

# **On Site Remediation of Micropollutants from Stormwater for Reuse**

By

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## CERTIFICATE

I certify that this thesis has not already been submitted for any degree and is not being submitted as part of candidature for any other degree.

I also certify that the thesis has been written by me and that any help that I have received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

Signature of Candidate

.....  
(Thamer Mohammed Ahmed Mohammed)

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## Nomenclature

A	=	Surface area (m <sup>2</sup> )
AC	=	Activated Carbon
ANZECC Council	=	Australian and New Zealand Environment and Conservation Council
ASTM	=	American Standard Testing and Methods
BV	=	Bed Volume
BMP	=	Best Management Practice
BOD	=	Biological Oxygen Demand
BOM	=	Biodegradable Organic Matter
C <sub>b</sub>	=	The concentration of particles in a feed water
COD	=	Chemical Oxygen Demand
Da	=	Dalton
DOC	=	Dissolved Organic Carbon
DOM	=	Dissolved Organic Matter
DMF	=	Dual media filter
EF	=	Enrichment Factor
EfOM	=	Effluent Organic Matter
GAC	=	Granular Activated Carbon
EPS	=	Extracellular Polymeric Substances
FAO	=	Food Agriculture Organisation for the United Nation
h	=	hour
HFO	=	Hydrous Ferric Oxide
HPSEC	=	High Pressure Size Exclusion Chromatography
IE	=	Ion Exchangers
kPa	=	Kilo Pascal
MFI	=	Modified Fouling Index

MWD	=	Molecular Weight Distribution
MF	=	Microfiltration
MFI-UF	=	Modified fouling index by using ultra filter membrane
MFI-NF	=	Modified fouling index by using nano filter membrane
MWCO	=	Molecular Weight Cut-off
$M_w$	=	Weight Average Molecular Weight
$M_n$	=	Number Average Molecular Weight
NF	=	Nanofiltration
NOM	=	Natural Organic Matter
NTU	=	Nephelometric Turbidity Unit
PAC	=	Powdered Activated Carbon
PI	=	Pullotion Index
$R_m$	=	Membrane resistance
RO	=	Reverse Osmosis
SEC	=	Size Exclusion Chromatography
SS	=	Suspended Solids
SWOM	=	Seawater Organic Matter
t	=	Filtration time (s)
THM	=	Trihalomethanes
TDS	=	Total Dissolved Solid
TMP	=	Trans-membrane Pressure
UF	=	Ultrafilter
ULPRO	=	Ultra Low-pressure Reverse Osmosis Membranes
V	=	Total permeate volume (l)
WHO	=	World Health Organisation
ZVI	=	zero-valent iron
$\Delta P$	=	Applied trans-membrane pressure (Pa)
$\eta$	=	Water viscosity at 20 <sup>0</sup> C (N s/m <sup>2</sup> )
$\alpha$	=	The specific resistance of the cake deposited
$\rho$	=	Polydispersity
<sup>0</sup> C	=	Degree Celsius

## **Abstract**

Water scarcity due to persistent drought is forcing the countries around the world to explore alternative fresh water resources. Australia is the driest inhabited continent, and has one of the most variable rainfall intensities in the world. In the last one hundred years Australia has suffered six major droughts and fifteen less severe droughts. The drought that commenced in 2001 has encouraged the harvesting of stormwater and re-use of water in order to lower the demand placed on municipal water supplies. Urban and industrial stormwater runoff has high potential as a reusable water resource, although it requires treatment due to the presence of several types of contaminants including inorganic ones that have adverse ecological impacts on receiving waters. The main aim of this research was to focus on the identification of contaminants of concern in Australian stormwater and provide suitable remediation solutions with effective onsite treatment practices such as biofiltration and adsorption/ ion exchange column techniques.

Long term biofilter experiments were conducted with raw stormwater collected from a canal at Carlton, in Sydney. Anthracite and granular activated carbon (GAC) were used as a single filter media in biofilter columns. Media heights of 75 and 40 cm were used. The filter columns were operated at filtration velocities of 0.12 and 0.25 m/h. The removal efficiency for turbidity and DOC for the GAC filter media were found to be 75% and almost 100% respectively. The removal efficiency for the anthracite filter was much lower. Molecular weight distribution analysis showed an almost similar trend to the DOC removal. When compared to the anthracite filter media, the GAC biofilter removed a much larger range of organic compounds present in the stormwater. The GAC biofilter removed organic matter earlier as compared to the anthracite filter. Based on a limited sample of stormwater, the removal efficiency for phosphorus was upto 74% and that of nitrogen was up to 30%. In general, the GAC filter showed higher heavy metal removal efficiency than the anthracite filter. The removal of zinc, iron, lead and nickel were good, however, the concentration of heavy metals in the raw surface water sample was low.

In another study, Organic matter removal from a diluted synthetic landfill leachate was studied using a GAC biofilter. This filter with a depth of 35cm was found to remove a

significant amount of organic matter from the diluted synthetic landfill leachate. The experiments were conducted at low (0.2 m/h) and high (2 m/h) flow velocity through the GAC filter to represent insitu and exsitu biofiltration. The results showed that organic matter can be removed in a consistent manner for a long period of time. GAC bio-filtration led to a consistent TOC removal even after a long period of operation without the need to regenerate the activated carbon. Even after 30-50 days of continuous running, the organic removal efficiency from the GAC bio-filter was approximately 40% and 60% when high (2 m/hr) and low (0.2 m/hr) filtration velocities were used. It should be noted that the performance can be enhanced by using a larger filter depth which is the case in real situations.

A study was conducted using three filters in series to evaluate the efficiency of removal of TOC, turbidity and nutrients from stormwater. The first filter system containing sand removed 70% turbidity and 6% TOC. The second filter system containing GAC removed 99% of the remaining TOC and 43% of the remaining turbidity. The use of a Purolite A520E filter media as the third stage filter was found to be capable of removing up to 89% of nitrate within 6 hours, however no phosphate removal was achieved. Therefore it is vital to have GAC and Purolite as a media in filtration system along with sand to achieve organic and nutrient removal.

Combined removal of a mixture of heavy metals (Cd, Cu, Ni and Zn) and an oxy anion of Se (predominantly selenate species,  $\text{SeO}_4^-$ ) from a synthetic stormwater sample was investigated by their sorption on hydrous ferric oxide (HFO) (5%), HFO+Ca(OH)<sub>2</sub> (6%), and HFO+Ca(OH)<sub>2</sub>+MnO<sub>2</sub> (7%) in columns containing 93-95% anthracite, conducted under seven intermittent runoffs (wetting and drying) each of 8 h duration within a 40 h period. The contaminants removal behaviour varied between the ions and between the sorbents as well as with flow rate and time. The removal efficiency was greater at a low flow rate (0.75 m/h) than at a high flow rate (1.5 m/h). At the initial period when Ca(OH)<sub>2</sub> produced elevated pHs, the HFO only column removed less heavy metals but more Se than the HFO+Ca(OH)<sub>2</sub> columns. With increased time when the pH effect of Ca(OH)<sub>2</sub> became insignificant, the MnO<sub>2</sub> in the column increased the removal of all contaminants. The removal efficiencies (%) at the low flow rate for Cd, Cu, Ni, Zn by the HFO+Ca(OH)<sub>2</sub>+MnO<sub>2</sub> column, and Se by the HFO column were 95-

100, 94-98, 88-99, 96-100, 92-94 for the 1st and 3rd runs and 61-76, 85-88, 51-69, 57-79, 82-88 for the 5th and 7th runs, respectively.

Urban road-deposited sediments (RDS) are potential heavy metal pollution sources of both terrestrial and aquatic environments. A study was conducted to determine the heavy metals enrichments, their possible sources and potential bioavailability and mobility in RDS from nine sites along major motorways of Sydney, the largest city with highest road traffic density in Australia. The results showed that the mean total concentrations of metals in the RDS decreased in the order, Fe > Mn > Zn > Cu > Cr > Pb > Ni > Cd. The corresponding order in the background soils (minimally contaminated from roads) was Fe > Mn > Zn ~ Ni > Cu ~ Pb > Cr > Cd. Both the pollution index (PI) and metal enrichment factor (EF), which are comparative measures between contaminated and uncontaminated sites were highest for Cu and Zn suggesting that Cu and Zn inputs to RDS were mainly the likely result of brake and tyre wear, respectively. Cluster and correlation analyses showed that while the concentrations of these two metals were related in the soil, they were not correlated in the RDS. Low PI and EF values as well as the close inter-relationships of Fe, Mn, Cr and Ni in both RDS and soils, would suggest that these metals were derived mainly from natural sources. Metal fractionation data showed that 50-95% of Cr and Fe in RDS were present in the immobile and bio-unavailable residual fraction, whereas 15-65% of Zn was contained in the exchangeable fraction which is considered to be mobile and bioavailable. Significant quantities of Mn, Ni, Cu, Pb and Cd were detected in all fractions, although the residual fraction contained the majority in all instances. Copper was the only metal appreciably present (5-25%) in the organic fraction.