for its high calorific value in anaerobic digestion and international biofuel markets.

4.8 THE WASTE HEIRARCHY: DIFFERENCES BETWEEN THE WASTE & WATER SECTORS

The waste hierarchy (refer to Figure 3) currently dominates waste management planning in Australia. It clearly directs those considering options in planning and management of waste to consider, in order of preference, avoidance, reduction, reuse, recycling, recovery (e.g. energy) and treatment through to disposal. With avoidance being the most preferred and disposal to landfill being the least preferred. Whilst the waste hierarchy has significant strengths it also exhibits some potential barriers to innovation and lack of consideration of context specifics and opportunities that may significantly change what is considered a preferred option in a specific location[35]. For example, SWC's Cronulla WWTP waste-to-energy trial (refer to Box 2) would be low on the hierarchy. However, to SWC, a water/wastewater utility with particular objectives and drivers, the trial represents a significant business and energy production opportunity that may be adopted by other WWTPs in the future. This highlights just one of the emerging

[35] Giurco, D., Herriman, J., Turner, A., Mason, L., White, S., Moore, D., Klostermann, F., 2015, 'Integrated Resource Planning for Urban Waste Management', Resources 2015, 4, pp. 3-24 http://www.mdpi.com/2079-9276/4/1/3 (accessed 29.03.17)

misalignments of drivers and objectives between the water and waste sectors where 'waste' streams overlap between two sectors. This also highlights how the regulatory environment and decision-making frameworks in different sectors might incentivise different outcomes.

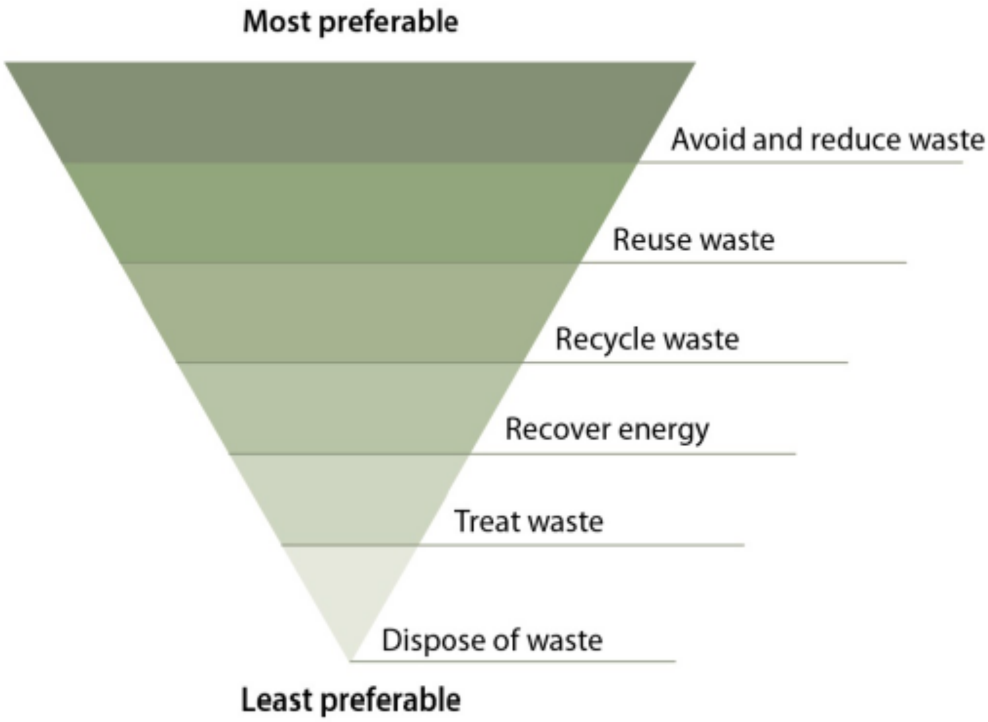

Figure 3: Example of waste hierarchy from NSW[36]

In considering the waste hierarchy framework, there is also a competing tension between hazard protection and resource efficiency that is not the case with non-hazardous wastes and poses the question - which one should out weigh the other in an integrated environmental assessment? This dilemma is represented below in Figure 4.

[36] http://www.epa.nsw.gov.au/wastestrategy/waste-hierarchy.htm (accessed 29.03.17)

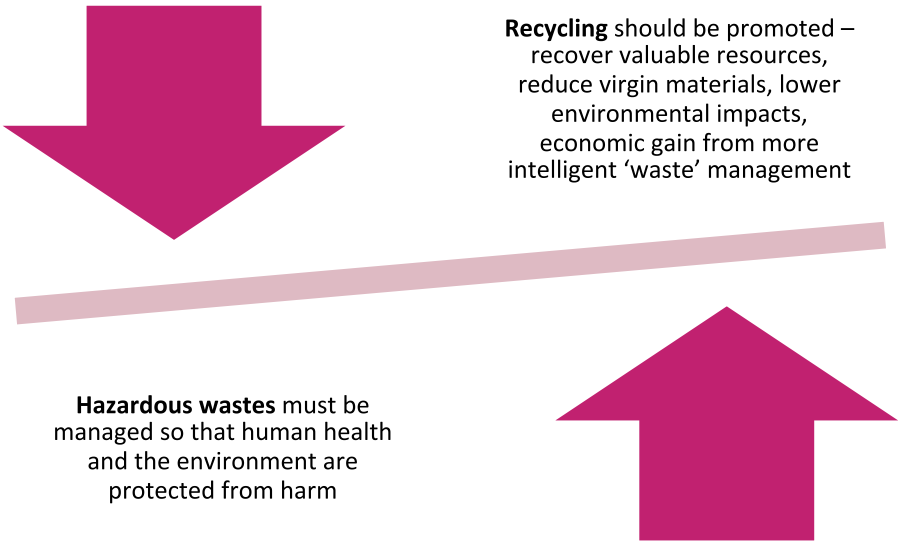

Figure 4: The hazardous waste 'recover' versus 'protect' dilemma

Source: Hazardous Waste in Australia 2017[37]

The waste hierarchy[38] is silent on the issue of protection from harm, which makes it limited as a single decision tool for management of hazardous wastes. This limitation is recognised by the Department for Environment, Food and Rural Affairs (DEFRA) in the UK, through specific guidance on applying the waste hierarchy to hazardous waste (DEFRA, 2011)[39], which has been written to assist compliance with the Waste (England and Wales) Regulations 2011.

DEFRA's advice and the regulations themselves require waste management that "takes into account the resource value of the hazardous wastes and the need for health and safety to be maintained", which "may result in a lower option in the hierarchy being chosen but results in a better overall environmental outcome." Clause 12(3) of the Regulations also require "technical feasibility (such as lack of infrastructure availability) and economic viability" to be considered when applying the hierarchy.

This dilemma is evident for biosolids, where nutrient resource value for agricultural soil beneficiation is a driver for the water industry, versus the need to protect from inorganic and organic chemical hazards that may be present (the nature of the hazardous waste management). While no one framework is perfect, the challenge of managing emerging risks relies on analysing and thinking through the issues associated with each particular context and circumstance, involve relevant stakeholders across sectors in the decision making process and a need to add nuance to the perception of risk and be ready for where it could lead the argument of risk management.

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[37] Ascend Waste and Environment and Blue Environment (2017) *Hazardous Waste in Australia* 2017, prepared for the Department of the Environment and Energy (not yet published).
[38] The wastes hierarchy is represented in environmental literature around the world. EPA Victoria's application of the wastes hierarchy is described at: *http://www.epa.vic.gov.au/your-environment/waste* (accessed 6.02.17)
[39] DEFRA (2011), *Guidance on applying the waste hierarchy to hazardous waste*, available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69457/pb13687-hazardous-waste-hierarchy-111202.pdf (accessed 6.02.17)

5.DISCUSSION

Improving the management of water and waste streams requires uncovering opportunities, reducing risk profiles and stakeholder engagement. Residents, local authorities, governments and academia ideally would be encouraged to participate in the decision making process. Technical solutions, when coupled with stakeholder participation, can lead to policy implementation with a higher chance of improving these ‘convergence’ issues and improving the present situation.

5.1 A MORE SOPHISTICATED APPROACH TO CIRCULAR FLOWS

The circular economy is an important complement to this discussion of convergence between water and waste sectors. It has the potential to provide an expanded systems view beyond the waste hierarchy as a guiding principle, yet circular economy discourse also prioritises reuse, remanufacturing and recycling as goals in themselves, without sophisticated consideration of the risk profile (including contaminants) of resource streams which are to be circulated.

Lifecycle trade-offs remain, in relation to managing biosolids and nutrient recovery in a circular economy, as the uptake in circular-economic thinking rises, so too does the need to adopt a more critical perspective and find ways to bring in new science as it emerges, mindful of the potential for technological lock-in within systems (which may make any new science question the risks of, for example, biosolids application to land, unwelcome).

5.2 CAN STEWARDSHIP MANAGE WATER-WASTE NEXUS ISSUES?

Stewardship has been put in place over time in Australia to manage products, but how might it affect the management of systems, namely water, waste and their nexus? New thinking is required to understand nexus issues in relation to stewardship and intervention points. For some hazards such as ingested pharmaceuticals there is the potential to take unwanted surplus and out-of-date medicines to incineration or pharmaceutical companies but residue from human ingestion is still an issue so only part of the solution and hard to influence. For flame retardants, plastic mats an avenue to biosolids is not clear.

5.3 ADAPTIVE MANAGEMENT AND REGULATION OF EMERGING POLLUTANTS

Novel pollutants, including nanoparticles and pharmaceuticals such as endocrine disruptors are problematic as the science regarding toxicity and impacts over time (to human and environmental health) are not always well characterised at the time of release into the market and the precautionary principle may not be heeded. These types of risks require more than a "laissez faire" approach which is likely to result in market and regulatory failure (for example perfluorooctane sulfonate). Strengthened monitoring and reporting, which informs adaptive management involving re-planning the management strategy as new science comes to light is needed. Furthermore, flexible regulatory postures and financial disincentives aimed more directly at avoidance will be important. In practice, this can be difficult terrain to navigate as new science could render existing infrastructure or practices redundant.

It raises questions, for example in relation to microbeads and pharmaceutical stewardship, to consider avoiding manufacture in the first place. However, the benefits and impacts from use need to be balanced. In future, greater testing, and treatment, of water and waste quality may be necessary which would impose an additional cost.

Biosolids have a strong management regime in place in Australia, in the form of various guidelines applied throughout Australian jurisdictions. In addition to contaminant and pathogenic assessment grading, these guidelines also place controls on placement of biosolids near sensitive land areas and water resources via buffer distances, and generally require limiting of re-application or at least soil testing prior to doing so. However, the weakness of this regime is two-fold:

- the scope of contaminants it considers is too narrow - a suite of heavy metals and organochlorine pesticides does not address the risks that a near-future set of concerns will pose
- there is insufficient biosolids analysis data available to gauge the level of risk that an emerging set of pollutants could pose to the industry's current management practices.

Australian governments have identified environmental management of PFOS and associated guidance as a priority issue, as evidenced by the October 2016 release of the draft *Commonwealth Environmental Management Guidance on Perfluorooctane Sulfonic Acid (PFOS) and Perfluorooctanoic Acid (PFOA).*[40] Land application of biosolids is caught in the middle of this emerging area of study. More extensive testing and subsequent modernisation of the biosolids management framework, considering PFOS at a minimum, is growing in urgency.

[40] Australian Government Department of the Environment and Energy, DoEE (2016), *Commonwealth Environmental Management Guidance on Perfluorooctane Sulfonic Acid (PFOS) and Perfluorooctanoic Acid (PFOA) draft*, available from: https://www.environment.gov.au/system/files/pages/dfb876c5-581e-48b7-868c-242fe69dad68/files/draft-environmental-mgt-guidance-pfos-pfoa.pdf (accessed 6.02.17)

6. RECOMMENDATIONS

The brief overview of emerging issues in the convergence of the water and waste sectors and associated case studies has highlighted the need for the water and waste sectors to not only communicate across sectoral boundaries but also ensure that regulators and decision-makers in each sector are aware of what each sector is doing. To that end suggested recommendations to aid the water and waste sectors move in that direction include the need to facilitate:

- ***Increasing engagement between water and waste regulators***

  Industry and government decisions pertaining to water must take into consideration waste sector opportunities and impacts and vice versa. State and federal level environmental protection agencies that regulate waste, hazardous waste and receiving water pollution etc. need to actively open dialogue with WSAA and the key water/wastewater utilities to discuss the emerging issues, current regulatory and decision making frameworks, what might need to change and how to potentially create consistency in approach across states and territories.

- ***Increasing communication across water and waste practitioners***
  From the regulators through to the practitioners in the water and waste sectors greater awareness of what each sector is doing is required. Hence greater focus in environmental, water and waste conferences on knowledge sharing of the emerging issues and opportunities to stimulate cross-sectoral debate and generation of solutions

- ***A co-ordinated approach to planning and managing waste streams***

  Levies and incentives to manage waste streams in the water and waste sectors need a more holistic view using a broader systems thinking approach to assist in driving in the same direction and allowing for more context specific solutions.

- ***Monitoring and evaluation of emerging waste streams across sectors:***

  New waste streams are constantly emerging in the water and waste sectors (e.g. EDCs, POPs, CSG waste streams). These chemicals and pollutants are emerging in some cases without the technology or science to manage them. Greater collaboration between the water and waste sectors on developing monitoring and evaluation frameworks is required to streamline such processes and reduce testing costs.

- **A co-ordinated approach to assessment of research needs**
  The water and waste sectors need to identify opportunities and risks in emerging areas of convergence and assess priority research needs to assist in finding clarity in the issues and potential solutions.

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