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Water Quality in Rainwater Tanks in Rural and Metropolitan Areas of New South Wales, Australia

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ABSTRACT

This paper compares the water quality of rainwater tanks throughout the Sydney metropolitan area to that in rural New South Wales, Australia. The water quality is compared against the Australian Guidelines for Water Recycling (AGWR) to determine if the untreated rainwater from both areas can be considered suitable for non-potable water supply without filtration. Additionally this paper reports on a set of experiments where rainwater collected from a typical domestic roof in Sydney, New South Wales, Australia was treated by a pre-treatment of granular activated carbon (GAC) adsorption filter followed by micro-filtration. The GAC column removed the pollutants through an adsorption mechanism. GAC is a macroporous solid with a very large surface area providing many sites for adsorption and it is this property that makes it an efficient adsorbent. The parameters analysed were ammonia, anions and cations, heavy metals, nitrate and nitrite, pH, total hardness, total organic carbon, total suspended solids and turbidity. The results indicate that before treatment, the rainwater already complied to many of the parameters specified in the AGWR, certain pollutants have the potential at times to exceed the AGWR. The water quality was within the AGWR limits after the treatment. The micro-filtration flux values demonstrate that rainwater was able to be filtered through the membranes under low gravitational heads that are typically available in a rainwater tank while still producing sufficient membrane flux and pollutant removal rates.

Keywords: Rainwater, Characterisation, Membrane filtration, Granular activated carbon, Bio-filtration, Adsorption, Heavy metals, Nutrients

1.0 INTRODUCTION

Although many Australians receive their domestic water supply from reticulated mains or town water there are vast areas of Australia with low population densities with no reticulated supplies (Australian Bureau of Statistics 2001). In many of these areas, rainwater collected in tanks is the primary source of drinking water. Even in areas that are serviced by town mains water, many households, schools, community and commercial centres collect rainwater in rainwater tanks to augment supplies or provide alternative and sustainable sources of water. In Australia a prolonged drought has occurred and has lasted since the late 1990's. Widespread water restrictions, as a result of the drought, in recent years in cities such as Sydney, Adelaide and Brisbane have brought to prominence water conservation measures, including the use of rainwater tanks.

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Heavy metals have recently become a concern as their concentration in rainwater tanks was found to exceed the recommended levels making it unsuitable for human consumption (Magyar et al 2007, Magyar et al 2008, Han et al 2006, Simmons et al 2001, Schets et al. 2010, Oosterom et al. 2000). Kus et al (2010) found high concentration in lead in roof runoff collected in Sydney. Rainwater storage tanks also accumulate contaminants and sediments that settle to the bottom of the rainwater tank over time. According to Magyar et al (2007, 2008), it is common to find contaminants in Melbourne rainwater tanks that exceed safe levels for potable water. In particular, Magyar et al. (2007) was concerned with levels of lead that exceeded safe levels for potable water by up to 35 times. Other heavy metals that exceeded the safe levels were aluminium, cadmium, iron and zinc. These studies that found high concentrations of heavy metal all sampled rainwater in urban areas. It is noteworthy that in Australia there is frequent occurrence of metal roofs in both urban and rural settings.

This paper compares the water quality in 11 rainwater tanks located in the Sydney metropolitan area in Australia that were previously reported (Kus et al., 2010) and 5 rural rainwater tanks located 160 km south west of Sydney, Australia and with the Australian Guidelines for Water Recycling (2009) (AGWR). The AGWR provides an authoritative reference for recycling readily available water resources such as water generated from stormwater, sewage and grey water and for augmentation of water supplies. Rainwater collected in the rainwater tank located at Ingleburn, Sydney was pre-treated by granular activated carbon (GAC) followed by membrane filtration to determine the improvements in water quality. Here, the GAC and membrane hybrid system was chosen due to ability for removal of trace heavy metals and microorgnisms. Trace heavy metals and basic water quality parameters were investigated in this study.

2.0 EXPERIMENTAL APPARATUS AND MATERIALS

2.1 Collection and Sampling of Raw Rainwater

In addition to the data collected from eleven rainwater tanks previously sampled in the metropolitan area of Sydney, New South Wales, Australia, (Kus, 2010), detailed sampling was carried out on five rural rainwater tanks located in the Kangaroo Valley, which approximately 160 km southwest of Sydney. The rainwater tanks ranged in age from 10 to 25 years of age, were constructed from various materials including PVC, concrete and galvanised steel, and all collected water off Colorbond (ie steel with a zinc/aluminium alloy coat) roof. The houses are located in a rural country area with lower vehicular activity compared to Sydney. As there is no town supply, all residents rely upon these rainwater tanks as their main drinking water supply.

2.2 Laboratory Water Quality Analysis

Detailed laboratory analysis was carried out on water collected in the rainwater tanks and the effluent of the treatment system to determine its quality and how it compares against the AGWR. The pollutants analysed were ammonia, anions and cations, heavy metals (aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver and zinc), mineral salts (calcium, magnesium, chloride, potassium, sodium and sulphate), nitrate and nitrite, pH, total hardness, total organic carbon (TOC), total suspended solids (TSS) and turbidity. These pollutants are the typical range of physical and chemical parameters that characterise water for water reuse purposes. The testing methods are given in Kus (2010).

2.3 GAC Pre-Treatment

The adsorbent medium used was Granular Activated Carbon (GAC) supplied by James Cumming, Australia. The prepared GAC filter media was packed in the flow column up to a bed depth of 300 mm with its flow rate regulated. The flow column was 2000 mm in length with an internal diameter of 100 mm. The column contained tap junctions at 250 mm increments along both sides of its length with an open top. Although the GAC column removed the pollutants through an adsorption mechanism during the initial few hours of operation, biosorption was found to be the mechanism during the long term. The influent hose was connected to one of the side taps and a tap junction was installed at the base for the effluent which was then plumbed to the MF membrane filtration vessel. The indicative apparatus setup is shown in Figure 1.

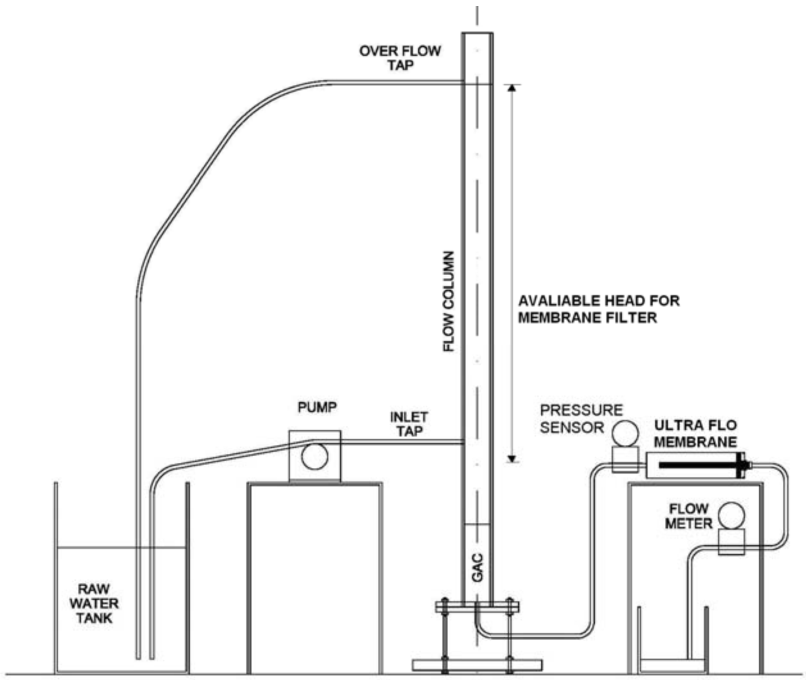

Figure 1 GAC adsorption - membrane treatment set-up

The water level above the GAC media was regulated at various heights in accordance with the required gravitation head height above the MF membrane. The excess influent overflow over the regulated water level was drained by gravity back into the raw feed tank. The raw feed tank was located within the laboratory and was constructed from similar polyethylene as the original rainwater tank source water. The feed tank contained a volume of 300 L which was periodically topped up when required from the residential dwelling's larger rainwater tank. As such, the uniformity of the feed water varied with time as periodic rainfall occurred and topped up the rainwater tank. All influent values from the feed tank were analysed when sampling the effluent water to monitor changes in the rainwater over time.

2.4 Membrane Filtration

Membrane filtration experiments were carried out using a polymeric membrane from Ultra Flo, Singapore. The pore size was 0.1 μm and the filter area was 0.3 m^2. The flow was from outside in. This system was tested in a dead end filtration mode. The membrane was located horizontally with water head pressure above the membrane, Figure 1. The flux decline procedure begins with a clean membrane filter to manufacturers specifications followed by a benchmark flux test using distilled water at 10 kPa to ensure a uniform starting condition between each flux decline test. Each flux decline test was analysed under a constant water heads of 0.15 and 1 m. Data logging equipment was utilised to monitor the flow rates and the trans-membrane pressures associated with the experimental procedures. Water analysis samples were collected at each stage of the process including a raw rainwater sample, the pre-treated water sample after passing through the GAC pre-treatment and after passing through the membrane filter during some of the flux decline tests.

3.0 RESULTS AND DISCUSSION

3.1 Comparison of Water Quality in Metropolitan and Rural Rainwater Tanks

The concentration of pollutants from the samples collected from the metropolitan and rural rainwater tanks T1 to T11 and R1 to R5 respectively, are shown in Table 1.

3.1.1 Anions and Cations, Total Dissolved Salts, Water Hardness and pH

Anions and Cations in the form of mineral salts are a part of our daily dietary intake. The AGWR does not provide any recommended limits for these parameters although analysis of metropolitan potable water (Sydney Water Corporation) showed that the metropolitan rainwater were generally equivalent to or had lower concentrations of sodium, calcium, magnesium, chloride and sulphate. The only parameter that was higher in concentration than the potable water supply was potassium in the metropolitan rainwater tanks. The rural rainwater tanks generally had low concentrations of sodium, calcium, magnesium, chloride and sulphate. Again potassium levels were marginally higher than metropolitan potable water.

Total dissolved salts (TDS) are the combined measurement of all anions and cations within the water. The metropolitan rainwater tanks generally had 7-107 mg/L of TDS, while all of the rural rainwater tanks had considerably lower levels of TDS (12-24 mg/L). The TDS of the metropolitan rainwater was 2.8 times higher than that of the rural rainwater. This may be due to the ionised contamination of higher concentration attached with dusts, bird drippings, etc. Compared to the TDS of typical tap water (150-420 mg/L), wastewater (300-1000 mg/L), brackish water (1500-5000 mg/L) and saline water (>5000 mg/L), the TDS from both rainwater tanks was much lower.

Metropolitan rainwater tanks generally had equivalent or lower water hardness to the metropolitan potable water supply. The metropolitan rainwater tanks which contained reasonable buffers or water hardness levels (with the exception of T5) drained from concrete tiled roofs. The metropolitan rainwater tanks which contained low buffers or water hardness levels drained from galvanised colourbond or zincalum metal roofing. All of the rural rainwater tanks had considerably lower water hardness at one third or less than the metropolitan potable water. The rural rainwater tanks all drained from galvanised colourbond roofs and were constructed from PVC with the exception of R4 which was a concrete tank, which actually resulted in the highest water hardness level from among rural rainwater tanks. Water hardness acts as a buffer to the addition of any acidic elements to this system such as animal acids or humic acids from leaves to prevent the pH from resulting in an acidic range.

Table 1 Rainwater Tank water Quality in located in metropolitan and rural areas

	pH*	TDS (mg/L)*	TSS (mg/L)*	Turbidity (NTU)*	Water Hardness (mg/L**)*	TOC (mg/L)*	Iron (mg/L)*	Lead (mg/L)*
AGWR	6.5 - 8.0			< 5	< 200		<0.3	< 0.01
Metro								
T1	6.89 - 7.30 7.13	39 - 71 55.3	0.5 - 17.0 6.2	0.2 -12.0 5.1	17 - 34 27.7	2.17 - 13.26 9.44	0.05 - 4.70 1.69	0.006 - 0.033 0.016
T2	6.71 - 7.49 7.12	30 - 33 31.1	1.0 - 2.0 1.7	0.2 - 2.0 0.9	7 - 8 7.5		0.01 - 0.02 0.02	<0.001 - 0.001 <0.001
T3	7.13 - 7.48 7.28	80 - 99 86.4	1.0 - 2.0 1.3	0.2 - 0.6 0.3	26 - 37 30.2		0.02 - 0.02 0.02	0.001 - 0.006 0.003
T4	6.39 - 8.19 7.27	43 - 48 45.3	0.5 - 2.5 1.2	0.2 - 4.0 2.1	17 - 24 21.9		0.01 - 0.03 0.02	0.001 - 0.029 0.010
T5	5.79 - 7.09 6.52	7 - 9 8.4	1.0 - 12.5 4.8	0.8 - 8.0 3.6	0.6 - 1 0.9		0.07 - 4.18 1.51	0.038 - 0.067 0.049
T6	5.41 - 5.83 5.70	14 - 15 14.5	1.0 - 1.5 1.1	0.4 - 2.0 1.1	0.6 - 2 1.3		<0.01 - 0.08 0.03	0.004 - 0.007 0.006
T7	7.19 - 7.38 7.26	50 - 53 51.9	1.0 - 3.5 1.8	0.6 - 2.0 1.5	27 - 31 28.6		0.01 - 0.06 0.04	<0.001 - 0.001 <0.001
T8	6.64 - 7.45 6.96	80 - 107 91.8	2.0 - 5.5 3.3	0.2 - 6.0 2.7	33 -47 40.0		0.03 - 0.11 0.07	0.001 - 0.017 0.007
T9	6.60 - 8.62 7.54	27 - 35 30.2	1.0 - 2.5 1.5	0.2 - 2.0 1.1	9 - 17 13.2		0.00 - 0.01 0.00	0.001 - 0.001 0.001
T10	6.58 - 7.54 7.10	46 - 67 59.2	0.5 - 3.5 1.8	1.0 - 2.0 1.7	21 - 38 29.2		0.01 - 0.02 0.01	0.008 - 0.021 0.013
T11	6.48 - 6.90 6.74	24 - 40 34.7	0.5 - 1.0 0.8	0.6 - 2.0 1.1	5 - 7 6.0		0.01 - 0.02 0.01	0.001 - 0.008 0.003
Metro Overall	5.41 - 8.62 6.97	7 - 107 46.2	0.5 - 17.0 2.3	0.2 - 12.0 1.9	0.6 - 47 18.8	2.17 - 13.26 9.44	<0.01 - 4.70 0.31	<0.001 - 0.067 0.010
Rural								
R1	6.07 - 6.11 6.09	12 - 15 13.5	<0.5 - 1 0.75	0.7 - 1.0 0.85	2 - 2 2	0.20 - 0.27 0.235	<0.01 - <0.01 <0.01	<0.001 - <0.001 <0.001
R2	5.69 - 5.81 5.75	12 12	<0.5 - <0.5 <0.5	0.6 - 0.8 0.7	2 - 3 2.5	0.33 - 0.37 0.35	<0.01 - <0.01 <0.01	<0.001 - <0.001 <0.001
R3	6.02 - 6.03 6.03	12 - 13 12.5	<0.5 - <0.5 <0.5	0.6 - 0.8 0.7	3 - 3 3	0.49 - 0.58 0.535	<0.01 - <0.01 <0.01	<0.001 - <0.001 <0.001
R4	6.93 - 7.23 7.08	24 24	<0.5 - <0.5 <0.5	0.9 - 1.0 0.95	12 - 12 12	0.47 - 0.50 0.485	<0.01 - <0.01 <0.01	<0.001 - <0.001 <0.001
R5	5.95 - 6.05 6.00	20 - 21 20.5	<0.5 - <0.5 <0.5	0.3 - 0.4 0.35	4 - 5 4.5	0.36 - 0.36 0.36	<0.01 - <0.01 <0.01	<0.001 - <0.001 <0.001
Rural Overall	5.69 - 7.23 6.19	12 - 24 16.5	<0.5 - 1 <0.5	0.3 - 1.0 0.71	2 - 12 4.8	0.20 - 0.58 0.393	<0.01 - <0.01 <0.01	<0.001 - <0.001 <0.001

*1st row-range of value, 2nd row - average value, Values excceding the AGWR (2009) are shown in bold,
** $CaCO_3$ equivalent

The pH analysis demonstrated that the metropolitan rainwater tanks are generally within or close to compliance of the AGWR guideline of between pH 6.5 and 8.5 with the exception of T6 which on average was around pH 5.7. The water hardness of T5 and T6 was rather low at an average value of 0.92 mg/L and 1.26 mg/L of $CaCO_3$ respectively which indicates that there is little water buffer. With the addition of any acidic elements such as from bird droppings or humic acids from leaves, the pH of these rainwater tank would be expected to drop rapidly. This seems true for T5 which is actually approaching the minimum limit with a pH 6.52. With all rural rainwater tanks having considerably low water hardness, it is not surprising that all rainwater tanks except R4, at times, do not comply with the pH limit of 6.5 resulting in acidic rainwater conditions.

3.1.2 Ammonia, Nitrate, Nitrite and Orthophosphate

With regards to ammonia, nitrate, nitrite and orthophosphate, all metropolitan and rural rainwater tanks complied with the AGWR limits of 0.5 mg/L, 50 mg/L, 3 mg/L and 1 mg/L respectively.

3.1.3 Turbidity and Total Suspended Solids (TSS)

The AGWR has a recommended limit of turbidity of 5 NTU. Metropolitan rainwater tanks T1, T5 and T8 on average complied with this limit although at times this limit was exceeded with the highest individual readings of 12 NTU, 8 NTU and 6 NTU respectively. This was due to a dirty roof on the house draining to T1 and T5 and because the rainfall collected in tank T8 had stirred up sediments within the tank as the volume within the tank was low. All other metropolitan rainwater tanks complied with the 5 NTU limit. All rural rainwater tanks complied and were well below the 5 NTU limit. The general observations made for most of the samples is that the bigger the rainwater tank volume, the lower the turbidity was. This is true for T1 which was the smallest rainwater tank and had the highest turbidity levels. Rural rainwater tanks were larger than most metropolitan rainwater tanks resulting in low turbidity levels with an overall average of 0.71 NTU across the 5 rural rainwater tanks. Possible reason for this observed trend is the larger tanks provide a longer settling time resulting in better turbidity levels, and also because the larger rainwater tanks captures water for a longer duration of a rainfall event. This is because runoff tends to becomes cleaner the longer washoff period from the roof. A small rainwater tanks would only collect the first flush of the rainfall event which contains more polluted wash off from the roof. Minute particles which cause turbidity can act as shields for virus and pathogens when UV treatment is applied UV. If such a treatment is applied downstream, low values of turbidity is important.

The AGWR does not state a limit for TSS. As this is somewhat similar to turbidity it could be assumed that if the turbidity complies with the recommended limits then TSS should also be satisfactory. TSS mostly ranged from less than 0.5 mg/l to 3.5 mg/L in most of the metropolitan tanks when they complied with turbidity of less than 5 NTU except for T1, T5 and T8 which contained concentrations of 5.5 mg/L and above when their turbidity levels exceeded 5 NTU. All samples from the rural rainwater tanks had a TSS of 1.0 mg/l or less.

3.1.4 Total Organic Carbon (TOC)

Although the AGWR does not recommend a limit for TOC, a range of specific organic contaminants such as pesticides are regulated or stated in the guideline. A high TOC value of raw rainwater would be of concern. The influent rainwater samples for the metropolitan rainwater tanks contained an average value of 9.44 mg/L with a range of 2.17 mg/L to 13.26 mg/L, while the rural rainwater tanks contained a much lower average value of 0.393 mg/L within a range of 0.20 mg/L to 0.58 mg/L.

3.1.5 Heavy Metals

The water from the majority of both metropolitan and rural rainwater tanks complied with the AGWR for most of the heavy metals tested with the exception of iron and lead. The metropolitan rainwater tanks T1 and T5 averaged under the AGWR iron limit of 0.3 mg/L however each tank contained at least one sample over this limit with individual results of 4.70 mg/L and 4.18 mg/L respectively. The rural rainwater tanks however all complied with AGWR with all samples of iron concentrations measuring at the detectable limit of 0.001 mg/L.

The lead concentration was a concern with individual samples and average samples from most of the metropolitan tanks exceeding the AGWR lead limit of 0.01 mg/L. T1 contained an average of 0.016 mg/L with an upper limit of 0.033 mg/L, T4 contained an average of 0.010 mg/L with an upper limit of 0.029 mg/L, T5 contained an average of 0.049 mg/L with an upper limit of 0.067 mg/L, T8 contained an average of 0.007 mg/L with an upper limit of 0.017 mg/L and T10 contained an average of 0.013mg/L with an upper limit of 0.021 mg/L. The rural rainwater tanks however all complied with the AGWR with all samples of lead concentrations measuring at the detectable limit of 0.001 mg/L.

All other heavy metals were well within the guideline recommended limits. The concentration levels of arsenic, cadmium, chromium, mercury, nickel selenium and silver all showed as negligible concentration of less than 0.001mg/L.

Overall, the water collected in both the metropolitan and rural rainwater tanks generally comply with most parameters specified in the AGWR except for a few individual parameters such as the pH, in the metropolitan and rural rainwater tanks and the turbidity, iron and lead levels from individual metropolitan rainwater tanks.

3.2 Gravity Fed Micro-Filtration (MF)

The flux decline of the MF membrane was monitored for the micro-filter under two different driving head and using rainwater pre-treated with GAC. The results of the flux decline are shown in Figure 2. The flux decline reaches a final stable flux of around 4 to 5 L/m^2/hr regardless of driving head after approximately 100 hours of operation.

3.3 Performance of MF Membrane Filtration and GAC Pre-treatment

While monitoring the flux decline of the Ultra Flo MF filter, grab samples were collected to analyse pollutant removal efficiencies of the GAC pre-treatment and the MF membrane. The removal efficiencies of water quality parameters are shown in Table 2.

3.3.1 Anions and Cations, Total Dissolved Salts, Water Hardness and pH

GAC pre-treatment and MF membrane filtration had little to no effect on removing anions, cations, or reducing the TDS and water hardness. The change in pH was negligible.

3.3.2 Turbidity and Total Suspended Solids (TSS)

The influent rainwater to MF with GAC pre-treatment was already below the recommended AGWR limit (5 NTU) with an average value of 3.1 NTU. The GAC pre-treatment achieved a reduction of turbidity to 1.3 NTU giving a 58% removal efficiency. The MF filtered most of the NTU from GAC pre-treated rainwater and reduced it further to 0.1 NTU (instrument detection limits) giving an overall reduction of 96.8%.

The AGWR does not state a limit for TSS. As this is related to turbidity it could be assumed that if the turbidity complies with the recommended limits then so should TSS. The influent rainwater to the MF membrane treatment with GAC pre-treatment was already quite low with an average value of 1.2 mg/L. The GAC pre-treatment achieved an average reduction to 0.79 mg/L or a 34.2% removal efficiency. The MF membrane filtration reduced TSS to less than 0.5 mg/L (instrument detection limits) which gave an overall reduction of 58.3%. In reality the removal could more as the MF membrane could remove TSS to below detectable limits.

Table 2 MF Membrane Filtration Pollutant Removal With GAC Pre-Treatment

	pH*	**TDS (mg/L)***	**TSS (mg/L)***	**Turbidity (ntu)***	**Water Hardness (mg/L**)***	**TOC (mg/L)***	**Iron (mg/L)***	**Lead (mg/L)***
AGWR Limit	6.5 - 8.0			< 5	< 200		<0.3	< 0.01
0.15m Head + GAC PT								
Influent	6.6 - 7.1 6.9	52 - 72 57	<0.5 - 5 1.4	0.5 - 4.0 1.1	5 - 8 6	2.17 - 3.73 2.71	0.060 - 0.052 0.035	0.001 - 0.006 0.002
After GAC Pre-treatment	6.6 - 7.1 6.9	52 - 61 56	<0.5 - 3 0.77	0.2 - 0.8 0.6	5 - 7 6	0.42 - 1.37 0.75	<0.005 - 0.024 0.013	<0.001 - 0.002 0.001
MF Effluent	6.6 - 7.1 7.0	49 - 57 54	<0.5 - <0.5 <0.5	0.1 - 0.2 0.12	5 - 7 6	0.29 - 0.48 0.39	<0.005 - 0.011 0.005	<0.001 - <0.001 <0.001
1.0m Head+ GAC PT								
Influent	6.7 - 7.0 6.8	105 - 123 112	0.5 - 2.0 1.0	2.0 - 3.0 2.3	42 - 49 44.7	12.30 - 12.38 12.34	0.217 - 0.373 0.261	0.019 - 0.020 0.020
After GAC Pre-treatment	6.8 - 6.8 6.8	80 - 107 97	<0.5 - 1.5 0.8	1.0 - 3.0 2.0	24 - 39 34.0	2.14 - 5.90 4.02	0.200 - 0.260 0.223	0.014 - 0.015 0.014
MF Effluent	6.9 - 7.0 7.0	37 - 112 85	<0.5 - <0.5 <0.5	0.1 - 0.1 0.1	7 - 42 29	0.068 - 2.12 1.09	<0.005 - 0.01 0.007	<0.001 - <0.001 <0.001
Raw Water Metro Overall								
Influent	6.6 - 7.1 6.8	52 - 123 96	<0.5 - 5 1.2	0.5 - 5.9 3.1	5 - 49 30.6	2.17 - 13.26 9.44	0.060 – 0.83 0.375	0.001 - 0 .031 0.018
After Pre-treatment	6.5- 7.0 6.8	52 - 114 89	<0.5 - 3 0.79	0.2 – 3.0 1.3	5 - 39 25.7	0.42 - 7.91 4.23	<0.005 - 0.610 0.282	<0.001 - 0.025 0.013
Effluent	6.6 - 7.1 6.8	37 - 112 78.3	<0.5 - <0.5 <0.5	0.1 - 3 1.1	5 - 42 23.7	0.29 - 4.10 1.86	<0.005 - 0.373 <0.005	<0.001 - <0.001 <0.001

*1st row-range of value, 2nd row - average value, Values excceding the AGWR (2009) are shown in bold,

** $CaCO_3$ equivalent

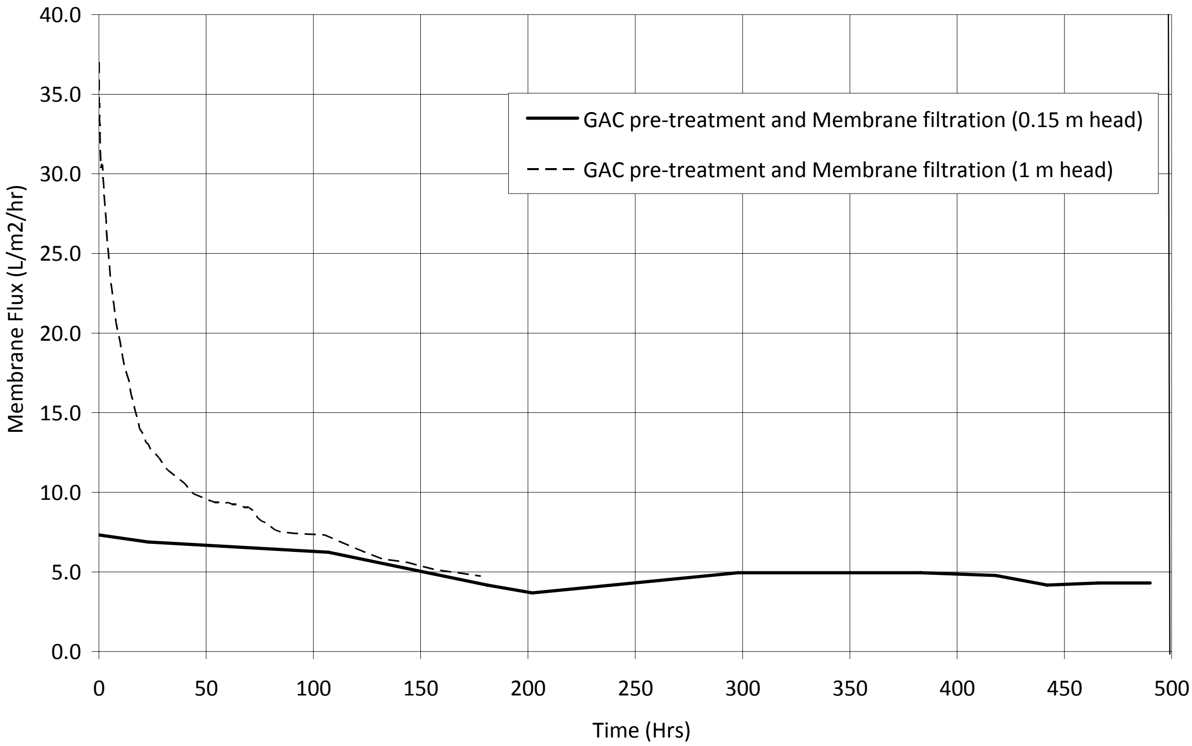

Figure 2 Ultra Flow filter flux decline under various gravity head with GAC pre-treatment

3.3.3 Total Organic Carbon (TOC)

The AGWR does not recommend a limit for TOC. The influent rainwater samples for the MF membrane treatment with GAC pre-treatment contained an average TOC of 9.44 mg/L. The GAC pre-treatment achieved an average reduction in TOC to 4.23 mg/L or a 55.2% removal efficiency. The MF membrane filtered the GAC pre-treated rainwater to 1.86 mg/L which results in an overall reduction in TOC of 80.3%.

3.3.4 Heavy Metals

The AGWR recommends a limit for iron of 0.3 mg/L. The influent rainwater samples for the MF membrane filtration exceeded the recommended limit with an average value of 0.375 mg/L. The GAC pre-treatment achieved an average reduction to 0.282 mg/L or a 24.8% removal efficiency. The MF membrane filtration reduces iron to less than 0.005 mg/L (instrument detection limits) and an overall reduction of more than 98.7%.

The AGWR recommend a limit for lead of 0.01 mg/L. The influent rainwater samples for the MF membrane filtration after GAC pre-treatment exceeded the recommended limit with an average value of 0.018 mg/L. The GAC pre-treatment achieved an average reduction of 0.013 mg/L or a 27.8% removal efficiency of lead. The MF membrane filtration reduced the level of lead to less than 0.001 mg/L (instrument detection limits) which results in an overall reduction of 94.4%.

All other heavy metals were well within the AWGR recommended limits. The concentration levels of arsenic, boron, cadmium, chromium, mercury, molybdenum, nickel selenium and silver all showed negligible concentration of less than 0.001mg/L.

4.0 CONCLUSIONS

Rainwater collected and stored in rainwater tanks has been used for a variety of non-potable purposes. In Australia this use has become very popular as a means of augmenting dwindling water supplies. However no prior testing and analysis has been done to assess the adequacy of this practice. This paper provides such an assessment. It also demonstrates that simple yet effective treatment are available to bring the water quality to desired standards for non-potable purposes.

Detailed sampling and analysis was undertaken to compare eleven metropolitan rainwater tanks with five rural rainwater tanks located 160 kilometres south west of Sydney, Australia. Overall, the water collected in both the metropolitan and rural rainwater tanks generally comply with the standards for most parameters in the AGWR except for a few such as the pH, in the metropolitan and rural rainwater tanks and the turbidity, iron and lead levels from individual metropolitan rainwater tanks.

Observations of the membrane flux decline show that after approximately 100 hours of operation the flux decline converges to a similar path regardless of the driving water head.

The GAC pre-treatment have negligible effects on anions, cations, TDS, water hardness and pH. The GAC pre-treatment achieves a 58% reduction in turbidity while the MF membrane filtration achieved a reduction in turbidity to instrument detectable levels. This again was true with TSS where the GAC pre-treatment removed 36.7% and the MF membrane filtration reduced TSS to instrument detectable levels. GAC pre-treatment play an important role in the removal of TOC. The MF membrane filtration also contributes to the TOC removal. In regards to heavy metals, the GAC pre-treatment was able to reduce iron and lead by 24.8% and 27.8% respectively while the MF membrane filtration was able to further reduce iron and lead to detectable limits.

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