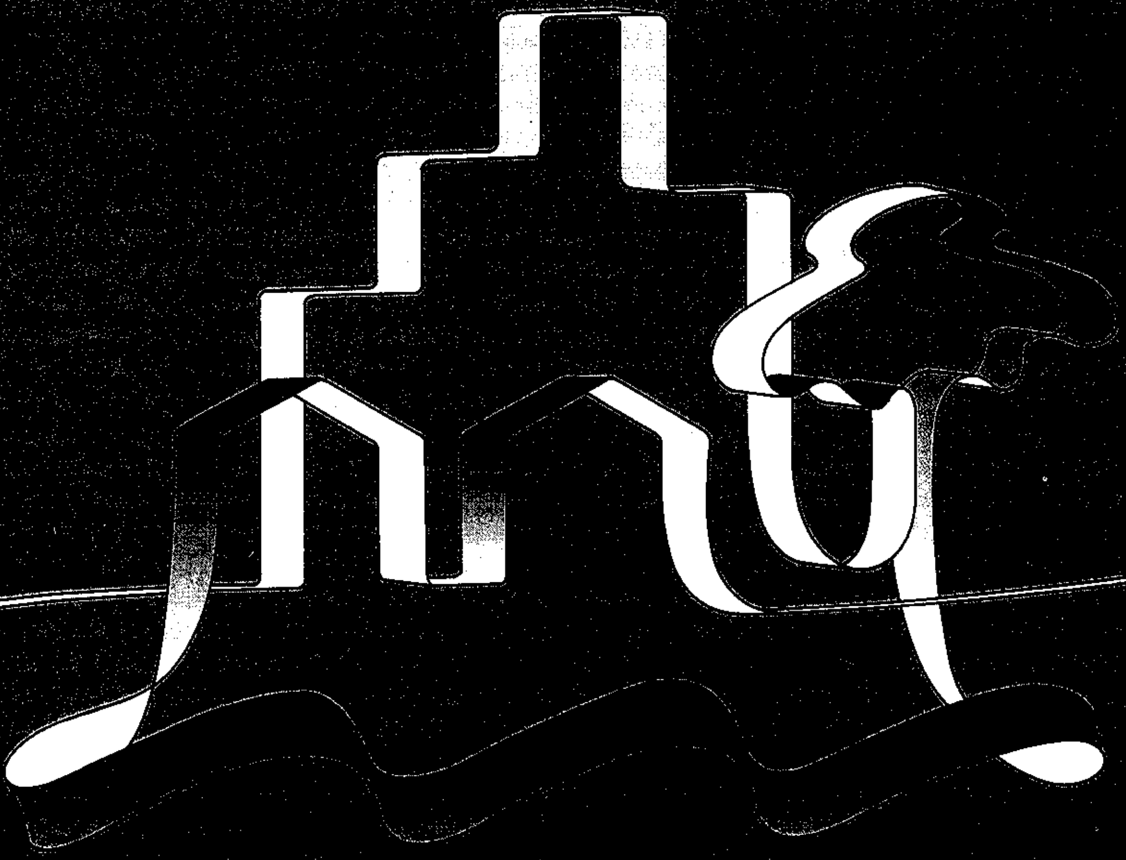
Urban Water Research Association of Australia

Impact on Water Quality of Gross Pollutants



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FOREWORD

This report is based on UWRAA Research Project No WR-11: 'Gross Pollutants in Urban Areas' which was undertaken during the period September 1989 to February 1997. Organisational responsibility for the project was as follows:

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ABSTRACT

Gross pollutants represent a problem of visual pollution but less is known of their chemical impacts on aquatic ecosystems. This paper reports the results of an experiment in which the impact of gross pollutants on water quality was examined. Rubbish (gross pollutants) was retrieved from urban sites in the Lane Cove Valley. The material was sorted and placed in drums containing either deionised water or local urban creek water. Some of the treatments were aerated. Water quality parameters were monitored over 262 days.

Results of the analyses suggest that many gross pollutants are benign in terms of key water quality parameters. However, there are several types of rubbish which will present serious problems. Rubbish left in water for periods in excess of 30 days will degrade water quality. The study suggests that rubbish should be frequently (at least once a month) removed from ponded environments.

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INTRODUCTION

There has been a great increase in solid wastes, especially food packaging, since the technological revolution (Connell, 1974). Many solid wastes, such as plastics, foam, glass, paper, aluminium cans and the like accumulate on urban surfaces as a form of urban sediment. This urban sediment, gross pollutants, can consist of biodegradable materials, such as animal droppings, paper and grass clippings, or non-biodegradable products, such as glass, cans and tyres.

Sator and Boyd (1972) define litter as a "myriad of refuse items which are discarded (intentionally or otherwise) by the public at large. Two major components of this litter are packaging materials of all sorts (paper, plastic, metals, glass, etc) and printed matter (newspapers, magazines, advertising flyers, etc). Another source of litter is the intentional disposal of waste material into the street" (Sator and Boyd, 1972). The nature and sources of gross pollutants, or urban litter, have been described elsewhere (Sator and Boyd, 1972; Molinari and Carleton, 1987; Sheaffer *et al.*, 1982).

Media coverage has highlighted the persistent problems of gross pollutants; Cleaning Australia focuses on gross pollutants. Rubbish is, by its nature, of a large size and therefore conspicuous. It is an obvious sign to the public of water pollution. However, it has long been the view that rubbish is 'biologically insignificant' and the 'least costly problem' of water pollution (Sator and Boyd, 1972; Pitt, 1979; Sheaffer *et al.*, 1982). As a research officer for the Nature Council of NSW once said, "the plastic bottle, polystyrene and swill floating down the creek are the pollution you notice first but ... it was the pollution you couldn't see that was most worrying" (Ms Stricker, reported in Sydney Morning Herald, 4 March, 1989: Survey of Duck Creek).

Whilst data are accumulating on gross pollutant loads in urban streams, less is known about their impact on water quality. Effectiveness of pollution control procedures is related more to the biochemical impact of control than it is to visual impacts. Hence, it is worth knowing the contribution of gross pollutants to the water quality deterioration of urban waterways.

This report describes an experiment in which gross pollutants were treated in laboratory controlled conditions in order to identify their chemical impact on streams in Sydney.

The primary aim of the experiment was to determine whether different types of rubbish (gross pollutants) immersed in water over a period of time would alter water quality. The experiment was based on the assumption that rubbish immersed in water will produce leachates which alter water chemistry. The experiment was oriented towards the impact on water quality and less attention was paid to the micro-biochemical processes that cause the changes in water quality. The aims of the experiment were:

- to determine whether biodegradable rubbish produces leachates;
- to determine whether non-biodegradable rubbish produces leachates;
- to determine changes in leachate production over time;
- to establish the types of rubbish and the aeration conditions which have the most significant effect on water quality.

The essential element of the experiment was to place representative samples of rubbish in drums of different types of water, subject them to different aeration treatments, and monitor the change in water quality over time.

REVIEW

There has been limited documentation and research on rubbish and its effects on water quality in urban waterways. With the increase in the amount of disposable goods and population densities in urban areas, the rubbish or waste disposal problem has become a priority. Media coverage has highlighted the persistent problem which has existed for many years. Most of the concern has been with the socio-cultural aspects of rubbish in waterways. Numerous complaints have prompted localised investigations and public interest for the reason that it is aesthetically unpleasing and inhibits passive and recreational activities. There are factors to consider other than the socio-cultural aspect of water quality. Little is known of the direct and indirect effects of rubbish on the physical, chemical and biological aspects of water quality.

Rubbish consists of a wide range of materials which may have different effects on water quality. Waste products can be examined in terms of organic and inorganic or biodegradable and non-biodegradable materials. For the purpose of this study the latter classification will be used. The effects of rubbish, particularly non-biodegradable products, are unknown. Reports describe the effects to be minor. They are;

1. visually unpleasing, reducing the environmental and recreational values of water;
2. a hindrance to recreational activities as a result of increased siltation from flow retardation;
3. may provide increased space and shelter for biological activity, the accumulation of fine sediments and the growth of algal mats; many materials such as cans, bottles, pieces of hosing and tyres have a large surface-area to volume ratio (Molinari and Carleton, 1987);
4. exert an oxygen demand but much lower than sewage (Molinari and Carleton, 1987).

Urban aquatic ecosystems are fragile environments (eg Lawrence, 1995; Riley and Banks, 1996). The presence and breakdown of rubbish in waterways may result in the loss of habitats through additional nutrients, toxic chemicals, introduction of organisms and foreign substances. This may reduce the chances of survival and reproduction of many organisms. Similarly, the accumulation of rubbish in waterways may cause a reduction in the capacity of the drainage ways and storages.

Leachate production from municipal landfills is a well-studied area of research with aerobic and anaerobic processes being well understood (Andreottola and Cannas, 1992; Henry and Heinke 1995, p.607). There are significant difference between solid waste disposal sites and open channel environments. In urban streams the waste is more likely to be subject to aeration, there is no deliberate compaction, smaller quantities per unit area are involved, and there is a greater flow of water per unit area through the sites.

The aim of this report is to determine the physio-chemical effects of rubbish on water quality. A laboratory experiment used 20 high-density plastic drums containing different types of rubbish under different conditions. Leachate samples were collected at designated time periods between December 1990 and September 1991 and the physio-chemical parameters measured.

METHOD

The essential elements of the method used in this study were to place rubbish of different composition into waters subject to different treatments (aerated and not aerated) and examine the changes in water chemistry over an eight month period.

Due to the variety of influences on water quality which occur under natural conditions there were many factors to consider in designing the laboratory experiment. The factors considered were;

- the representativeness of the rubbish loads;
- surface-area to volume ratios and representative particle size of individual rubbish components;
- oxygenated conditions versus low oxygen conditions.

Factors such as temperature, wind, light and flow conditions were constant under laboratory conditions. Representative samples of rubbish loads were determined according to the following considerations.

DETERMINATION OF REPRESENTATIVE RUBBISH LOADS

A local study of the composition of rubbish collected from three field sites on the Cooks River catchment, Sydney by Neilson and Carleton (1989) provided a useful guideline for the determination of representative laboratory rubbish loads. Neilson and Carleton (1989) examined whether the amount and type of rubbish affected the self-cleansing ability of trash racks. Determination of their laboratory samples was based on field data as shown in Table 1. They found that rubbish comprised approximately 36.5% garden refuse, 33.4% plastic and 17.7% paper.

Table 1 Type of rubbish intercepted from Cooks River

Sub-categories of trash (average % volume)

Materials	**Muddy Creek Boom**	**Cup &Saucer Creek**	**Marrickville Trash Rack**
No. of Samples	5	3	4
Glass	0.5	0.7	0.6
Cans	2.6	1.7	0.3
Plastic bottles	9.9	11.2	4.7
Polystyrene foam >50mm	4.9	16.2	18.0
Polystyrene foam < 50mm	2.3	1.3	0.6
Paper cartons	8.9	17.5	13.7
Confectionery wrapping	1.8	0.4	18.8
Garden refuse	46.3	36.0	25.0
Bags & sheeting (plastic & paper)	3.5	1.0	11.8
Deliberately dumped[1]	8.2	12.1	6.1
Miscellaneous	11.1	1.9	0.4

1. Material in rubbish bags

Source: Neilson and Carleton (1989)

Assessment of representative size of individual rubbish types

Fieldwork surveys were conducted to determine the appropriate size of individual rubbish types. Random 1m^2 quadrat surveys were conducted within Creeks in the Terrys Creek Catchment, Macquarie University catchments (College Creek) and at Mackey Park, Marrickville (Fig 1). Individual rubbish items were measured and recorded to obtain the average size of the various rubbish components (Table 2). It was important to establish the average size of individual rubbish components because surface area to volume ratios are an important consideration in leachate rates. The greater the surface area to volume ratio the greater the leachate rate. Surveys were also conducted along urban streets in the North Ryde area, in the vicinity of Macquarie University. These surveys were transects surveys in which 50 metre lines were laid along gutters and the material intercepted by the line measured (Table 3).

Finally, at a later date (1991), a survey began into the actual rubbish loads being transported by College Creek, a small stream passing through Macquarie University. This consisted of installing a specially designed litter trap (Fig 2) and cleaning it after storm events. While the study did not conclude, a number of samples were retrieved and sorted according to composition. These data (Table 4) indicated the composition of loads rather than deposits within the drainage lines.

From the surveys it was found that 90% of hard non biodegradable products such as bottles, cans and tetra drink packs remained the same size as they were transported within the catchment. In contrast 90% of biodegradable products, for example leaf litter and paper, and soft non biodegradable products such as plastic bags confectionery, packaging and non plastic lined cardboard cartons were reduced in size as they were transported across the catchment into the receiving basins. These products therefore had a greater surface area to volume ratio.

On the basis of previous studies and the field surveys a representative rubbish was constructed, as detailed in Table 5. There will always be variation in the composition of rubbish in different sections of a catchment. The aim of developing a 'typical rubbish' was to ensure reproducability of experiments, although we always accepted that there would be no such entity as a typical rubbish and even the 'typical rubbish' samples would have some variability in them.

Table 2 Average size of assorted items intercepted in 1m^2 quadrats for College Creek, Macquarie University, Terrys Creek, Epping and Mackey Park, Marrickville (June - July 1989)

Items	Average size range (cms)	Comments
Glass bottles	6*22	Generally entire material
375ml cans	6*12	Generally entire material
tetra packets	9*7	Generally entire material
Polystyrene foam <50mm	2*1.5	Usually < ½ of original
Polystyrene foam >50mm	6*5-10*7	Usually < ½ of original
Confectionary wrapping	12*6-9*5	Always smaller than original
Bags and sheeting (paper and plastic)	13*5	Usually < ½ of original
Cigarette buts	1.5*0.5	Generally only buts left - either filter plus paper or separate leaves
Vegetation	9*2-13*2	

Table 3 Summary of transect studies (June-July 1989)

Number of samples	Eden Park Estate North Ryde (average number/ 50m transect)	Lane Cove Road between Waterloo and Talavera Rds (average number/ 50m transect)	Macquarie University (average number/ 50m transect)
Glass	0.6	2.6	0.3
Cans	0	0	0.3
Plastic	0.6	0.3	0.3
Polystyrene foam >50mm	1	0.6	0.3
Polystyrene foam <50mm	1	4	1
Confectionary wrapping	5	6	5
Garden refuse/Vegetation litter as %	60	45	70
Bags and sheeting (paper and plastic)	8	17	9
Deliberately dumped	13	5	5
Miscellaneous	10	3	5
Cigarette remnants	12	48	7

Table 4 Summary of analysis of rubbish intercepted in trash rack at College Creek, Macquarie University in 1991 (g)

Date	9 Jul	13 Jul	10 Sep	11 Sep	26 Sep	25 Oct	15 Nov	20 Nov	29 Nov
Height of flow (cm)	78	48	82.5	20.5	42.0	127	95	10	20.5
Vegetation	903	123.91	2196.38	45.15	550.68	3681.25	2792.75	243.77	1937.99
Glass									
Cans/tetra drink packets	71.63		33.7	67.42	17.99		17.23		
Plastic	16.23		88.18		15.33	23.93	12.04	2.77	14.64
Polystyrene <50mm	2.82	168	11.93	0.95	8.21	2.4	5.15		0.16
Polystyrene >50mm			2.9		4.84		2.65		
Confectionary wrapping and cigarette foil	9.0	0.74	5.39		18.35	4.63	3.84	0.58	4.10
Bags and sheeting (plastic and paper)	26.75	0.28			17.87	12.03	11.78		6.33
Deliberately dumped									
Miscellaneous	427.34	50.38	39.98	3.23	33.7	160.69	1.73		12.79
Cigarette butts	10.25	1.61	10.4		1.81	7.19	9.6	0.52	1.15
Comments	421.52 fat	24.38 fat		snail shells	678.78				
Total (g)	1467.04	178.6	2388.86	117.19	678.78	3892.12	2856.97	247.64	1977.76

Table 5 Composition of rubbish sample used in experiments

Biodegradable rubbish (60% by volume: approx. 250g)
- 2 sheets newspaper
- 1 piece of fruit eg apple core
- 20 cigarette butts
- 75g leaves (exotic and native)
- 50g bark/twigs

Non-biodegradable rubbish (40% by volume)
- 2 aluminium cans
- 1 food container
- 1 1L PET bottle
- 1 750mL glass bottle
- 2 pieces cigarette foil
- 1 plastic drink lid
- 2 plastic shopping bags
- 20 pieces packing foam
- 2 straws
- 2 confectionery wrappers

For the purpose of the laboratory experiments bottles, cans, plastic straws, tetra drink packs were immersed as the whole size. Plastic bags were divided into three parts, polystyrene foam ranged from 1cm cubes to 6cm cubes, cigarettes were usually butts and cigarette packets were divided into two. Paper was torn into two to three pieces. Leaf litter and grass clippings were used in the condition they were collected.

EXPERIMENTAL DESIGN

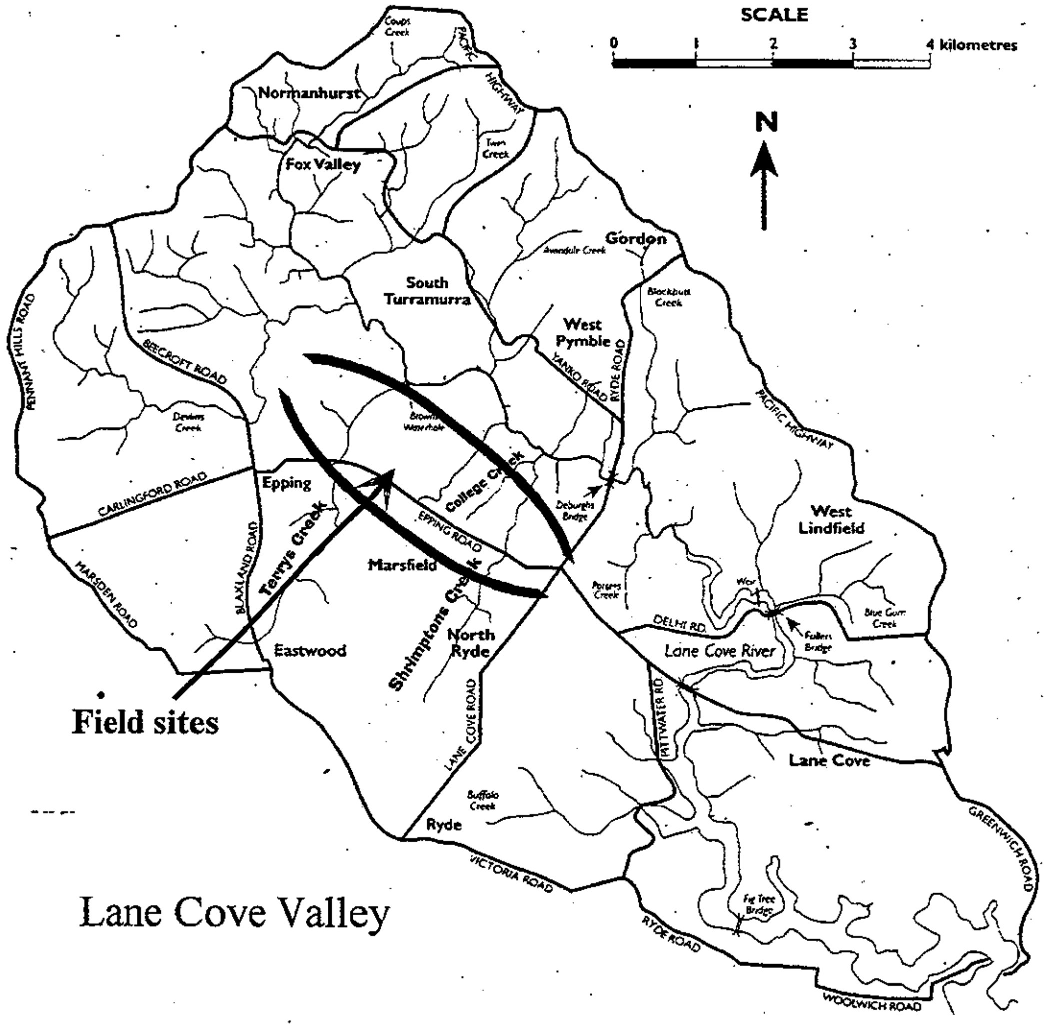
Significance of oxygen conditions

Urban hydraulic conditions vary in space and time. Quite often oxygen levels become low and have a significant effect on the biochemical processes. The experiment was designed so that certain testing vessels would be constantly aerated with aquarium pumps over the 8 months and the others would remain unaerated. The aim of aerating some samples was to determine whether oxygen conditions affected the rate of leachate from the rubbish.

Water Sampling Containers

High density polyethyene white 60L and 20L containers were used as storage vessels for the water samples containing the different types of rubbish. Colourless drums were chosen due to their inert qualities. These containers are often used as food storage containers. Bowditch *et al.* (1976) recommended low density polyethylene colourless containers or high density polyethylene containers impregnated with iodine to minimise orthophosphate adsorption.

Figure 1 Lane Cove catchment and sampling sites within it



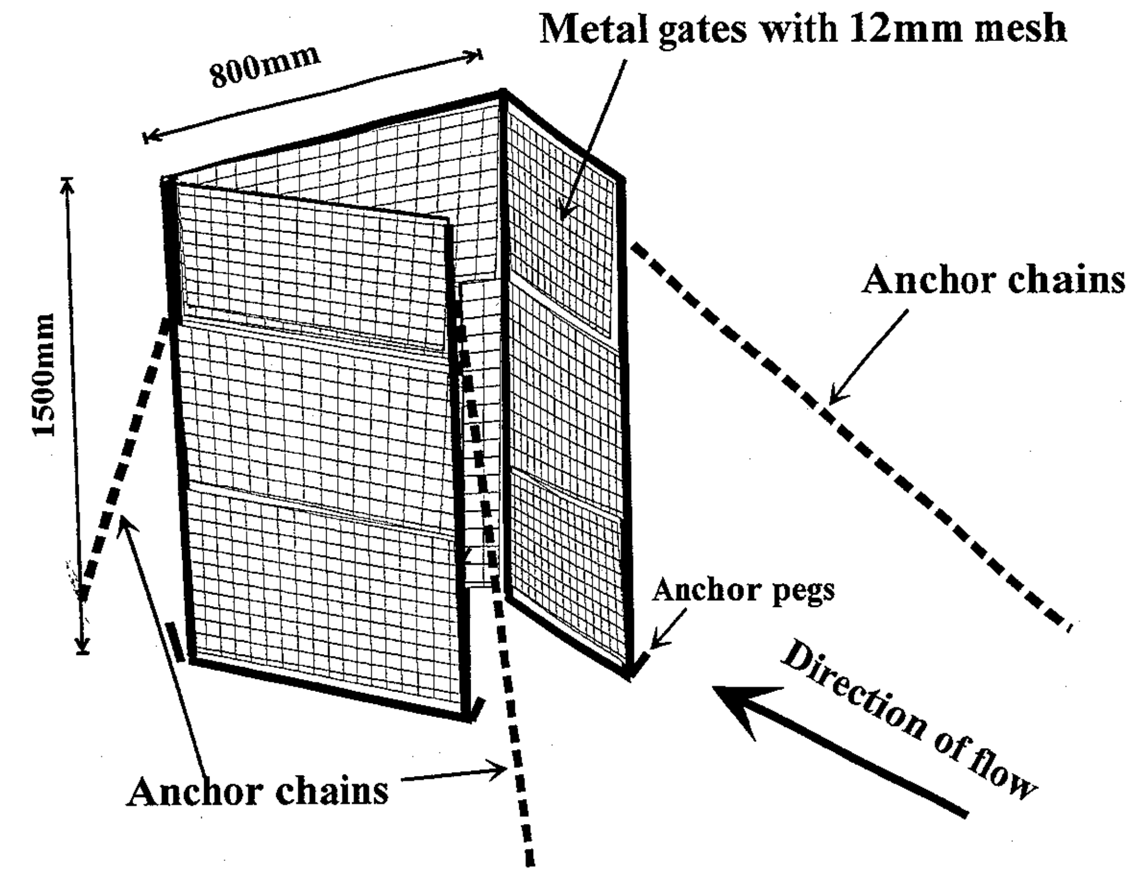


Figure 2 Sketch design of basket sampler for rubbish in College Creek, 1991.

Container preparation

Containers were prepared prior to the addition of water and rubbish samples by washing each vessel with acid water and rinsing several times with deionised water. Vessels were impregnated with an iodine solution and rinsed several times with deionised water before use. Containers were then labelled 1 to 20 and filled with water. Drums 1-6, 13-16 and 19-20 were filled with deionised distilled water. Drums 7-12 and 17-18 were filled with stream water from Terrys Creek, Epping, collected when stream flow was low. The two different types of water were used to determine the difference in leachate rates in the presence of seeded micro-organisms. It was assumed that stream water has solutes and micro-organisms which may affect the leachate rate of the immersed rubbish samples. Deionised distilled water was used to determine the rate of leachate from the rubbish samples alone, although it was realised that communities of micro-organisms would probably develop.

Sampling Preparation

A range of biodegradable and non-biodegradable rubbish items were collected from the College Creek catchment and Mars Creek catchment, Macquarie University and Macquarie Shopping Centre, North Ryde (Figure 1). Samples were collected, placed in plastic bags and taken to the laboratory with minimal delay. In the laboratory the rubbish was sorted, weighed, recorded and delivered to the appropriate storage containers. Rubbish was immersed in the appropriate water sampling containers on the same day of collection to minimise any significant biochemical alteration. Testing of water samples from the various sampling containers commenced 15-18 hours after the rubbish was immersed into the appropriate containers.

The aim of the experiment was to examine the difference between leachate rates for the various types of rubbish under different water and oxygen conditions. Table 4 shows the contents of each water storage container and the associated conditions. Drum 1 contained deionised distilled water and was a control for low oxygen conditions for drums 3, 5, 6, 17 and 20. Drum 2 contained deionised distilled water and was a control for aerobic conditions for drums 4, 13-16 . Drum 7 contained stream water and was a control for low oxygen conditions for drums 9, 11, 12, 17 and 18. Drum 8 contained stream water and was a control for aerobic conditions for drum 10. Drums 3, 4, 9 and 10 contained identical rubbish components however the difference being the oxygen and water conditions under which they were placed. Drums 18 and 20 were replications of drums 9 and 3 respectively. In drums 13-16 the effects of individual products in distilled water under aerobic conditions was monitored. The results for drums 17 to 20 are not presented in the following analysis as they were included as quality control checks and the data has been integrated with their primary duplicates.

Table 6 Sampling strategy

Treatment (Drum Number)	Water	Aerated	Rubbish	Controls and replicates
1	Deionised	Not aerated	No Rubbish	- control for 3,5,6,17,18
2	Deionised	Aerated	No rubbish	- control for 4, 13,14,15,16
3	Deionised	Not aerated	Rubbish	
4	Deionised	Aerated	Rubbish	
5	Deionised	Not aerated	400g biodegradable rubbish	
6	Deionised	Not aerated	Non biodegradable rubbish in state collected	
7	Terrys Creek water	Not aerated	No rubbish	- control for 9, 11,12,19, 20
8	Terrys Creek water	Aerated	No rubbish	- control for 10
9	Terrys Creek water	Not aerated	Rubbish	
10	Terrys Creek water	Aerated	Rubbish	
11	Terrys Creek water	Not aerated	400g biodegradable rubbish	
12	Terrys Creek water	Not aerated	Non biodegradable rubbish in state collected	
13 20L	Deionised	Aerated	Plastic. Non-biodegradable rubbish washed with distilled water	
14 20L	Deionised	Aerated	Cans. Non-biodegradable rubbish washed with distilled water	
15 20L	Deionised	Aerated	Polystyrene. Non-biodegradable rubbish washed with distilled water	
16 20L	Deionised	Aerated	Cigarette butts.	
17	Terrys Creek water	Not aerated	Non-biodegradable rubbish washed with distilled water	
18	Terrys Creek water	Not aerated	Rubbish	
19	Deionised	Not aerated	Non-biodegradable rubbish washed with distilled water	
20	Deionised	Not aerated	Rubbish	

Testing Periods

The laboratory experiment was conducted in two stages due to the number of tests run and the time required to complete each test. Stage one included drums 1-12 and stage two drums 13-20. Stage two commenced 6 weeks after the commencement date of stage one. Nitrogen and phosphorus measurements required approximately 6 hours to complete. To ensue that all tests were completed on the day of sampling both stages one and two were subdivided into two. Drums 1-6 were set up one day prior to drums 7-12. Similarly, drums 13-16 were set up one day prior to drums 17-20. There were nine testing periods within the 8 month period for each stage. With each testing period water samples were collected at the same time of day to minimise effects of possible differences in photosynthetic cycles that may occur within the day.

Samples were tested on days 1, 3, 5, 8, 11, 18, 32, 64, and 262 from the commencement of experiments.

WATER QUALITY PARAMETERS

The parameters listed in Table 7 were tested under controlled conditions for all the different water samples. Details of the procedures are given in Appendix 1.

Table 7 Water quality parameters

Parameter	Method
Total Organic Nitrogen -TON	modified Kjeldahl: APHA-AWWA-WPCF 1989; Bremner 1965 and Lambert 1982.
Total phosphorus - P	stannous chloride method: APHA-AWWA-WPCF, 1989
Suspended solids - SS	APHA-AWWA-WPCF, 1989: 0.45µm filter
Chemical oxygen demand - COD	modified APHA AWWA WPCF, 1989: Jardim and Rohweeder, 1989 microwave digestion
Conductivity - S	APHA AWWA APCF, 1989
Iron - Fe	AAS. APHA-AWWA APCF, 1989: nitric acid digestion and preserved in 0.15ml nitric acid
Lead - Pb	AAS. APHA-AWWA APCF, 1989: nitric acid digestion and preserved in 0.15ml nitric acid (for Treatments 1-12 up to day 18) then Anodic stripping voltammetry: PDV model 2000 by Chemtronics
Copper -Cu	AAS. APHA-AWWA APCF, 1989: nitric acid digestion and preserved in 0.15ml nitric acid then Anodic stripping voltammetry: PDV model 2000 by Chemtronics
pH	Orion model 81 pH meter
Temperature - T	Temperature (°C)
Colour - Co	Visual assessment (see Appendix)

RESULTS

CONTROLS

The controls for the experiments were drum 1 (no rubbish, deionised water and not aerated), drum 2 (no rubbish, deionised water and aerated), drum 7 (Terrys Creek water, no rubbish and not aerated) and drum 8 (Terrys Creek water, no rubbish and aerated)

The means and standard deviations of the parameters for Drums 1 and 2 (Table 8) show some conductivity and slight acidity in the samples. In addition, there were detectable levels of TON and Cu in the controls. The copper readings are of most concern, as they suggest that there is a change in copper concentration during the period of the experiments. Figure 3 shows the changes in the values of the parameters over time and the trend in Cu is most evident. The regressions of copper concentrations on time for both drums 1 and 2 are statistically significant ($P<0.001$ and $P=0.008$ respectively). Why there was an initial high level of copper and why it declined over time for both controls is unknown.

There appears to be abnormally high values for conductivity on day 64, which suggests an instrument error for this day, although there is no evidence of error in the calibration procedure.

Table 8 Controls for aerated and non-aerated deionised water

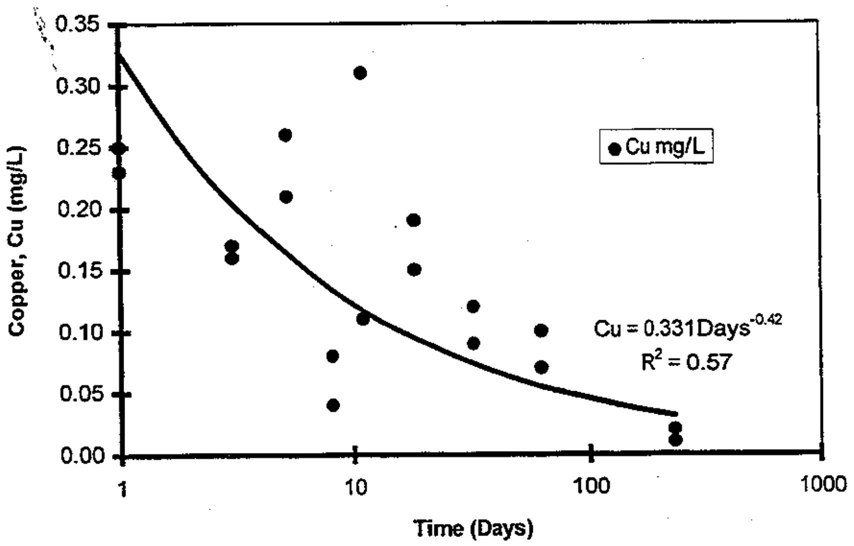
	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Drum 1 (Not aerated)											
Mean	6.44	0.00	0.00	0.00	0.06	24.3	1	12	0.00	0.00	0.14
Std dev	0.14	0.00	0.00	0.00	0.05	2.3	0	22	0.00	0.00	0.09
Drum 2 (Aerated)											
Mean	6.49	0.00	0.00	0.00	0.06	24.0	1	13	0.00	0.00	0.12
Std dev	0.13	0.00	0.00	0.00	0.05	2.2	0	23	0.00	0.00	0.07

While the values of the chemical parameters are much higher for the Terrys Creek control water (Table 9; drum 7 not aerated, drum 8 aerated) than for the distilled water controls (Table 8) there is no evidence of any temporal trends in the data. The Phosphorus levels of drum 7 and 8 increase at day 18 but no statistically significant trends could be found.

Table 9 Aerated and non-aerated Terrys Ck water controls

	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Drum 7 (non-aerated Terrys Ck water)											
Mean	8.04	1.54	0.00	0.47	0.14	24.08	3.00	7078	13.61	0.32	0.13
Std dev	0.28	2.81	0.00	1.33	0.13	1.71	0.00	532	18.84	0.17	0.10
Drum 8 (aerated Terrys Ck water)											
Mean	7.62	1.01	0.00	0.00	0.15	24.19	3.00	7014	30.50	0.20	0.16
Std dev	0.38	1.33	0.00	0.00	0.15	1.81	0.00	558	25.40	0.15	0.14

Drum 1



Drum 2

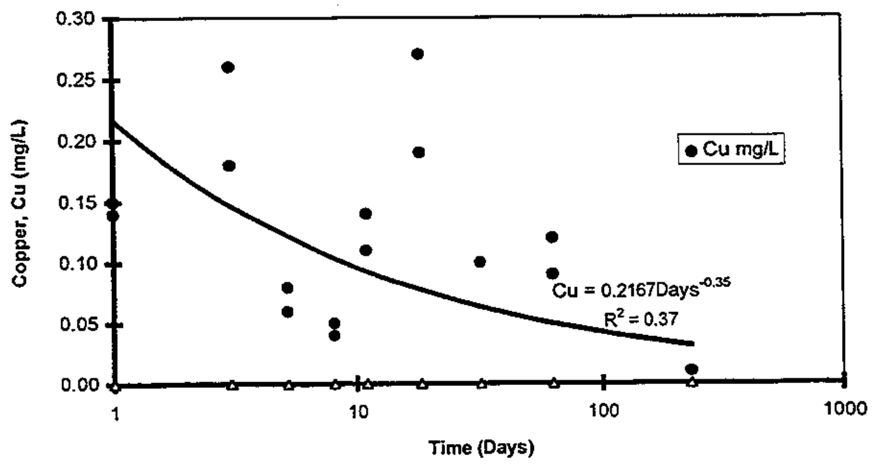


Figure 3 Temporal changes in copper concentrations for aerated and non-aerated deionised water controls

The suspended solids concentration of the aerated drums is zero and significantly less than that of the non-aerated drums. The COD of the aerated drums is higher than that of the non-aerated drums, but not statistically significantly higher.

NON-AERATED RUBBISH

The non-aerated rubbish in deionised water (drum 3) shows temporal trends in the concentration of phosphorus, suspended solids, TON and conductivity (Fig 4). These temporal trends are all significant (Phosphorus, P=0.006; Suspended solids, P<0.001; Conductivity, P<0.001, TON<0.006). On the other hand, the statistically significant trends for the non-aerated rubbish in the Terry Creek water (Fig 4; drum 9) are TON and Suspended solids (P<0.001).

Both experiments show a similar pattern of increasing levels of pollutants and then a decline in concentrations after three or four months. The exception is conductivity of the deionised water experiment, where there is a steady increase throughout the experiment.

The mean values of pH, Suspended solids, Colour, conductivity, COD and iron are lower for the dionised water samples than the rubbish treated in Terrys Creek water. The greatest difference is in conductivity, which is very much lower for the rubbish treated in deionised water.

Table 10 Non-aerated rubbish

	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Drum 3 (Non-aerated rubbish in deionised water)											
Mean	5.13	104	0.02	19.72	1.24	24.2	5.67	1289	572	0.45	0.27
St dev	0.73	104	0.02	7.82	0.56	2.5	1.53	713	602	0.15	0.21
diff	-1.31	104	0.02	19.72	1.18	-0.02	4.67	1276	572	0.45	0.13
Drum 9 (Non-aerated rubbish in Terrys Ck water)											
Mean	6.56	76	0.00	27.67	1.31	24.3	8.78	7669	237	1.66	0.08
Std dev	0.38	41	0.00	46.30	1.17	2.0	0.99	718	106	0.65	0.07
diff	-1.48	75	0	27.2	1.17	0.3	5.78	590	224	1.34	-0.05

diff = mean - control mean

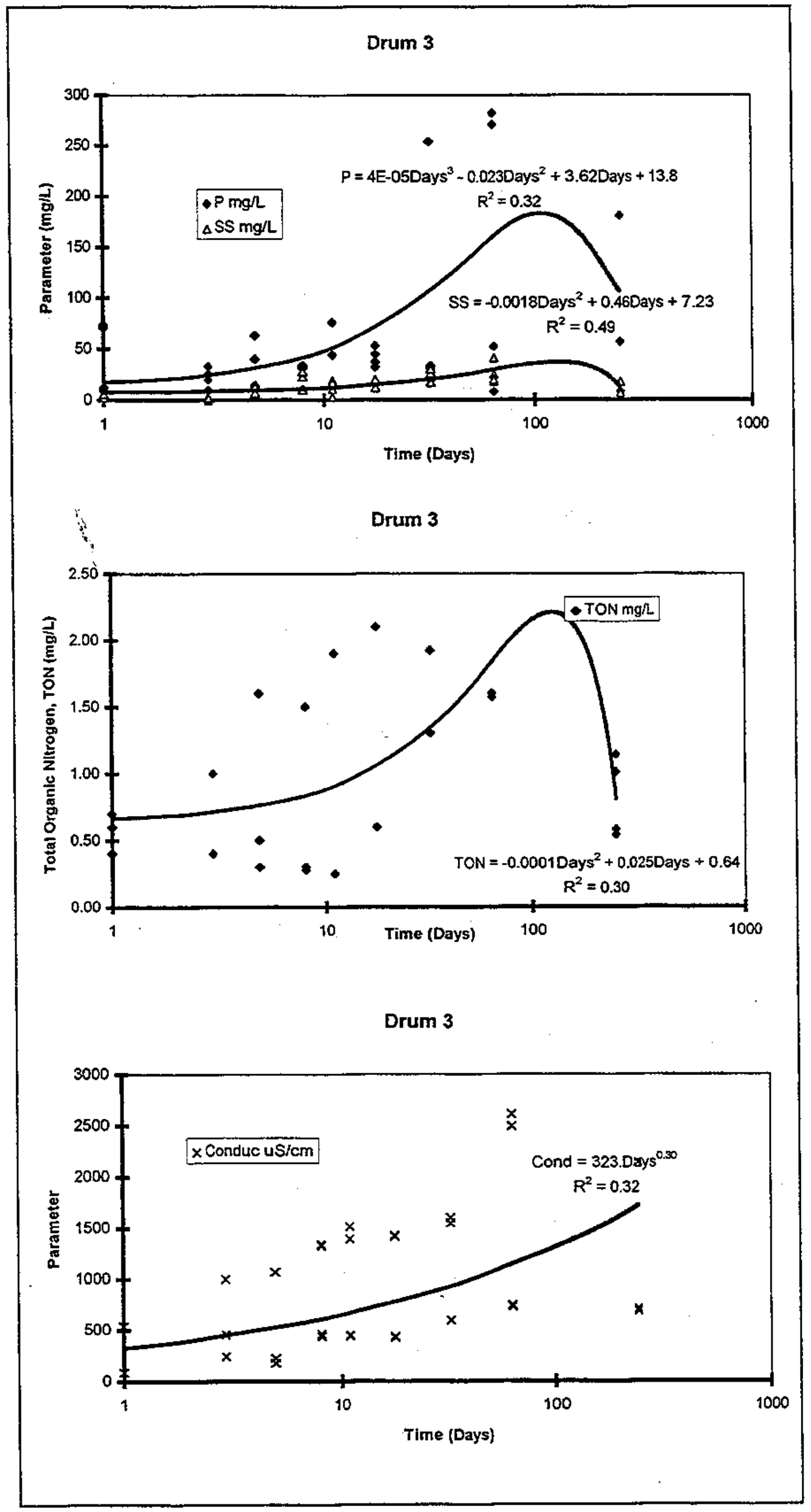


Figure 4 Temporal changes of parameters of Non-aerated rubbish in deionised water

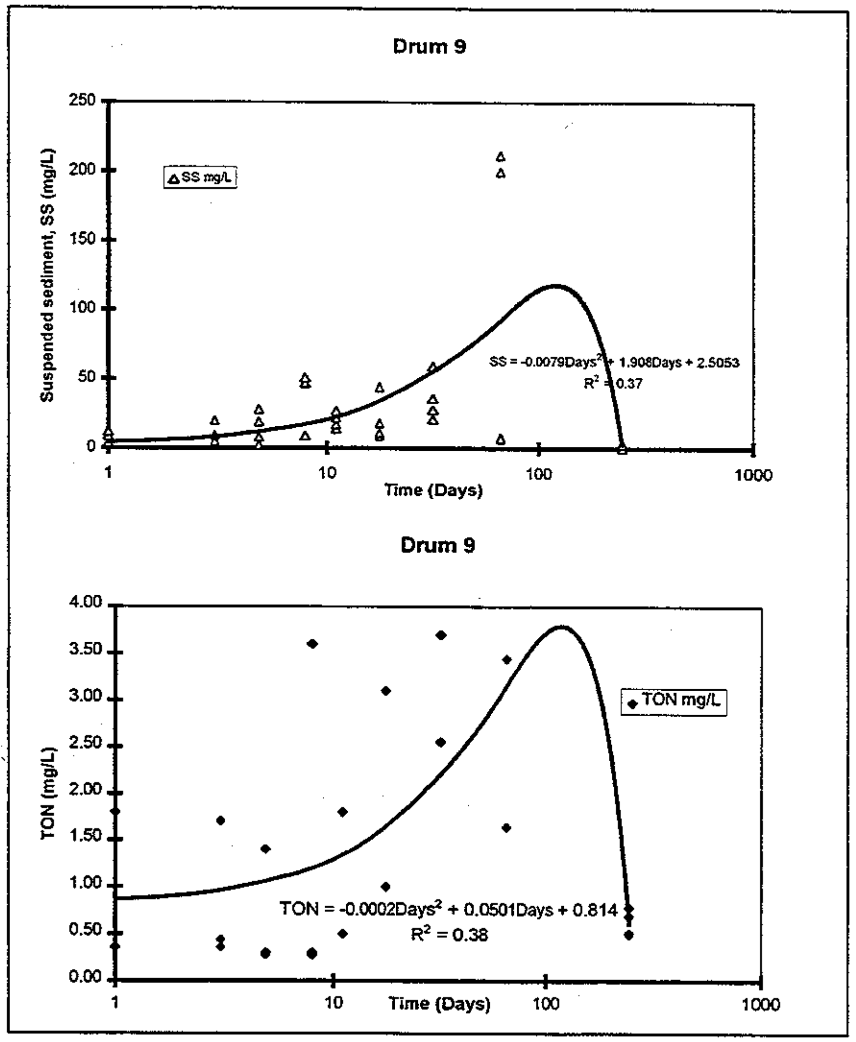


Figure 5 Temporal changes of parameters of Non-aerated rubbish in Terrys Ck water

AERATED RUBBISH

There are statistically significant trends in Phosphorus concentration ($P<0.001$), Suspended solids ($P<0.001$), Total Organic Nitrogen ($P<0.001$) and Conductivity ($P<0.001$) of the aerated deionised water containing rubbish(Table 10; Fig 6). For the drum (drum 10) which used Terrys Creek water the only statistically significant trends are in Phosphorus, Total Organic Nitrogen and Suspended solids (Fig 7). The trend in Phosphorus is a decreasing one, whereas the Suspended solids and TON parameters show a rise for the majority of the experiment with a fall towards the end. Both experiments show similar temporal trends and concentration values for Total Organic Nitrogen.

The pH, Colour, Conductivity and Fe concentrations of the rubbish immersed in distilled water are lower than those for the rubbish immersed in Terrys Creek water.

The aerated and non-aerated drums of rubbish in distilled water show different trends for Phosphorus and suspended solids concentration (Figs 4 and 6), both of which decrease towards the end of the experiment for the non-aerated situation. On the other hand, the TON temporal trends are similar. The phosphorus and conductivity values are also higher for the non-aerated drum

The aerated and non-aerated rubbish treated with Terrys Creek water shows a similar trend in suspended solid concentration although the concentration is less for the aerated rubbish (Figs 5 and 7). The TON trends are similar.

Table 11 Aerated rubbish

	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Drum 4 (aerated rubbish in deionised water)											
Mean	6.81	41	0.02	15.29	0.64	24.1	5.11	736	112	0.23	0.12
Std dev	0.62	11	0.02	10.19	0.55	2.2	1.13	285	62	0.12	0.06
diff	0.32	41	0.02	15.29	0.58	0.05	4.11	723	112	0.23	0
Drum 10 (aerated rubbish in Terrys Ck water)											
Mean	7.56	28	0.00	7.33	0.61	24.0	6.78	7344	140	0.76	0.11
Std dev	0.22	16	0.01	7.36	0.30	1.8	0.65	628	61	0.25	0.09
diff	-0.06	27	0	7.33	0.46	-0.11	3.78	329	110	0.56	-0.05

diff = mean- standard mean

NON-AERATED BIODEGRADABLE RUBBISH

For the non-aerated biodegradable rubbish in deionised water the trends in Phosphorus, Conductivity, Total Organic Nitrogen and COD are significant ($P<0.001$) (Fig 8). Each shows a decline in concentration after three to four months, although the trends in phosphorus and COD are not the same as the other parameters.

Mean concentrations of Phosphorus, suspended sediments, Total organic nitrogen, conductivity, COD and copper are lower for these experiments than for the whole rubbish in non-aerated deionised water (Tables 10 and 12). Iron is higher for the biodegradable rubbish. The concentrations for all significant parameters are higher than for the control drums (Tables 8 and 12).

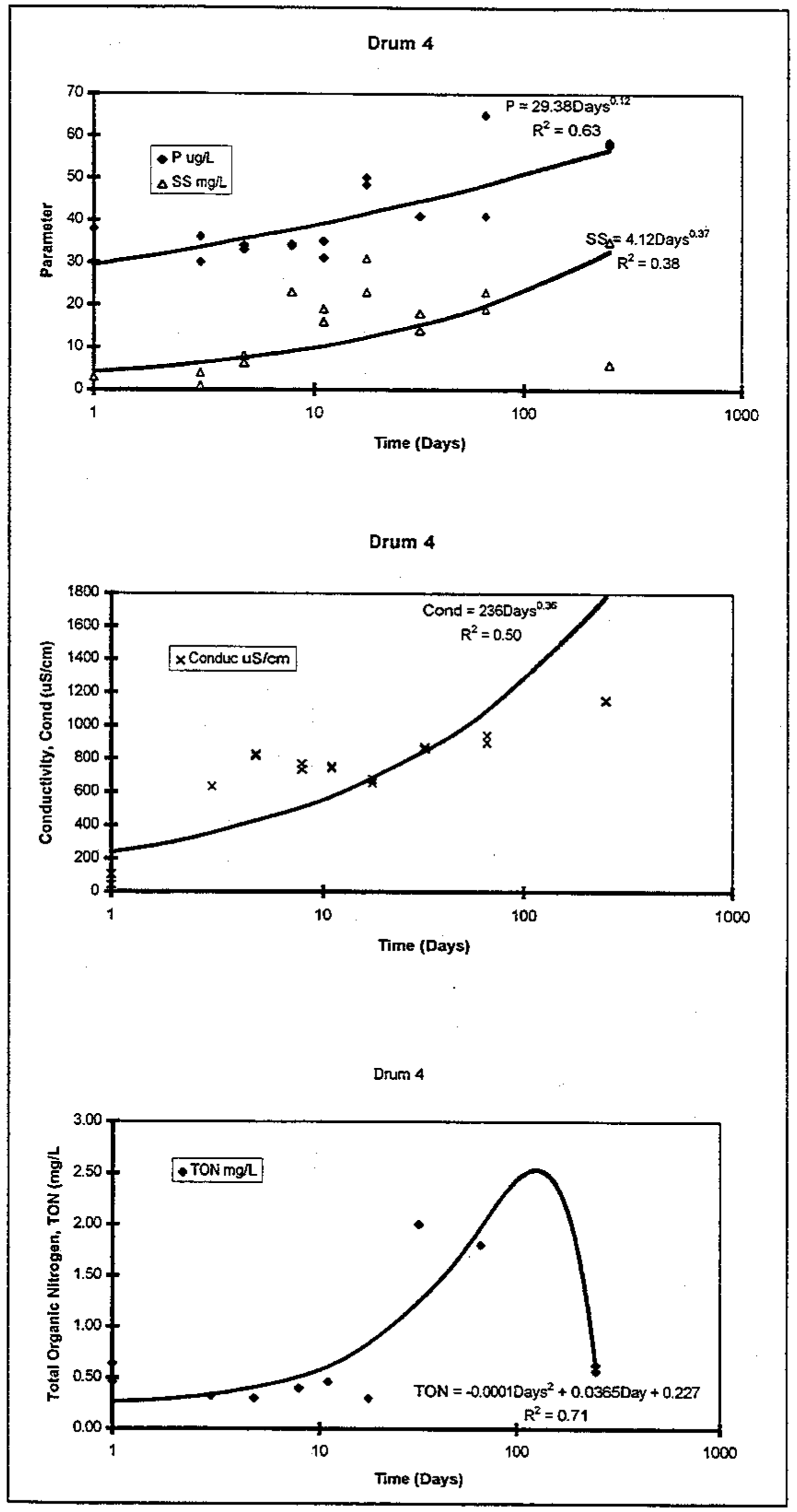


Figure 6 Temporal changes of water quality parameters of aerated rubbish in deionised water

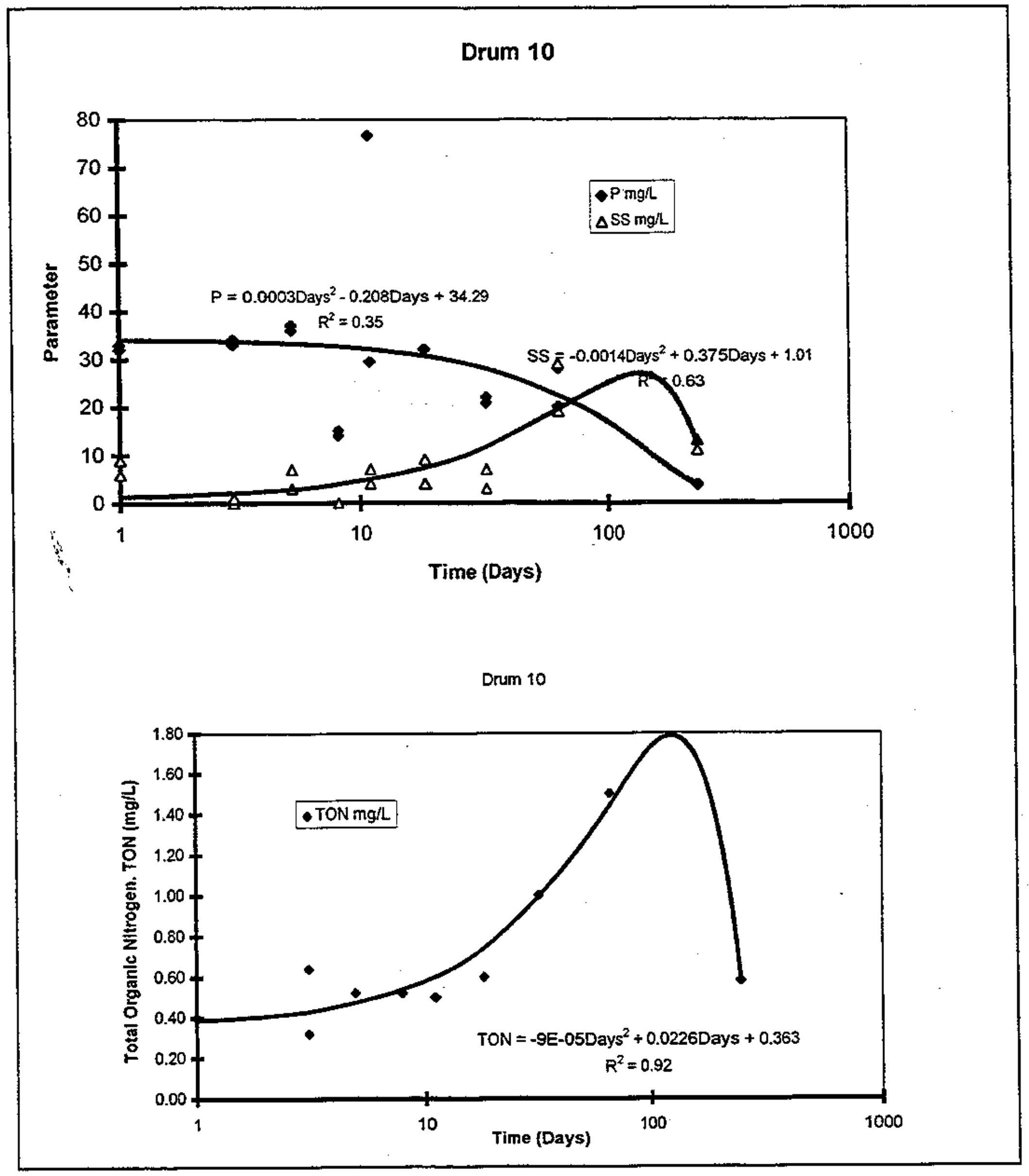


Figure 7 Temporal changes of water quality parameters of aerated rubbish in Terrys Ck water

The temporal trends in Phosphorus and Suspended solids are significant for the non-aerated biodegradable rubbish in Terrys Creek water (Fig 9). Both parameters show a decrease in concentration after three to four months. The temporal trend in Total Organic Nitrogen is not significant but it does show a pattern similar to phosphorus and suspended sediment and consistent with the temporal trends in TON for the previous experiments.

The concentrations of Phosphorus and suspended sediment and conductivity are higher for the whole rubbish samples in Terrys Creek water, all the other parameters have higher values for the biodegradable rubbish samples (Table 10 and 12). The concentrations for all significant parameters are higher than for the control drums (Tables 9 and 12)

Table 12 Non-aerated biodegradable rubbish

	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Drum 5 (non-aerated biodegradable rubbish in deionised water)											
Mean	5.18	46.01	0.01	11.24	0.74	24.1	3.56	660	188.45	0.74	0.15
Std dev	0.73	16.02	0.02	5.72	0.51	2.2	0.86	227	64.81	0.95	0.09
diff	-1.26	46	0.01	11.24	0.68	-0.2	2.56	648	188	0.74	0.01
Drum 11 (non-aerated biodegradable rubbish in Terrys Ck water)											
Mean	6.25	63.94	0.00	12.71	2.06	24.0	8.56	7467	303.05	1.97	0.11
Std dev	0.48	37.03	0.00	9.73	3.46	1.8	0.86	426	73.88	0.47	0.10
diff	-1.79	62	0	12.24	1.92	0	5.56	389	289	1.65	-0.02

diff = mean- standard mean

NON-AERATED NON-BIODEGRADABLE RUBBISH

There are statistically significant (P<0.001) temporal trends in Suspended solids, Total Organic Nitrogen and Conductivity for the non-aerated, non-biodegradable samples in deionised water (Fig 10). The values of the parameters for this treatment (Table 13) are lower than for the treatments with biodegradable rubbish and mixed rubbish samples (Tables 10 and 12). Furthermore, the differences between the control drums (Table 8) and the water samples for the non-biodegradable samples are not large (Table 13)

There are statistically significant (P<0.001) temporal trends in suspended solids, Total Organic Nitrogen and COD for the samples in Terrys Creek water (Fig 11). The trend in COD is an increasing one and no similar trend was found for the deionised water sample (Fig 10). The values of the water quality parameters (Table 13) are less for these non-biodegradable samples than they are for the biodegradable rubbish and mixed rubbish treatments in Terrys Creek water (Tables 10 and 12). The values of the parameters are also not much different from those in the control drums (Table 9).

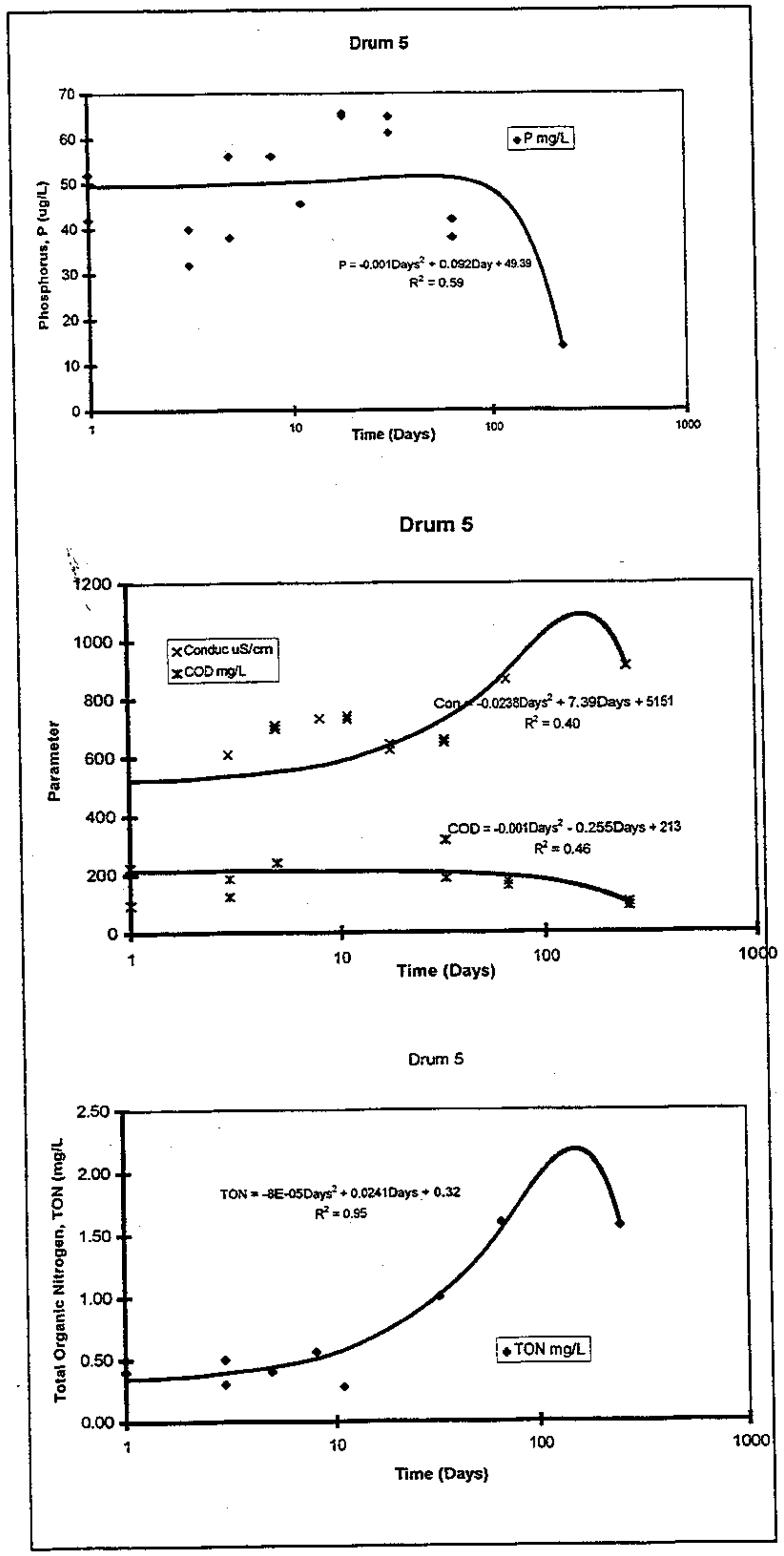


Figure 8 Temporal changes of water quality parameters of non-aerated rubbish in deionised water

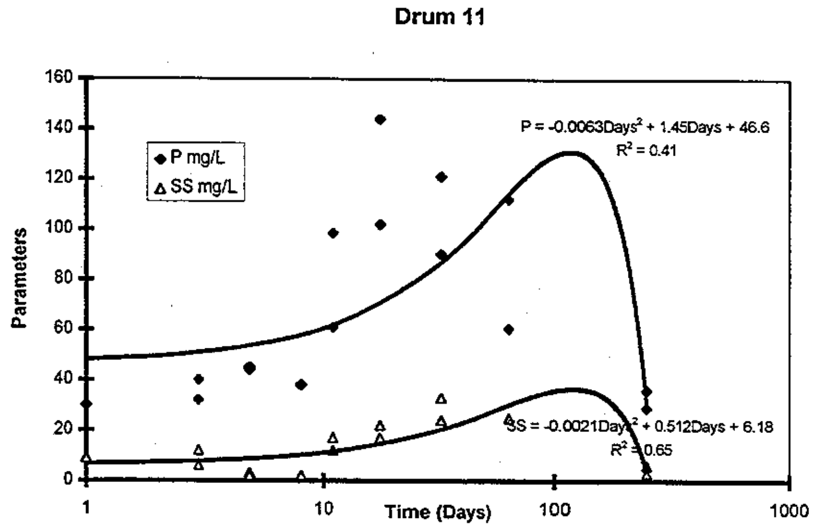


Figure 9 Temporal changes of water quality parameters of non-aerated biodegradable rubbish in Terrys Ck water

Table 13. Non-aerated non-biodegradable rubbish

	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Drum 6 Non-aerated non-biodegradable rubbish in deionised water											
Mean	6.20	4	0.00	3.06	0.32	24.1	2.00	120	3	0.16	0.14
Std dev	0.33	3	0.00	3.99	0.16	2.3	0.00	71	8	0.08	0.14
Diff	-0.24	4	0	3.06	0.26	-0.2	1	107	3	0.16	0
Drum 12 Non-aerated non-biodegradable rubbish in Terrys Ck water											
Mean	7.10	20	0.00	2.11	0.26	24.1	3.56	7123	26	1.17	0.12
Std dev	0.35	7	0.01	2.68	0.24	1.8	0.51	562	32	0.72	0.10
Diff	-0.94	18	0	1.64	0.12	0.06	0.56	45	12	0.85	-0.01

Diff = mean - standard mean

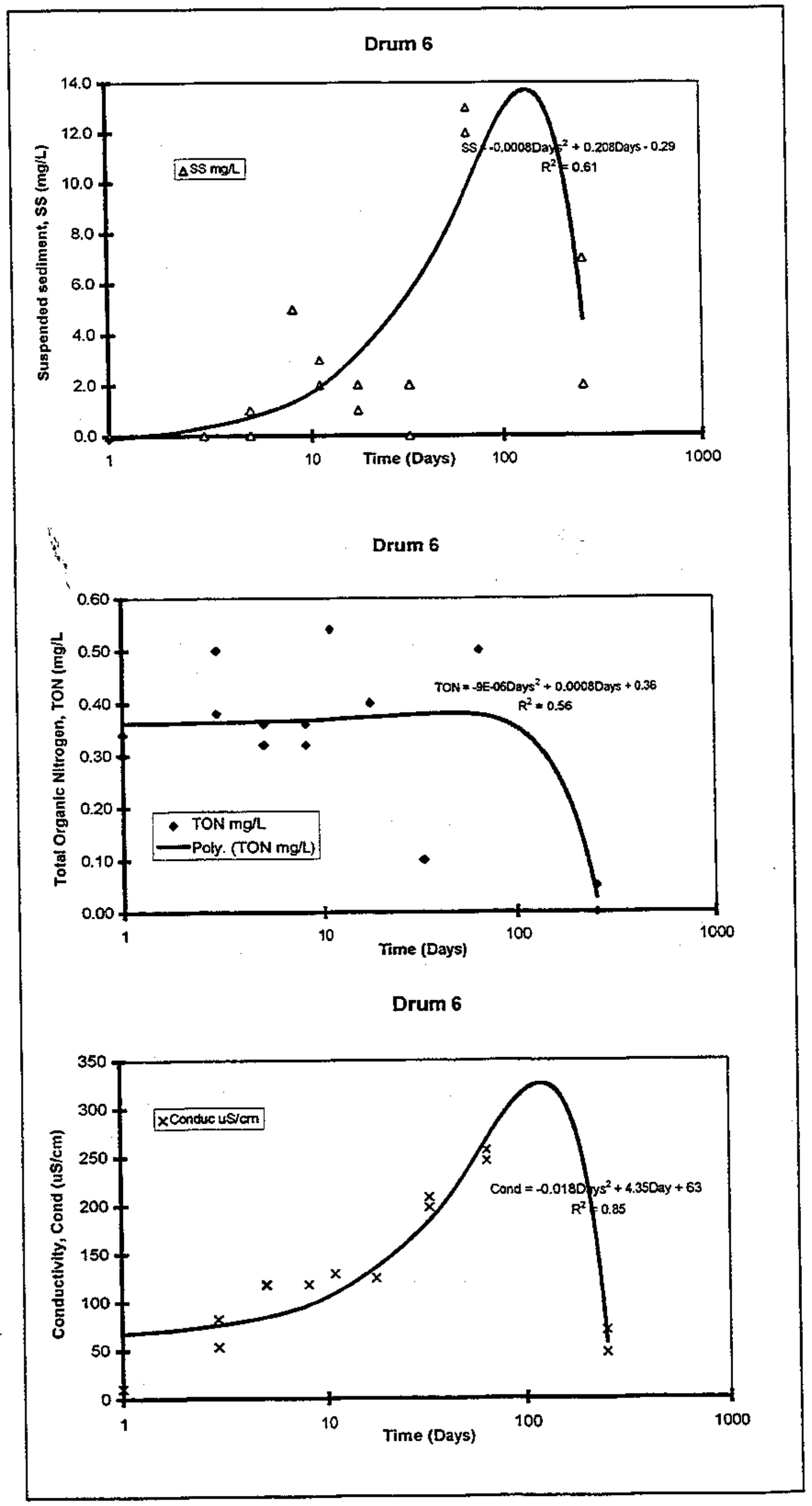


Figure 10 Temporal changes of water quality parameters of non-aerated non-biodegradable rubbish in deionised water

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SPECIFIC RUBBISH

Plastic

There is a significant temporal trend in Phosphorus concentration and conductivity (Fig 12) but in no other parameters. There are no significant differences between the mean values of the control drums and the test sample, except for conductivity (Tables 8 and 14). The conclusion is that the plastics are nearly inert in the water, for the parameters measured in this experiment.

Table 14 Plastic in deionised water (Drum 13)

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Mean	6.22	0.40	0.00	0.00	0.18	24.6	1.00	90.61	0.00	0.01	0.09
Std dev	0.26	0.49	0.00	0.00	0.21	2.2	0.00	12.51	0.00	0.02	0.09
Diff	-0.22	0	0	0	0.12	0.37	0	78	0	0.01	-0.05

Diff = mean - standard mean

Cans

There is a significant temporal trend in conductivity, which shows a rise for the first three to four months then a rapid decline (Fig 13). None of the other parameters show significant temporal trends. There is a small increase in conductivity when compared with the control drums (Tables 8 and 15), but it is not great. During the period of this experiment even the iron content of the water did not show any major change. The cans appear to be inert for the parameters measured in this experiment.

Table 15 Cans in non-aerated deionised water

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Mean	6.41	0.80	0.00	0.00	0.26	24.53	1.00	97	0.80	0.03	0.06
Std dev	0.13	0.99	0.00	0.00	0.20	2.24	0.00	14	2.34	0.05	0.04
Diff	-0.03	1	0	0	0.2	0.22	0	85	1	0.03	-0.08

Diff = mean - standard mean

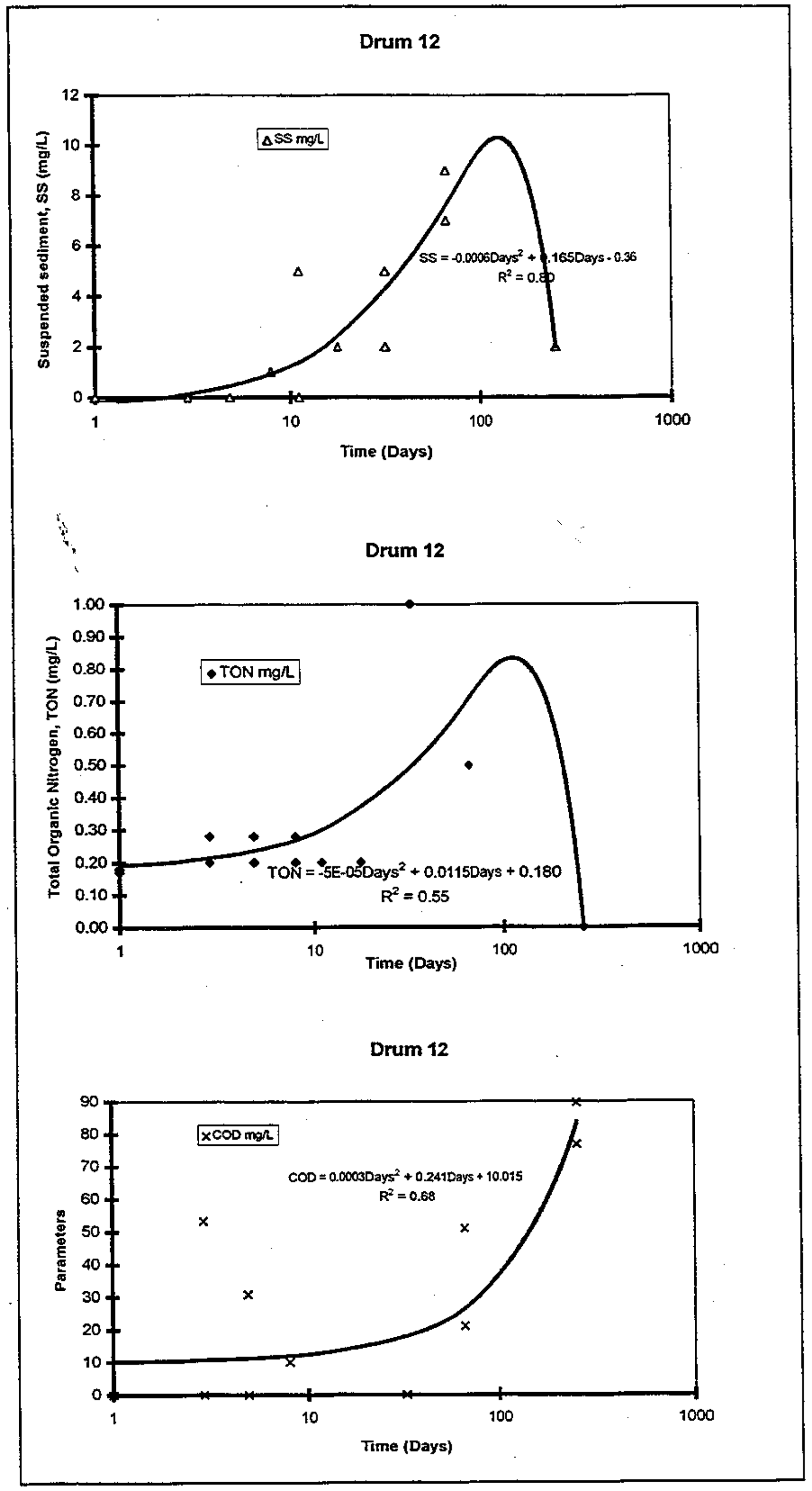

Figure 11 Temporal changes of water quality parameters of non-aerated non-biodegradable rubbish in Terrys Ck water

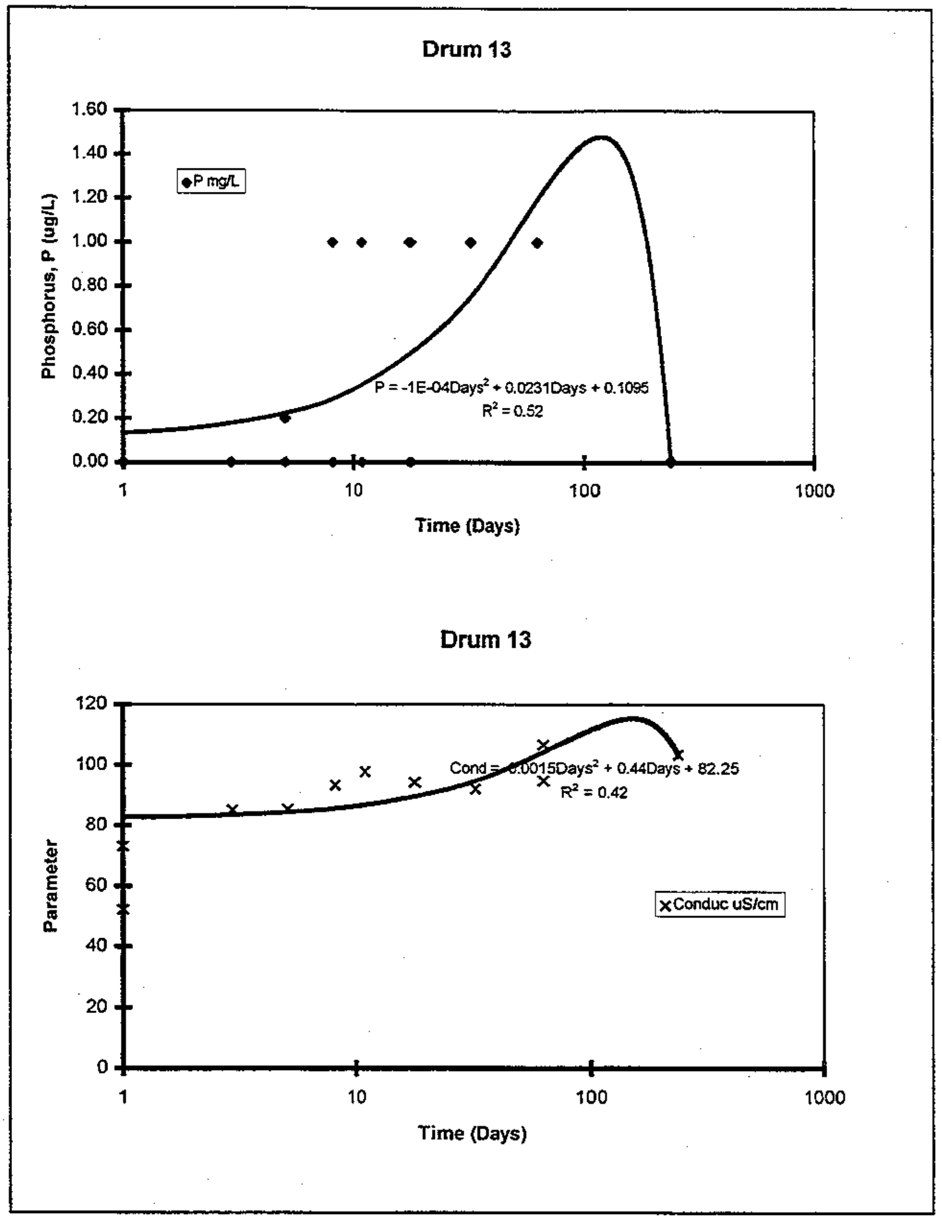

Figure 12. Temporal changes of water quality parameters of plastic in non-aerated deionised water

Polystyrene

There is a significant increase in conductivity for the first three to four months then a decline (Fig 14). None of the other parameters show significant temporal trends. As for the plastics and cans, the polystyrene samples show an increase in conductivity but not in any other parameter when compared with the control (Tables 8 and 16). Polystyrene is inert in terms of the parameters examined in this study.

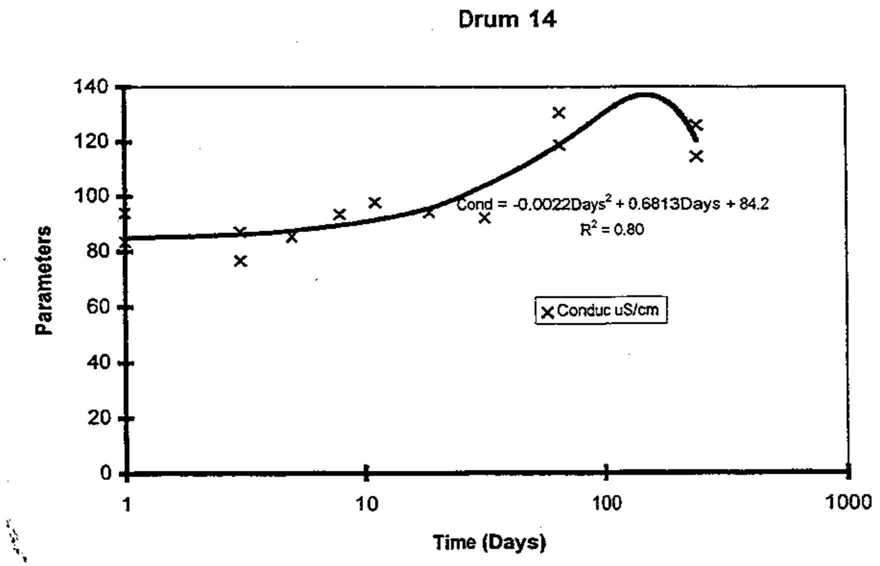

Figure 13 Temporal changes of water quality parameters of cans in non-aerated deionised water

Table 16 Polystyrene in non-aerated deionised water (Drum 15)

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Mean	6.31	2.53	0.00	0.22	0.37	24.51	1.00	83	0.00	0.00	0.07
Std dev	0.16	1.50	0.00	0.55	0.23	2.22	0.00	24	0.00	0.00	0.03
Diff	-0.13	3	0	0.22	0.31	0.2	0	70	0	0	-0.07

Diff = mean - standard mean

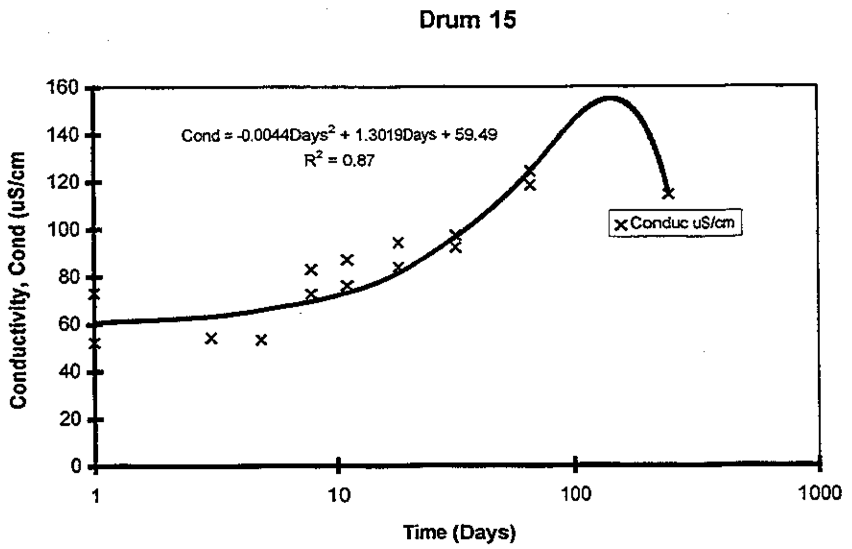

Figure 14 Temporal changes of water quality parameters of polystyrene in non-aerated deionised water

Cigarette butts

There are increases in phosphorus, suspended sediment, conductivity and COD for the water samples treated with cigarette buts (Table 17). The temporal trend in conductivity is statistically significant (Fig 15). Cigarettes have the potential to pollute stream water and contribute to its degradation.

Table 17 Cigarette butts in non-aerated deionised water (Drum 16)

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
Mean	6.69	15.19	0.00	2.33	0.54	24.73	3.00	241	17.76	0.00	0.07
Std dev	0.04	9.93	0.00	2.00	0.34	2.11	0.00	53	22.83	0.00	0.04
Diff	0.25	15	0	2.33	0.48	0.42	2	229	18	0	-0.07

Diff = mean - standard mean

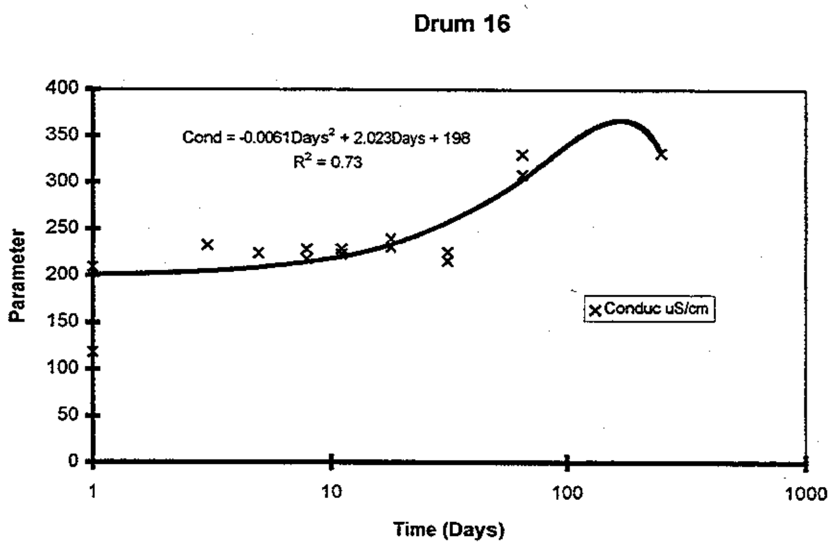

Figure 15. Temporal change in conductivity of water treated with cigarette butts

DISCUSSION

Total Nitrogen

The values of Nitrogen are low for most of the treatments (Table 18). The highest values are associated with treatments 9 and 11, in which Terrys Creek water was used. The samples were not aerated, and the rubbish contained biodegradable material. The Terrys Creek water samples, not spiked with rubbish (Treatments 7 and 8) showed values of N approximately 3 times higher than the controls with deionised water (Treatments 1 and 2). Rubbish obviously increased the N values by an order of magnitude (Treatments 1 and 2 compared with 3 and 4) but it appears that aeration will keep the values low (compare Treatments 9 and 10). The N concentration of samples spiked with non-biodegradable rubbish (Treatments 13, 14 and 15) are higher than the controls (Treatments 1 and 2) even though the rubbish was initially washed and placed in deionised water. The levels are higher than the controls for Terrys Creek water (Treatments 7 and 8).

Table 18 Total Organic Nitrogen (TON) for different treatments

Treatment Number	Treatment Type#	No. of samples	N Mean mg/L	N St Dev mg/L
1	NA, D, Control	14	0.06	0.05
2	A, D, Control	14	0.06	0.05
3 *	NA, D, Mixed	24	0.94	0.60
4 *	A, D, Mixed	14	0.64	0.55
5 *	NA, D, Bio	14	0.82	0.58
6 *	NA, D, NBio	14	0.32	0.16
7	NA, S, Control	14	0.14	0.13
8	A, S, Control	14	0.15	0.15
9	NA, S, Mixed	24	1.52	1.86
10*	A, S, Mixed	14	0.61	0.30
11	NA, S, Bio	14	2.06	3.46
12*	NA, S, NBio	14	0.26	0.24
13	A, D, Plastic	10	0.18	0.21
14	A, D, Cans	10	0.26	0.20
15	A, D, Polystyrene	10	0.37	0.23
16	A, D, Butts	10	0.54	0.34

* statistically significant trends

NA = non-aerated, A= Aerated, D=Distilled and deionised water, S=Terrys Ck Water, Bio= biodegradable rubbish, NBio=non-biodegradable rubbish, Mixed=mixed rubbish sample

There are no clearly identified temporal trends in N for all of the treatments. However, there are some patterns indicating an increase in N over time and then a decrease towards the end of the experiments. These patterns are not highly statistically significant. For treatments 3, 4, 5, 6, 9 and 10 the polynomial regressions are significant, but the regression is not significant for treatment 11.

Total phosphorus

The level of Total Phosphorus increases significantly with rubbish-spiked samples (Table 19). The P level of treatments in Terrys Creek water was significantly higher than in the controls treatments. The highest readings were recorded for the treatments which were spiked with biodegradable rubbish and not aerated (Treatments 3, 9, and 11). Even with aeration the levels of P are very high. Plastic and cans gave low values of phosphorus but cigarette butts are obviously a health hazard for streams (Treatment 16).

Table 19 Phosphorus concentrations for different treatments

Treatment	Treatment Type#	No. of samples	P Mean µg/L	P StDev µg/L
1	NA, D, Control	18	0.0	0.0
2	A, D, Control	18	0.0	0.0
3*	NA, D, Mixed	35	68.3	81.9
4*	A, D, Mixed	18	46.0	23.7
5*	NA, D, Bio	18	44.2	17.3
6	NA, D, NBio	18	4.0	3.5
7	NA, S, Control	18	1.5	2.8
8	A, S, Control	18	1.0	1.3
9	NA, S, Mixed	36	76.2	40.8
10*	A, S, Mixed	18	26.4	16.8
11*	NA, S, Bio	18	69.5	43.4
12	NA, S, NBio	18	19.6	7.3
13*	A, D, Plastic	18	0.4	0.5
14	A, D, Cans	18	0.8	1.0
15	A, D, Polystyrene	18	2.5	1.5
16	A, D, Butts	18	14.4	10.2

* statistically significant trends

NA = non-aerated, A= Aerated, D=Distilled and deionised water, S=Terrys Ck Water, Bio= biodegradable rubbish, NBio=non-biodegradable rubbish, Mixed=mixed rubbish sample

There are significant temporal variations in the phosphorus level for some of the treatments (3, 4, 5, 10, 11, 13). However, the pattern of change is not consistent between treatments nor is it a simple linear one. There is no doubt that the trends are a result of microbial activity.

pH

pH values are in the range of 6 to 7 (Table 20) for most experiments. One treatment, Treatment 7, had a mean pH higher than 7. This is a control, using Terrys Creek water, and the higher value is not easily explained. One treatment, Treatment 5, deionised and non-aerated water spiked with biodegradable rubbish, had a pH of 5.2.

There were no obvious temporal trends in pH during the period of the experiment for each of the treatments.

Suspended sediment

The suspended sediment concentrations are not high, the highest being with the rubbish samples in both the deionised and Terrys Creek water (Table 21). Seven of the tests showed significant temporal trends in suspended sediment, but not all showed a decrease after a three to four month rise in concentration.

Table 20 pH for different treatments

Treatment	Treatment Type#	No. of samples	pH Mean	pH StDev
1	NA, D, Control	18	6.4	0.1
2	A, D, Control	18	6.5	0.1
3	NA, D, Mixed	36	5.1	0.6
4	A, D, Mixed	18	6.8	0.6
5	NA, D, Bio	18	5.2	0.7
6	NA, D, NBio	18	6.2	0.3
7	NA, S, Control	18	8.0	0.3
8	A, S, Control	18	7.6	0.4
9	NA, S, Mixed	36	6.6	0.4
10	A, S, Mixed	18	7.6	0.2
11	NA, S, Bio	18	6.2	0.5
12	NA, S, NBio	18	7.1	0.4
13	A, D, Plastic	18	6.2	0.3
14	A, D, Cans	18	6.4	0.1
15	A, D, Polystyrene	18	6.3	0.2
16	A, D, Butts	18	6.7	0.0

NA = non-aerated, A= Aerated, D=Distilled and deionised water, S=Terrys Ck Water, Bio= biodegradable rubbish, NBio=non-biodegradable rubbish, Mixed=mixed rubbish sample

Chemical Oxygen Demand (COD)

The highest COD values are for the non-aerated rubbish in the deionised water (Drum 3) and in Terrys Creek water (Drum 9). Much lower values of COD were observed for the other treatments, the aerated treatments having the lower values, as expected. Temporal trends for two treatments were statistically significant (Table 22), in both cases non-aerated biodegradable rubbish.

Table 21. Suspended sediment concentrations for different treatments

Treatment	Treatment Type#	No. of samples	SS Mean mg/L	SS StDev mg/L
1	NA, D, Control	18	0	0
2	A, D, Control	18	0	0
3*	NA, D, Mixed	36	19.7	7.8
4*	A, D, Mixed	18	15.2	10.1
5	NA, D, Bio	18	11.2	5.7
6*	NA, D, NBio	18	3.0	3.9
7	NA, S, Control	18	0.4	1.3
8	A, S, Control	18	0	0
9*	NA, S, Mixed	36	27.6	46.3
10*	A, S, Mixed	18	7.3	7.3
11*	NA, S, Bio	18	12.7	9.7
12*	NA, S, NBio	18	2.1	2.6
13	A, D, Plastic	18	0	0
14	A, D, Cans	18	0	0
15	A, D, Polystyrene	18	0.2	0.5
16	A, D, Butts	18	2.3	2.0

* statistically significant trends

NA = non-aerated, A= Aerated, D=Distilled and deionised water, S=Terrys Ck Water, Bio= biodegradable rubbish, NBio=non-biodegradable rubbish, Mixed=mixed rubbish sample

Table 22. COD for different treatments

Treatment	Treatment Type#	No. of samples	COD Mean mg/L	COD StDev mg/L
1	NA, D, Control	18	0	0
2	A, D, Control	18	0	0
3	NA, D, Mixed	36	572	602
4	A, D, Mixed	18	112	62
5*	NA, D, Bio	18	188	65
6	NA, D, NBio	18	3	8
7	NA, S, Control	18	13.61	18.84
8	A, S, Control	18	30.5	25.4
9	NA, S, Mixed	36	237	106
10	A, S, Mixed	18	140	61
11	NA, S, Bio	18	303	74
12*	NA, S, NBio	18	26	32
13	A, D, Plastic	18	0	0
14	A, D, Cans	18	0.8	2.34
15	A, D, Polystyrene	18	0	0
16	A, D, Butts	18	17.76	22.83

* statistically significant trends

NA = non-aerated, A= Aerated, D=Distilled and deionised water, S=Terrys Ck Water, Bio= biodegradable rubbish, NBio=non-biodegradable rubbish, Mixed=mixed rubbish sample

Conductivity

The highest conductivities are associated with the samples treated with Terrys Creek water. As the creek drains a Wianamatta Shale area the conductivity is likely to be influenced by groundwater flushing of connate salts as well as the soluble material picked-up from the urban environment. Rubbish increases the conductivity, by similar amounts for samples treated in deionised water and Terrys Creek Water (Table 23). None of the samples treated in Terrys Creek water show significant temporal trends, whereas most of the samples treated in deionised water show an increase in conductivity for the first three or four months and then a decrease.

Table 23 Conductivity of different treatments

Treatment	Treatment Type#	No. of samples	Cond Mean uS/cm	Cond StDev uS/cm
1	NA, D, Control	18	12	22
2	A, D, Control	18	13	22
3*	NA, D, Mixed	36	1289	713
4*	A, D, Mixed	18	736	285
5*	NA, D, Bio	18	660	227
6*	NA, D, NBio	18	120	71
7	NA, S, Control	18	7078	532
8	A, S, Control	18	7014	558
9	NA, S, Mixed	36	7669	718
10	A, S, Mixed	18	7344	628
11	NA, S, Bio	18	7467	426
12	NA, S, NBio	18	7123	562
13*	A, D, Plastic	18	90	12
14*	A, D, Cans	18	97	14
15*	A, D, Polystyrene	18	83	24
16*	A, D, Butts	18	241	53

* statistically significant trends

\# NA = non-aerated, A= Aerated, D=Distilled and deionised water, S=Terrys Ck Water, Bio= biodegradable rubbish, NBio=non-biodegradable rubbish, Mixed=mixed rubbish sample

Iron

There are no statistically significant trends in the concentration of iron in the different treatments (Table 24). The highest iron concentration was for the treatment which consisted of non-aerated biodegradable rubbish immersed in Terrys Creek water (Treatment 11). The cans did not greatly increase iron concentration (Treatment 14).

Table 24. Iron concentrations for the different treatments

Treatment	Treatment Type#	No. of samples	Fe Mean mg/L	Fe StDev mg/L
1	NA, D, Control	18	0	0
2	A, D, Control	18	0	0
3	NA, D, Mixed	36	0.45	0.15
4	A, D, Mixed	18	0.23	0.12
5	NA, D, Bio	18	0.74	0.95
6	NA, D, NBio	18	0.16	0.08
7	NA, S, Control	18	0.32	0.17
8	A, S, Control	18	0.20	0.15
9	NA, S, Mixed	36	1.66	0.65
10	A, S, Mixed	18	0.76	0.25
11	NA, S, Bio	18	1.97	0.47
12	NA, S, NBio	18	1.17	0.72
13	A, D, Plastic	18	0.01	0.02
14	A, D, Cans	18	0.03	0.05
15	A, D, Polystyrene	18	0	0
16	A, D, Butts	18	0	0

\# NA = non-aerated, A= Aerated, D=Distilled and deionised water, S=Terrys Ck Water, Bio= biodegradable rubbish, NBio=non-biodegradable rubbish, Mixed=mixed rubbish sample

Lead

The highest concentrations of lead are found in treatments 3, 4, and 5, experiments which involved deionised water and biodegradable rubbish. The lead concentrations were low, often below the sensitivity of the instrument, particularly for treatments 7 and 8. Only small quantities of lead are released by the non biodegradable rubbish (Treatments 13, 14 and 15).

No significant temporal trends are evident in the concentration of lead for the different treatments. It appears that the rubbish will contaminate the water quickly, and maintains the concentration of contamination over time (Treatment 3 and 9)

Discussion

Except for treatments involving plastic, cans and polystyrene (Treatments 13, 14 and 15), the total phosphorus concentration in the treatments is high, although within the range of critical levels recommended by ANZECC Guidelines (1992) (Table 25) Similarly, the nitrogen values are within the range of critical values recommended by ANZECC, and this includes the more inert materials. Lead values are low and do not suggest a significant problem for water quality.

Table 25 ANZECC (1992) and SPCC (1989) Water Quality Criteria

Water Quality Indicator	Criteria SPCC (urban)	Criteria ANZECC
Total Phosphorus	<50 µg/L	10-100 µg/L
Total Nitrogen	<0.5 mg/L	0.1-0.75 mg/L
Lead	<25 µg/L	1-5 µg/L

An implication of this study is that gross pollutant material, even non-biodegradable material, degrades water quality to some extent. Levels of P and N recorded in this experiment are on the margins of, or exceed, recommended values for protection of aquatic ecosystems.

As gross pollutants have a deleterious effect on water quality and this degradation increases with time, it makes sense to remove gross pollutants as soon as possible from the water stream. The worst case scenario appears to be gross pollutants lying in a pool of water that is not aerated. Over a period the pool would be a major source of low quality water which would be flushed downstream in the early stages of a flood event. Programs of gross pollutant removal should be on a one month cycle, and possibly more frequent.

CONCLUSION

An experiment using a variety of rubbish, both degradable and non-degradable, in different waters and with different aeration treatments, indicates water quality deteriorates as a result of gross pollution. Water quality was monitored for a period of 262 days. Phosphorus and Nitrogen values were on the margins, and sometimes exceeded recommended levels for the protection of aquatic ecosystems.

Phosphorus and nitrogen showed temporal patterns of statistical significance.

Gross pollutants cannot be considered neutral material in urban streams for it appears that even the non-biodegradable materials may have an influence. This influence may not result in water quality exceeding criteria values of the SPCC and ANZECC. However, the cumulative effect of a number of different factors contributing to water quality degradation may make the effect of the gross pollutants significant.

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APPENDIX 1: WATER QUALITY TESTING PROCEDURES

Total Organic Nitrogen (TON) Methodology

Total organic nitrogen (TON) was determined by a Kjeldahl technique. This was a modified version of the Standard Method technique (APHA-AWWA-WPCF 1989), Bremner (1965) and Lambert (1982). In this method the nitrogen in the leachate was converted to ammonium ions by digestion with concentrated sulphuric acid and a catalyst. A catalyst mixture of selenium, potassium sulphate and copper sulphate was used to increase the rate of reaction by increasing the temperature and aiding complete conversion of the organic nitrogen. This technique was chosen because the presence of algal material in rubbish samples containing biodegradable components was evident in the trial stages

This method involved three stages;

i. acid digestion of the leachate
ii. distillation of the digestate
iii. titration of the distillate.

Acid Digestion

Many sample sizes were trialed to obtain the maximum total organic nitrogen yield. The optimum volume was a 50 mL sample. Each sample was digested with 1.1g of selenium catalyst and 3mL concentrated sulphuric acid in a 100mL kjeldahl flask. Flasks were placed on a heating mantle at low to moderate temperatures in a fume cupboard. After a period of 30-40 minutes when the initial frothing ceased, the temperature was increased. Digestion was complete when no visible residue or charred particles were visible and the digestate was a clear blue-green colour. A 50mL blank of deionised distilled water was also digested. This was used a baseline comparison for all the samples. After digestion each sample immediately covered with parafilm to minimise gaseous exchange or contamination.

Distillation

Fresh boiling chips were placed in the distillation flask with each run. The distillation unit was in operation 1 hour prior to use and 30 minutes after use. This allowed the steam to pass through and remove any possible contaminants.

Whilst the covered kjeldahl flasks were cooling, 50mL erlenmeyer flasks were prepared to collect the distillate. 5mL of Boric Acid indicator (20g A.R boric acid in 980mL deionised water and 20mL of mixed indicator solution-0.099g Bromocresol green and 0.66g methyl red in 100ml 95% ethyl alcohol) was placed into a 50mL flask. Each 50mL flask was marked at the 35mL position to denote the minimum amount of distillate to be collected. The flask was placed so that the condenser outlet and the indicator solution were about 4cm apart.

When the flask had cooled the parafilm cover was removed and approximately 5mL of deionised water was added. The flask was immediately transferred to the distillation unit where neutralisation was conducted to minimise the loss of ammonia by volatilisation. The flask was securely fitted to the distillation unit and 10mL (sometimes 12mL) of 20M sodium hydroxide was slowly added through the funnel. The sodium hydroxide was added drop-wise up to the point where the sulphuric acid was neutralised. The neutralisation point was indicated by the solution turning dark brown black, due to the precipitation of iron. When the distillate reached the 35mL indicator mark on the flask, the process was stopped by opening the clamps. Each flask containing distillate was immediately covered with parafilm to prevent gaseous exchange or contamination.

Titration

The amount of ammonium-nitrogen in the distillate was determined by titration. The distillate was titrated with 0.71mM hydrochloric acid. The endpoint was indicated by a solution colour change from blue-green to pink-grey-lavender. The amount of ammonium-nitrogen in the distillate is determined by the volume of acid used. 1ml of titrant is equivalent to 0.01mg ammonium-nitrogen. Therefore sample determination was found by;

Sample titration(mL) x 0.01= mg ammonium-nitrogen/50mL

All glassware was prepared by soaking in 20% acid solution for 12 hours, washed and rinsed in deionised water.

Total Phosphorus

Total phosphorus determination was by the Standard Methods technique (APHA-AWWA-WPCF 1989). This technique involved two stages of analysis;

i. the conversion of phosphorus to orthophosphate by the nitric acid-sulphuric acid digestion technique without filtration.
ii. colorimetric determination of the dissolved orthophosphate using the stannous chloride method.

All glassware used for phosphorus determination was prepared by soaking overnight in an acid solution of sulphuric and hydrochloric acid. Glassware was then rinsed with hot dilute hydrochloric acid and then rinsed several times with deionised water.

Sample preparation

i. Digestion

A 25mL leachate sample was collected from the storage sampling containers. The leachate was transferred into a 100mL kjeldahl flask with 1mL concentrated sulphuric acid and 5mL concentrated nitric acid. Digestion flasks were placed on the digestion racks with initial temperature settings low to medium. When the volume of digest had reduced after a 20-30 minute period then the heat was increased to aid complete digestion. A brown vapour, nitrous oxide was given off as the nitric acid decomposed leaving only the sulphuric acid and the orthophosphate. The kjeldahl flasks were allowed to cool.

ii. Neutralisation of digest

The digest was slowly diluted with 20mL of deionised water. The neutralisation process followed these steps;

i. One pasteur pipette of 20M sodium hydroxide was added to each flask and gently mixed
ii. Each flask was allowed to cool
iii. 1 drop of phenolphthalein indicator aqueous solution was added to each flask
iv. 1M sodium hydroxide was added until the solution turned a faint pink colour
v. The neutralised solution was poured into a 50mL volumetric flask. The digestion flask was rinsed several times with deionised water and transferred to the volumetric flask.

The final volume was made to 50mL using deionised water.

iii. Colorimetric Method

The stannous chloride method was used because it was a more sensitive method than the other colorimetric techniques. The minimum detectable concentration was 3µg P/L (APHA-AWWA-WPCF 1989).

Determination of orthophosphate

The determination of orthophosphate concentrations in the digest was determined by the following steps:

1. The neutralised digest was acidifed with strong acid solution (300mL concentrated sulphuric acid and 4mL concentrated nitric acid in 1l of deionised water). This was added drop-wise until the pink digest became clear. Usually only one drop was required.
2. 2mL Molybdate reagent (25g ammonium molybdate in 175mL distilled water. Add 280mL concentrated sulphuric acid to 400mL distilled water. Cool, add molybdate and dilute to 1L) was added to each flask.
3. 5 drops of stannous chloride reagent (2.5g stannous chloridein 100mL glycerol) was added to each flask at staggered 30 second intervals.
4. Exactly 10 minutes later each sample was measured photometrically at an absorbance 690nm in the spectrophotometer and the absorbance recorded.
5. A blank of deionised water was measured following the above procedure to determine whether there was any contamination or interference.

Preparation of standards

A set of 4-6 standards were prepared each day of testing. The concentration range was between 5µg-70µg phosphate/litre. The standards were prepared using the following procedure;

i. The appropriate volume of stock solution (1mL=5µg phosphate) was pipetted and diluted accordingly in a 50 mL volumetric flask.
ii. Molybdate and stannous chloride reagent were added.
iii. The absorbance was read at 690nm after a period of 10minutes.
iv. A calibration curve was produced to determine sample phosphate values.

Total Suspended Solids (TSS)

Total suspended solids (TSS) were determined by the Standard Methods (APHA-AWWA-WPCF,1989) A well mixed 100mL sample free of large floating particles was collected and then filtered through a vacuum controlled glass filter fitted with 45µm filter papers. Filter papers were oven dried at 105C and then cooled in a dessicator. Each paper was weighed and then placed in the filtering unit. After filtration each paper was carefully removed and placed in an oven at 105C for 1 hour. After drying papers were placed in the dessicator for 20-30 minutes to cool. Each paper was reweighed and the TSS was calculated by;

$$\text{mg of SS/L} = \frac{(A-B)*1000}{\text{Sample Volume in mL}}$$

A= weight of filter and dried residue in mg
B= weight of filter in mg.

Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant (APHA AWWA WPCF, 1989, pp5-10). A modified version of the Standard Methods (APHA AWWA WPCF, 1989) dichromate reflux technique was used. COD was determined using the microwave digestion technique devised by Jardim and Rohwedder (1989). The procedure was similar to the Standard Methods (APHA AWWA WPCF 1989 pp5.10-5.16) except that the digestion occurred in teflon vessels in a microwave requiring only 7 minutes compared to 2 hours for the reflux method. Another advantage of this method was that it required smaller volumes of reagents. To determine the reliability of this method samples were sent twice to a reputable water testing laboratory to cross reference results. In most cases the results were comparable however some of the results were questionable, for example blanks had higher COD values than samples that contained high organic matter. It was concluded that this technique is sensitive to interference and was as reliable as the longer, more tedious refux method.

COD determination required two stages of analysis;
i. Microwave digestion
ii. Titration

Digestion Procedure

In this technique organic matter is oxidised by a mixture of sulphuric and chromic acids. The sample is digested with a strong acid solution and with a known amount of excess of potassium dichromate. After digestion the remaining unreduced potassium dichromate was titrated with ferrous ammonium sulphate (FAS) to determine the amount of dichromate consumed. The oxidised organic matter was calculated in terms of the oxygen equivalent (APHA AWWA APCF 1989 pp5.12).

Samples were collected and digested with the minimum of delay. Using Gilson and Eppendorf Pipettes, 500µL of sample, 3mL sulphuric acid reagent, 0.04g mercuric sulphate and 1000mL dichromate solution were placed in tefflon vessels. The teflon vessels had a 5mm thick wall and a 60mL volume. Samples were placed in a 350W microwave with a turntable and digested for 9 minutes. A synthetic sample of glucose was used as a standard. Glucose has a theoetical COD 1.067g/g or 500mg Oxygen /L (APHA AWWA APCF 1976) The standard was prepared by dissolving 0.4686g in distilled water and diluted to 1000mL. Standards were prepared for each testing day to ensure maximum recovery and to minimise the risk of the glucose deteriorating. A 95-100% recovery of the expected theoretical value was obtained.

Titration

After digestion the vessels were left in the microwave for 3 minutes before they were transferred to an ice bath for 10 minutes. The cooled digest was transferred to a 50mL erlenmeyer flask. The vessel was rinsed several times with 10-15 mL distilled water and emptied into the flask. The digest was titrated with FAS using 0.1-0.15mL ferroin indicator. The endpoint of the titration for the samples and for the standards was indicated by the first sharp colour change from blue-green to reddish-brown.

With titration techniques, ideally the volume of titrant used should be in the range 20mL The 0.25M FAS specified in Standard Methods (APHA AWWA APCF 1989) was too concentrated for the small volume used in the microwave digest technique. It was assumed that an equal volume of FAS solution required an equal volume of potassium dichromate solution when there was no oxygen was consumed that is no unreduced potassium dichromate solution. Based on this assumption and that the volume of titrant should not be greater than 20mL, 1:15-1:20 dilution of FAS solution was found to be most accurate. Dependent upon the daily standardisation, mostly 0.0125M FAS was used.

FAS was standardised each testing day against potassium dichromate solution. The standardisation procedure involved diluting 10mL potassium dichromate solution to 100mL. Then 30mL concentrated sulphuric acid was added in the fume cupboard and the solution allowed to cool. The standardised dichromate solution was then titrated with FAS containing 0.10mL-0.15mL ferroin indicator. The molarity of the FAS was determined by:

$$\text{Molarity of FAS} = 0.0125\text{M} * \frac{\text{Volume } 0.0147\text{M Dichromate in mL}}{\text{Volume FAS used in titration in mL}}$$

COD values for samples were determined by;

$$\text{COD mg } O_2/L = \frac{(A-B) * M * 8000}{\text{mL sample}}$$

A = mL FAS used for blank
B = mL FAS used for sample
M = Molarity of FAS (APHA AWWA WCPF 1989)

Conductivity

Conductivity is the measurement of the ability for an aqueous solution to carry an electric current (APHA AWWA APCF 1989). A SCT conductivity meter (YSI model#33) was used to measure the conductivity.

Conductivity was determined by accurate temperature and conductivity readings of the samples and standard solution. Conductivity values were calculated by determination of the following; i. cell constant
ii. sample values.

Determination of the Cell Constant

The cell constant was determined by measuring a standard reference solution with a known conductivity. 0.01N Potassium chloride (KCL) (APHA AWWA APCF 1989 p 2.60) was used as a standard reference solution. 0.01N KCL has a conductivity of 1413µmhos/cm at 25°C (APHA AWWA APCF 1989). The cell constant was determined by rinsing the conductivity cell several times with 0.01N KCL and then adjusting the temperature of the solution to 25C. The resistance and the temperature of the solution were measured. The cell constant was determined by;

$$C= (0.001413)\ (R_{kcl})\ (1+0.0191)\ (t-25)$$

where Rkcl = measured resistance, µmhos
t = observed temperature, °C

C, measured conductance, was converted to conductivity, Ks, by finding the reciprocal of the specific resistance, R;

$$\mathbf{Ks = \frac{1}{R}}$$

(APHA AWWA APCF 1989)

Conductivity measurement of samples

Before each sample reading the cell was rinsed several times with the sample and the temperature of the sample adjusted to 25°C. The temperature and resistance of each sample was taken. After each sample reading the cell was rinsed with distilled water several times. Sample conductivity K, at 25°C was determined by;

$$K = \frac{m\ (1000000)\ (C)}{1+[\ 0.0191\ (t-25)]}$$

where Km = measured conductivity at t °C in µmhos
C = cell constant, cm^{-1}
t = temperature of sample, C
(APHA AWWA APCF 1989 p2.61)

Heavy Metal Analysis

Water samples were analysed for iron, lead and copper. Samples were collected at the appropriate testing times and stored in 30mL sampling bottles. Samples were preserved with 0.15 mL concentrated nitric acid (5mL HNO_3/L or pH<2) and labelled. Two samples were collected for each treatment on each testing day. One sample was collected and acid preserved. The other sample was acid digested. This was to determine whether heavy metals were adsorbed to organic matter. In the majority of samples there was no difference in the undigested samples and digested samples. In digested samples which differed in value from the undigested sample, the digested value, the higher value was taken.

Preliminary Digestion for Heavy Metals

For total heavy metals determination preliminary digestion was required. Samples were digested to reduce interference by organic/particulate matter and to release metals adsorbed to organic matter. The Standard Methods nitric acid technique (APHA AWWA APCF 1989,p3.8) was chosen because the nitric-hydrochloric acid and the nitric-sulphuric acid techniques are not recommended for lead analysis (APHA AWWA APCF 1989,P3.7).

Acidified samples were transferred to 125mL acid washed erlenmeyer flasks with 5mL concentrated nitric acid and a few glass bead. Samples were placed on a hot plate in a fume cupboard and bought to a slow boil. Digestion was complete when the sample had evaporated to one-fifth of the total volume and before precipitation occurred. A light, clear solution indicated digestion was complete. The filtrate and several rinsings were transferred to the storage bottles.

Metal Determination by Flame Atomic Absorption Spectrometry(AAS)

Heavy metal concentrations were determined by Standard Methods flame atomic absorption spectrometry (AAS) technique(APHA AWWA APCF, 1989). The direct air-acetylene flame method was used for the determination of lead, iron and copper concentrations (APHA AWWA APCF 1989,p3.13-3.22). The instrument used to determine heavy metal concentrations was a Spectrophotometer AAEN (BG corrector) (0.019 AZ) Stoichmetric model.

This technique operates on the principle that each metal has its own characteristics absorption wavelength. A source lamp composed of that element is used to minimise spectral interference. The amount of energy at the characteristics wavelength absorbed in the direct flame is proportional to the concentration of element int he sample over a limited concentration range (APHA AWWA APCF 1989 3.13). Each metal has a specific signature thereefore each metal was tested separately. Table A1 shows the specific requirements for each metal tested.

Table A.1
Metal ranges and specifics for AAS

Metal	Wavelength nm	Detection limit mg/L	Sensitivity mg/L	Optimum range mg/L	Standard used for sample calibration ppm
Iron	248.3	0.02	0.12	0.3-10	5
Lead	217.0	0.05	0.5	1-12	1
Copper	324.7	0.01	0.1	0.2-10	10

Instrument Calibration

The following steps were used to standardise and calibrate the spectrophotometer:

1. Power on. All knobs in anticlockwise position
2. Lamp energy to 30nm (background continuous lamp)
3. Set the appropriate wavelength according to metal test
4. Set slit width of light path specified in instrument manual

5. Optimise wavelength energy using energy gain - approximately to a value of 75
6. Use fine adjustments to obtain a peak value. When a maximum value is reached turn energy gain back to 75
7. Wind burner up to light path until there is an energy readout
8. Wind burner to a position just under the light path. A business card was used to align the light beam. Adjust the vertical, horizontal and rotational positions of the burner to maximise sensitivity
9. Turn on air then fuel and ignite
10. Aspirate a standard solution with a value mid-range within the expected range. Adjust the nebuliser to obtain maximum sensitivity
11. Adjust the fuel-air ratio to maximise sensitivity. The characteristics flow rate is approximately 4mL/min. Adjust the fuel flow to maximise signal. Aspirate the sample standard solution. Check baseline and readjust if necessary. Adjust oxygen flow to maximise absorbance reading. Aspirate known sample standard solution. Check baseline and readjust if necessary.

Instrument standardisation

Three to five standard solution concentrations for each metal tested in the range of expected values were used to standardise the instrument. The absorbance of each concentration was recorded. A pike addition technique - an addition of a known concentration of metal solution - was added to each of the 3 to 5 solutions. Each absorbance value was recorded and plotted on graph paper against the concentration of each standard concentration to produce a linear calibration curve. Three concentrations within the linear range were selected to standardise the instrument. With the spike addition technique a 85-115% recovery rate was expected.

Sample analysis

All samples, standard solutions, blank samples and rinsing solutions used deionised water to minimise contamination of metals from other sources. Iron, lead and copper standard solutions were prepared according to standard methods (APHA AWWA APCF, 1989, 3-21). Iron standard solutions required 25ml calcium solution per 100ml of standard solution prior to aspiration.

Prior to a sample analysis the nebuliser was aspirated with deionised water containing 1.5mL HNO3/L. A blank sample was aspirated and the instrument zeroed. A blank sample of deionised water was run prior to each sample run to verify baseline stability. The sample standard solution was run after each testing period.

Technique 2. Anoidic Stripping Voltammetry for Lead and Copper

The direct flame air-acetylene method proved inadequate in detecting the low levels of metal in the sample solutions. Many of the samples recorded zero values, particularly lead. To determine whether the samples contained zero quantities or that the direct flame air-acetylene technique was too insensitive another technique was used. Anoidic stripping voltammetry (ASV) using a digital voltammeter was used to determine concentration, particularly low concentrations of lead and copper in sample solutions. Iron was not amenable to this technique.

The principle of this technique is that metals in solution are plated onto an electrode, stripped and reoxidised. Each metal has its own characteristics potential. An electrolyte solution was used to support the passage of an electric current and to provide a matrix for chemical analysis. For the analysis of copper and lead a mercury plated carbon electrode and heavy metal electrolyte (HME) were used. The HME was prepared by dissolving 117g NaCl, 35g ascorbic acid ($C_6H_8O_6$) and 7.7 g of NaOH in 500mL of deionised water. HME oxidises relatively quickly therefore new solutions were prepared every 4 days. Prepared solutions were stored in glass flasks covered in foil and refrigerated to minimise oxidation.

Instrument calibration and standardisation

Prior to standardisation the instrument was cleaned thoroughly. The cells in the portable digital voltammeter (PDV) were rinsed with deionised water several times. A dummy run was conducted to verify the baseline integrity of the mercury film on the electrode. The electrode was replated if required.

The instrument was standardised using the following steps:
1. Rinse cell thoroughly with deionised water several times
2. Place 10Mls of HME solution
3. Add 0.1mL: Pb/Cu/Cd standard solution
4. Set the appropriate menu (Menu 2 for Pb and Cu)
5. Standardise
6. If 100ppb showing then set standard
7. Press run
8. Run a blank sample to verify standardisation baseline stability

Analysis of Lead and Copper using spike addition method

1. Rinse cell several times with deionised water
2. Using Gilson pipette dispense 5mL of sample to the cell and 5mL HME
3. Press run
4. Record peak height
5. With a Gilson pipette dispense 0.1mL of standard solution to the cell'
6. Press run
7. Record new height and apply formula

$$U=HAC/(NA+(N-H)V)$$

where

H= Peak heoght of sample (ppb)
V = volume of sample (mL)
A = Volume of standard aliquot (mL)
C = known concentration of standard (ppb)
N = New peak height (ppb)
U = Unknown (ppb)

NB. The unknown solution has twice the concentration of the cell solution compared to standardised run.

After each sample run a blank sample ie. a sample of HME with no standard was run. This was necessary to verify that there was no background concentration of metal in the electrolyte. Also, this was essential to check the effectiveness of the technique and integrity of the mercury film. The spike addition technique was used in preference to the direct comparison technique because it is useful in highlighting any unknown substances which may cause enhancement or suppression of metal peak heights. The instrument was restandardised after every 10 samples. All samples were run twice to verify accuracy of method and instrument integrity.

Sensitivity and accuracy for the AAS and PDV

Sensitivity and accuracy of readings are dependent upon many factors. The use of blanks after each sample and restandardisation of the instruments after approximately 10 samples maintains consistency. Evaluation of accuracy for low concentration levels is difficult to assess.

Colour

Table A2
Colour scale

Value	Description
1	clear
2	slight cloudiness
3	light yellow and clear
4	light yellow and cloudy
5	mid yellow and clear
6	mid yellow and cloudy
7	dark yellow brown and clear
8	dark yellow brown and cloudy
9	dark brown/black
10	black/grey/whitish

APPENDIX 2: RESULTS OF TESTS FOR EACH DRUM

DRUM 1

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.55	0.00	0.00	0.0	0.00	25	1	0.00	0.00	0.00	0.25
1	6.45	0.00	0.00	0.0	0.00	25	1	0.00	0.00	0.00	0.23
3	6.60	0.00	0.00	0.0	0.10	22.5	1	0.00	0.00	0.00	0.16
3	6.59	0.00	0.00	0.0	0.10	22.5	1	0.00	0.00	0.00	0.17
5	6.45	0.00	0.00	0.0	0.15	20	1	0.00	0.00	0.00	0.26
5	6.42	0.00	0.00	0.0	0.06	20	1	0.00	0.00	0.00	0.21
8	6.60	0.00	0.00	0.0	0.10	27	1	0.00		0.00	0.04
8	6.60	0.00	0.00	0.0	0.10	27	1	0.00		0.00	0.08
11	6.60	0.00	0.00	0.0	0.12	24.75	1	0.00		0.00	0.11
11	6.60	0.00	0.00	0.0		24.75	1	0.00		0.00	0.31
18	6.26	0.00	0.00	0.0	0.04	26.5	1	0.00	0.00	0.00	0.19
18	6.26	0.00	0.00	0.0		26.5	1	0.00		0.00	0.15
32	6.30	0.00	0.00	0.0	0.04	26.5	1	10.37	0.00	0.00	0.09
32	6.27	0.00	0.00	0.0		26.5	1	10.37	0.00	0.00	0.12
64	6.27	0.00	0.00	0.0	0.00	24.75	1	53.45	0.00	0.00	0.07
64	6.29	0.00	0.00	0.0		24.75	1	64.15	0.00	0.00	0.10
242	6.39	0.00	0.00	0.0	0.00	21.75	1	46.73	0.00	0.00	0.02
242	6.43	0.00	0.00	0.0	0.00	21.75	1	46.73		0.00	0.01

DRUM 2

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.55	0.00	0.00	0.0	0.00	25	1	0.00	0.00	0.00	0.14
1	6.55	0.00	0.00	0.0	0.00	25	1	0.00	0.00	0.00	0.15
3	6.57	0.00	0.00	0.0	0.10	22.5	1	0.00	0.00	0.00	0.26
3	6.57	0.00	0.00	0.0	0.08	22.5	1	0.00	0.00	0.00	0.18
5	6.59	0.00	0.00	0.0	0.10	20	1	0.00	0.00	0.00	0.06
5	6.62	0.00	0.00	0.0	0.15	20	1	0.00	0.00	0.00	0.08
8	6.58	0.00	0.00	0.0	0.10	26	1	0.00	0.00	0.00	0.04
8	6.58	0.00	0.00	0.0	0.10	26	1	0.00		0.00	0.05
11	6.58	0.00	0.00	0.0	0.03	24.75	1	0.00		0.00	0.11
11	6.58	0.00	0.00	0.0		24.75	1	0.00		0.00	0.14
18	6.51	0.00	0.00	0.0	0.04	26.5	1	0.00		0.00	0.27
18	6.54	0.00		0.0		26.5	1	0.00		0.00	0.19
32	6.28	0.00	0.01	0.0	0.04	26	1	10.37	0.00	0.00	0.10
32	6.29	0.00	0.01	0.0		26	1	10.37	0.00	0.00	0.10
64	6.28	0.00	0.00	0.0	0.03	24.75	1	74.84	0.00	0.00	0.09
64	6.29	0.00	0.00	0.0		24.75	1	53.45	0.00	0.00	0.12
242	6.40	0.00	0.00	0.0	0.00	21	1	46.25	0.00	0.00	0.01
242	6.39	0.00	0.00	0.0	0.02	21	1	46.25	0.00	0.00	0.01

DRUM 3

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	5.56	12.00	0.01	3.0	0.40	25.5	3	84.9	176.40	0.50	0.06
1	5.56	9.00	0.02	3.0	0.60	25.5	3	84.9	176.40	0.25	0.08
1	4.80	73.40	0.00	6.0	0.70	26	5	540.4	186.94	0.60	0.12
1	4.80	71.20	0.00	6.0		26	5	540.4	200.00	0.40	0.10
3	5.59	20.00	0.01	2.0	0.40	22.5	3	454.8	313.00	0.50	0.20
3	5.59	10.00	0.02	3.0	0.40	22.5	3	240.8	426.00	0.25	0.14
3	4.68	25.80	0.00	0.0	1.00	25	5	1000.7	313.00	0.50	0.30
3	4.67	33.00	0.00	2.0		25	5	1000.7	616.00	0.50	0.33
5	5.28	13.00	0.00	6.0	0.50	20	3	177.5	320.00	0.50	0.07
5	5.29	14.00	0.00	7.0	0.30	20	3	224.8	463.00	0.50	0.06
5	4.71	63.00	0.01	14.0	1.60	26	5	1069.9	492.00	0.60	0.24
5	4.71	40.00	0.01	13.0		26	5	1069.9	320.00	0.60	0.22
8	5.24	10.40	0.02	10.0	0.30	26	4	461.1		0.25	0.09
8	5.21	34.00	0.02	23.0	0.28	26	4	437.5	860.00	0.25	0.11
8	4.59	31.00	0.00	28.0	1.50	26.5	7	1339.4	796.00	0.40	0.25
8	4.59	32.00	0.00	10.0		26.5	7	1329.0	923.59	0.40	0.24
11	5.24	12.50	0.02	3.0	0.25	24.75	4	451.6	571.42	3.00	0.09
11	5.21	76.00	0.02	11.0	1.90	24.75	4	440.8	889.92	0.75	0.02
11	4.40	44.00	0.00	19.0		24	7	1392.4		0.30	0.77
11	4.41	44.60	0.00	17.0		24	7	1513.0		0.30	0.73
18	5.07	44.60	0.02	12.0	0.60	26.5	4	436.5	629.28	0.50	0.38
18	5.07	37.00	0.02	19.0	2.10	26.5	4	426.1		0.50	0.36
18	4.34	53.00	0.00	19.0		26.5	7	1426.4		0.40	0.26
18	4.35	32.00	0.00	20.0		26.5	7	1417.7		0.40	0.14
32	4.90	33.00	0.06	17.0	1.30	27	4	596.1	1016.06	0.50	0.30
32	4.90	254.00	0.07	22.0	1.92	27	4	596.1	1026.40	0.60	0.30
32	4.40	254.00	0.02	26.0		26.6	7	1598.5	161.60	0.40	0.25
32	4.38	30.50	0.03	30.0		26.6	7	1547.3	176.20	0.40	0.23
64	5.30	52.00	0.03	41.0	1.60	24.75	4	727.0	57.14	0.80	0.21
64	5.34	271.00	0.03	25.0	1.57	24.75	4	743.0	17.04	0.70	0.18
64	5.18	282.00	0.01	18.0		20	7	2609.8	1733.76	0.30	0.30
64	5.18	8.00	0.02	20.0		20	7	2491.2	1632.96	0.30	0.36
242	6.51	8.00	0.02	7.0	0.58	21.25	4	709.0	64.00	0.30	0.04
242	6.54	180.70	0.03	7.0	0.54	21.25	4	685.7	76.80	0.50	0.03
242	6.01	180.70	0.00	18.0	1.14	22	7	2140.4	537.60	0.60	0.01
242	6.02	57.00	0.00	18.0	1.01	22	7	2140.4	302.08	0.30	0.01

DRUM 4

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	5.31	38.00	0.00	3.0	0.64	25.5	4	105.09	56.00	0.10	0.07
1	5.30	30.00	0.00	3.0	0.46	25.5	4	42.03	56.00	0.20	0.07
3	6.95	30.00	0.00	1.0	0.32	22.5	4	631.30	61.60	0.10	0.16
3	6.95	36.00	0.00	4.0	0.32	22.5	4	631.30	61.60	0.20	0.14
5	6.81	33.00	0.00	8.0	0.30	20	4	828.08	160.00	0.20	0.08
5	6.83	34.00	0.00	6.3	0.30	20	4	816.25	160.00	0.20	0.04
8	7.17	34.20	0.00	23.0	0.40	26	5	768.57		0.40	0.10
8	7.17	34.00	0.00	23.0	0.40	26	5	733.10		0.10	0.08
11	7.22	35.00	0.00	16.0	0.46	24.75	5	741.84		0.10	0.13
11	7.25	31.00	0.00	19.0		24.75	5	752.90		0.20	0.15
18	7.12	50.00	0.00	23.0	0.30	26.5	5	654.71		0.10	0.23
18	7.17	48.40	0.00	31.0		26.5	5	675.50		0.10	0.24
32	6.52		0.03	18.0	2.00	26	5	858.54	117.90	0.30	0.11
32	6.53	41.00	0.04	14.0		26	5	869.01	128.10	0.40	0.12
64	6.64	41.00	0.05	19.0	1.80	24.75	7	898.04	121.55	0.30	0.16
64	6.61	65.00	0.05	23.0		24.75	7	940.81	109.06	0.30	0.15
242	7.49	57.80	0.05	35.0	0.63	21	7	1156.37	51.20	0.40	0.05
242	7.53	58.50	0.06	6.0	0.57	21	7	1149.89	261.12	0.40	0.06

DRUM 5

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	4.46	42.00	0.00	5.0	0.40	25.5	2	94.58	224.00	0.20	0.06
1	4.47	52.00	0.00	5.0	0.50	25.5	2	94.58	224.00	0.20	0.06
3	4.78	32.00	0.00	12.0	0.30	22.5	2	609.90	184.80	0.20	0.28
3	4.78	40.00	0.00	6.0	0.50	22.5	2	609.90	123.20	0.30	0.16
5	4.85	38.00	0.00	9.0	0.40	20	4	709.78	240.00	0.30	0.20
5	4.85	56.00	0.00	11.0	0.40	20	4	697.95	240.00	0.30	0.24
8	4.59	56.00	0.00	13.0	0.56	26	4	733.10		0.30	0.05
8	4.59	56.00	0.00	13.0	0.56	26	4	733.10		0.20	0.08
11	4.74	45.50	0.00		0.28	24.75	4	741.84		0.50	0.12
11	4.75		0.00	20.0		24.75	4	731.09		0.50	0.32
18	4.85	65.60	0.00	23.0		26.5	4	623.54		0.40	0.23
18	4.85	65.00	0.00	18.0		26.5	4	644.32		0.30	0.26
32	5.97	64.80	0.04	15.0	1.00	26	4	659.61	184.90	0.40	0.13
32	5.98	61.20	0.04	15.0		26	4	649.14	314.50	0.50	0.15
64	5.69	42.00	0.04	8.0	1.60	24.75	4	865.97	174.00	1.00	0.18
64	5.68	38.00	0.04	10.0		24.75	4	865.97	160.00	1.20	0.21
242	6.67	14.00	0.02	4.0	1.57	21	4	911.24	89.60	3.30	0.02
242	6.67	14.00	0.02	4.0	1.57	21	4	911.24	102.40	3.20	0.02

DRUM 6

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.11	1.50	0.00	0.0	0.30	25.5	2	10.51	0.00	0.10	0.05
1	6.16	1.50	0.00	0.0	0.34	25.5	2	10.51	0.00	0.10	0.07
3	6.27	1.40	0.00	0.0	0.50	22.5	2	82.25	12.13	0.20	0.00
3	6.28	6.00	0.00	0.0	0.38	22.5	2	53.50	24.64	0.10	0.06
5	5.82	6.00	0.00	1.0	0.36	20	2	118.30	0.00	0.20	0.27
5	5.83	7.40	0.00	0.0	0.32	20	2	117.30	0.00	0.20	0.24
8	6.27	8.80	0.00	5.0	0.36	26	2	118.24		0.20	0.04
8	6.28	8.00	0.00	5.0	0.32	26	2	118.24		0.10	0.03
11	6.13	1.50	0.00	3.0	0.54	24.75	2	129.01		0.40	0.17
11	6.13	1.50	0.00	2.0		24.75	2	129.01		0.30	0.29
18	6.13	7.20	0.00	2.0	0.40	26.5	2	124.71		0.20	0.40
18	6.14	6.00	0.00	1.0		26.5	2	124.71		0.20	0.46
32	6.13	3.40	0.00	0.0	0.10	26.25	2	198.00	0.00	0.10	0.04
32	6.14	11.00	0.00	2.0		26.25	2	208.42		0.10	0.14
64	5.88		0.00	12.0	0.50	24.75	2	245.89	0.00	0.10	0.12
64	5.87	1.40	0.00	13.0		24.75	2	256.58	0.00	0.10	0.13
242	6.99	0.10	0.00	2.0	0.00	20.75	2	47.47	0.00	0.10	0.02
242	7.04	0.10	0.00	7.0	0.05	20.75	2	70.46	0.00	0.10	0.02

DRUM 7

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	8.08	0.00	0.00	0.0	0.30	25.5	3	6624.24	0.00	0.50	0.00
1	8.09	0.00	0.00	0.0	0.28	25.5	3	6624.24	28.88	0.50	0.00
3	8.00	0.00	0.00	0.0	0.28	23	3	7564.98	0.00	0.30	0.02
3	7.98	0.00	0.00	0.0	0.28	23	3	7787.48	0.00	0.40	0.00
5	7.92	0.00	0.00	0.0	0.00	22	3	7952.69	0.00	0.30	0.17
5	7.96	0.00	0.00	0.0	0.20	22	3	7952.69	0.00	0.40	0.25
8	8.16	0.00	0.00	0.0	0.00	25	3	6634.00		0.00	0.12
8	8.14	0.60	0.00	0.0	0.00	25	3	6634.00		0.60	0.17
11	8.19	1.60	0.00	0.0	0.00	24	3	7090.43		0.50	0.29
11	8.22	2.80	0.00	0.0		24	3	7199.51		0.60	0.23
18	8.23	5.00	0.00	0.0	0.00	26.5	3	6443.20		0.20	0.24
18	8.23	11.00	0.00	0.0		26.5	3	6443.20		0.20	0.30
32	8.22	3.00	0.00	4.0	0.10	25	3	7472.82	28.88	0.20	0.10
32	8.23	3.40	0.00	4.0		25	3	7582.80	0.00	0.20	0.13
64	7.31	0.00	0.00	0.0	0.30	24.75	3	6521.51	18.33	0.20	0.14
64	7.31	0.20	0.00			24.75	3	6628.42	61.60	0.20	0.11
242	8.20	0.10	0.00	0.0	0.10	21	3	7126.35	12.80	0.20	0.01
242	8.23	0.10	0.00	0.0	0.10	21	3	7126.35	12.80	0.20	0.01

DRUM 8

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	7.42	0.00	0.00	0.0	0.28	25.5	3	6624.24	0.00	0.40	0.00
1	7.42	0.00	0.00	0.0	0.24	25.5	3	6571.24	38.60	0.40	0.00
3	7.28	0.00	0.00	0.0	0.28	22	3	7945.26	0.00	0.40	0.00
3	7.27	0.00	0.00	0.0	0.40	22	3	7888.51	53.20	0.40	0.02
5	7.67	0.00	0.00	0.0	0.00	23	3	7794.76	30.80	0.40	0.27
5	7.69	0.00	0.00	0.0	0.00	23	3	7794.76	30.80	0.40	0.18
8	7.49	0.80	0.00	0.0	0.00	25	3	6420.00	23.00	0.00	0.26
8	7.49	0.60	0.00	0.0	0.10	25	3	6420.00		0.10	0.37
11	7.48	2.20	0.00	0.0	0.10	24	3	6872.62		0.10	0.27
11	7.46	1.00	0.00	0.0		24	3	6872.62		0.10	0.24
18	7.64	4.00	0.00		0.00	26.5	3	6443.20		0.10	0.27
18	8.65	4.00	0.00	0.0		26.5	3	6443.20		0.10	0.46
32	7.71	2.00	0.00		0.00	26	3	7440.68	89.68	0.10	0.20
32	7.72	2.20	0.00	0.0		26	3	7335.88	0.00	0.10	0.16
64	7.21	0.00	0.00	0.0	0.40	24.75	3	6521.51	18.65	0.10	0.09
64	7.21	0.80	0.00			24.75	3	6628.42	18.65	0.10	0.11
242	8.18	0.10	0.00	0.0	0.13	21	3	7126.35	44.00	0.20	0.01
242	8.18	0.50	0.00	0.0	0.10	21	3	7126.35	49.12	0.10	0.01

DRUM 9

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.56	42.60	0.00	3.0	0.36	25.5	8	6687.50	147.20	1.90	0.00
1	6.54	36.00	0.00	4.0	0.36	25.5	8	6687.50	310.00	1.90	0.00
1	6.43	42.60	0.01	9.0	1.80	26	8	7066.74	133.60	1.50	0.05
1	6.44	36.00	0.00	12.0		26	8	7170.66	133.60	1.70	0.06
3	6.40	88.00	0.00	5.0	0.44	22	10	7945.26	121.00	1.80	0.25
3	6.40	40.60	0.01	9.0	0.36	22	10	7831.76	118.00	2.20	0.04
3	6.40	88.00	0.00	20.0	1.70	25	10	7476.00	106.40	1.60	0.04
3	6.41	34.40	0.00	20.0		25	10	7582.80	159.60	1.60	0.04
5	6.50	91.00	0.01	2.0	0.28	23	10	8462.88	230.00	1.90	0.07
5	6.50	92.50	0.01	8.0	0.30	23	10	8128.82	295.60	2.00	0.15
5	6.61	93.60	0.00	19.0	1.40	26	10	7552.55	277.20	1.30	0.12
5	6.49	22.40	0.00	28.0		26	10	7552.55	492.80	1.20	0.10
8	6.28	154.00	0.01	9.0	0.28	25	8	6634.00	162.00	1.80	0.24
8	6.29	153.00	0.01	47.0	0.30	25	8	6634.00	219.12	1.40	0.24
8	6.57	28.00	0.00	51.0	3.60	26.5	10	7475.43	447.50	1.30	0.06
8	6.57	89.00	0.00	9.0		26.5	10	7475.43		1.20	0.03
11	6.45	110.40	0.01	14.0	0.50	23.75	8	7563.54	219.12	2.20	0.18
11	6.45	138.40	0.01	17.0	1.80	23.75	8	7673.16	447.50	2.30	0.20
11	6.38	90.00	0.00	22.0		24	10	7723.21		1.40	0.03
11	6.39	84.00	0.00	27.0		24	10	7831.99		1.40	0.04
18	6.27	74.00	0.01	9.0	1.00	26.5	8	6443.20	325.44	2.00	0.12
18	6.27	111.00	0.01	18.0	3.10	26.5	8	6443.20	325.44	2.00	0.05
18	6.30	100.00	0.00	11.0		26.5	10	8174.21		1.60	0.03
18	6.31	81.00	0.00	44.0		26.5	10	8174.21		1.60	0.03
32	6.40	31.60	0.01	36.0	3.70	26	8	7545.48	234.20	3.50	0.07
32	6.39	60.80	0.01	21.0	2.55	26	8	7545.48	241.70	2.80	0.06
32	6.35	44.00	0.01	28.0		25.5	8	8368.08	260.50	1.70	0.04
32	6.36	45.00	0.01	59.0		25.5	8	8472.69	247.50	3.20	0.04
64	6.30	61.50	0.01	200.0	3.44	24.75	8	7056.06	251.68	1.70	0.13
64	6.30	63.00	0.00	8.0	1.64	24.75	8	7376.79	316.80	1.60	0.17
64	6.90	44.00	0.00	7.0		20	8	9371.70	207.36	0.90	0.06
64	6.87	45.00	0.00	212.0		20	8	9490.33	236.16	0.70	0.05
242	7.19	9.00	0.00	2.0	0.69	20.75	8	7985.63	358.84	0.70	0.01
242	7.20	115.00	0.00	0.0	0.78	20.75	8	7985.63	128.00	0.80	0.01
242	7.76	147.60	0.00	3.0	0.50	22	8	8241.01	122.88	0.60	0.01
242	7.80	156.70	0.00	3.0	0.51	22	8	8241.01	76.80	0.70	0.01

DRUM 10

Time days	pH	P μg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	7.74	33.00	0.00	6.0	0.40	25	7	6955.00	93.52	0.60	0.00
1	7.83	32.00	0.00	9.0	0.40	25	7	6955.00	93.52	0.70	0.00
3	7.43	33.00	0.00	0.0	0.32	22	7	7945.26	138.32	0.70	0.00
3	7.49	34.00	0.00	1.0	0.64	22	7	7945.26	138.20	0.50	0.00
5	7.43	37.00	0.00	7.0	0.52	23	7	8017.47	174.00	0.80	0.16
5	7.49	36.00	0.00	3.0	0.52	23	7	8351.53	123.20	0.90	0.17
8	7.53	14.00	0.00	0.0	0.52	25	7	6634.00	123.20	1.10	0.17
8	7.54	15.00	0.00	0.0	0.52	25	7	6634.00	125.00	1.10	0.06
11	7.62	29.40	0.00	4.0	0.50	23.75	7	7563.54		1.00	0.20
11	7.63	76.60	0.00	7.0		23.75	7	7673.16		1.00	0.20
18	7.71		0.00	9.0	0.60	26.5	7	6547.12		1.10	0.25
18	7.71	32.00	0.00	4.0		26.5	7	6547.12		1.10	0.25
32	7.62	22.00	0.00	3.0	1.00	26	7	7545.48	109.44	0.40	0.06
32	7.63	20.80	0.00	7.0		26	7	7545.48	112.48	0.50	0.08
64	7.06	20.00	0.01	19.0	1.50	24.75	7	6735.55	288.64	0.60	0.20
64	7.06	28.00	0.01	29.0		24.75	7	6628.42	100.64	0.50	0.16
242	7.76	3.75	0.02	11.0	0.58	20.75	5	7982.32	89.60	0.60	0.01
242	7.78	3.75	0.02	13.0	0.58	20.75	5	7982.32	256.00	0.50	0.01

DRUM 11

Time days	pH	P μg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.58	30.00	0.00	9.0	1.50	25	9	7276.00	227.12	1.80	0.03
1	6.65	30.00	0.00	9.0	0.64	25	9	7276.00	222.12	1.70	0.02
3	6.02	32.00	0.00	12.0	0.36	22	10	7945.26	319.20	2.90	0.00
3	6.02	40.00	0.00	6.0	0.52	22	10	7945.26	478.80	3.00	0.00
5	6.02	45.00	0.00	3.0	0.44	23	10	8017.47	246.40	2.00	0.08
5	6.02	44.00	0.00	2.0	0.48	23	10	8017.47	369.60	2.00	0.21
8	6.11	38.00	0.00	2.0	0.44	25	8	7276.00	233.00	2.00	0.24
8	6.13	38.00	0.00	2.0	0.44	25	8	7276.00		1.90	0.03
11	6.27	61.00	0.00	12.0	2.10	23.75	8	7563.54		2.10	0.23
11	6.27	98.40	0.00	17.0		23.75	8	7673.16		2.10	0.33
18	6.01	144.00	0.00	22.0	2.10	26.5	8	6547.12		2.10	0.19
18	6.01	102.00	0.00	17.0		26.5	8	6547.12		2.10	0.17
32	5.63	121.00	0.00	24.0	13.70	26	8	7440.68	241.70	2.20	0.08
32	5.64	90.00	0.00	33.0		26	8	7440.68	367.20	2.00	0.12
64	6.16	112.00	0.00	25.0	2.50	24.75	8	7376.79	323.84	1.60	0.09
64	6.17	60.50	0.01	24.8		24.75	8	7376.79	330.88	1.50	0.13
242	7.36	29.00	0.00	6.0	0.98	20.75	8	7633.33	284.16	1.20	0.01
242	7.36	36.00	0.00	3.0	2.68	20.75	8	7783.01	295.68	1.20	0.01

DRUM 12

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	7.49	10.50	0.01	0.0	0.17	25.25	3	6679.53	0.00	1.30	0.01
1	7.53	10.50	0.01	0.0	0.18	25.25	3	6519.22	0.00	1.10	0.00
3	6.89	16.00	0.00	0.0	0.20	22	3	7945.26	0.00	1.90	0.00
3	6.89	16.00	0.00	0.0	0.28	22	3	7945.26	53.20	2.10	0.00
5	6.89	18.90	0.00	0.0	0.20	23	3	7906.11	0.00	2.10	0.16
5	6.89	18.00	0.00	0.0	0.28	23	3	7850.44	30.80	2.70	0.14
8	6.95	19.00	0.00	1.0	0.20	25	4	6527.00	10.00	1.20	0.29
8	6.95	19.00	0.00	1.0	0.28	25	4	6634.00		1.40	0.28
11	7.14	30.00	0.00	0.0	0.20	24	4	7417.68		0.70	0.21
11	7.17	28.20	0.00	5.0		24	4	7417.68		0.90	0.23
18	7.17	16.00	0.00	2.0	0.20	26.5	4	6443.20		1.20	0.22
18	7.18	34.00	0.00	2.0		26.5	4	6443.20		1.50	0.25
32	7.28	10.20	0.02	2.0	1.00	26	4	7335.88	0.00	1.10	0.09
32	7.28	10.20	0.02	5.0		26	4	7335.88	0.00	1.10	0.10
64	6.42	20.00	0.00	7.0	0.50	24.75	4	6628.42	21.12	0.30	0.10
64	6.44	28.00	0.00	9.0		24.75	4	6628.42	51.04	0.30	0.12
242	7.62	22.00	0.00	2.0	0.00	20.75	3	7281.02	76.80	0.10	0.02
242	7.63	27.00	0.00	2.0	0.00	20.75	3	7281.02	89.60	0.10	0.02

DRUM 13

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.40	0.00	0.00	0.0	0.00	26	1	52.25		0.00	0.08
1	6.39	0.00	0.00	0.0		26	1	73.15	0.00	0.00	0.07
3	6.70	0.00	0.00	0.0	0.30	25	1	85.20	0.00	0.00	0.05
3	6.72	0.00	0.00	0.0		25	1	85.20	0.00	0.00	0.04
5	6.23	0.00	0.00	0.0	0.30	25.5	1	85.36	0.00	0.00	0.04
5	6.24	0.20	0.00	0.0		25.5	1	85.36	0.00	0.00	0.04
8	6.03	0.00	0.00	0.0	0.30	26.5	1	93.44	0.00	0.00	0.10
8	6.04	1.00	0.00	0.0		26.5	1	93.44	0.00	0.00	0.09
11	6.14	0.00	0.00	0.0	0.60	24	1	97.90	0.00	0.00	0.07
11	6.15	1.00	0.00	0.0		24	1	97.90	0.00	0.00	0.07
18	6.10	1.00	0.00	0.0	0.30	26.5	1	94.32	0.00	0.00	0.05
18	6.11	0.00	0.00	0.0		26.5	1	94.32	0.00	0.00	0.06
32	6.14	1.00	0.01	0.0	0.00	26.6	1	92.22	0.00	0.00	0.31
32	6.16	1.00	0.01	0.0		26.6	1	92.22	0.00	0.10	0.35
64	6.45	1.00	0.01	0.0	0.00	20	1	94.90	0.00	0.00	0.12
64	6.42	1.00	0.01	0.0		20	1	106.77	0.00	0.00	0.12
242	5.78	0.00	0.00	0.0	0.00	22	1	103.54	0.00	0.00	0.01
242	5.78	0.01	0.00	0.0	0.00	22	1	103.54	0.00	0.00	0.01

DRUM 14

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.50	0.00	0.00	0.0	0.00	26	1	83.60	7.36	0.00	0.06
1	6.50	1.00	0.00	0.0		26	1	94.05	7.10	0.00	0.06
3	6.50	0.40	0.00	0.0	0.00	24	1	76.63	0.00	0.00	0.04
3	6.51	0.80	0.00			24	1	87.10	0.00	0.00	0.04
5	6.40	4.00	0.00	0.0	0.30	25	1	85.36	0.00	0.00	0.05
5	6.39	1.20	0.00	0.0		25	1	85.36	0.00	0.00	0.05
8	6.23	0.00	0.00	0.0	0.30	26.5	1	93.44	0.00	0.00	0.07
8	6.24	2.00	0.00	0.0		26.5	1	93.44	0.00	0.00	0.07
11	6.30	1.00	0.00	0.0	0.60	24	1	97.90	0.00	0.00	0.07
11	6.29	1.00	0.00	0.0		24	1	97.90	0.00	0.00	0.07
18	6.32	0.00	0.00	0.0	0.30	26.5	1	94.32	0.00	0.00	0.02
18	6.34	0.00	0.00	0.0		26.5	1	94.32	0.00	0.00	0.02
32	6.32	1.00	0.01	0.0	0.58	26.8	1	92.22	0.00	0.10	0.11
32	6.34	1.00	0.01	0.0		26.8	1	92.22	0.00	0.00	0.10
64	6.65	1.00	0.01	0.0	0.19	20	1	118.63	0.00	0.10	0.14
64	6.65	0.00	0.01	0.0		20	1	130.49	0.00	0.10	0.15
242	6.44	0.00	0.00	0.0	0.17	22	1	114.46	0.00	0.10	0.02
242	6.45	0.00	0.00	0.0	0.19	22	1	125.90	0.00	0.10	0.02

DRUM 15

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.43	0.00	0.00	0.0	0.00	26	1	52.25	0.00	0.00	0.05
1	6.42	2.60	0.00	0.0		26	1	73.15	0.00	0.00	0.04
3	6.45	2.40	0.00	1.0	0.20	24	1	54.43	0.00	0.00	0.03
3	6.46	1.20	0.00	2.0		24	1	54.43	0.00	0.00	0.03
5	6.31	2.80	0.00	0.0	0.20	25	1	53.35	0.00	0.00	0.09
5	6.30	3.60	0.00	0.0		25	1	53.35	0.00	0.00	0.09
8	6.19	4.00	0.00	0.0	0.20	26.5	1	83.06	0.00	0.00	0.08
8	6.20	4.00	0.00	1.0		26.5	1	72.68		0.00	0.08
11	6.20	4.00	0.00	0.0	0.60	24	1	76.14	0.00	0.00	0.07
11	6.18	3.00	0.00	0.0		24	1	87.10	0.00	0.00	0.06
18	6.20	2.00	0.00	0.0	0.20	26.5	1	94.32	0.00	0.00	0.06
18	6.18	4.00	0.00	0.0		26.5	1	83.84	0.00	0.00	0.06
32	6.20	4.00	0.00	0.0	0.72	26.6	1	92.22	0.00	0.00	0.12
32	6.18	4.00	0.00	0.0		26.6	1	97.35		0.00	0.12
64	6.66	0.00	0.00	0.0	0.51	20	1	118.63	0.00	0.00	0.09
64	6.62	0.00	0.00	0.0		20	1	124.56	0.00	0.00	0.08
242	6.20	3.00	0.00	0.0	0.51	22	1	114.46	0.00	0.00	0.10
242	6.22	1.00	0.00	0.0	0.51	22	1	114.46	0.00	0.00	0.01

DRUM 16

Time days	pH	P µg/L	Pb mg/L	SS mg/L	TON mg/L	Temp C	Colour	Conduc uS/cm	COD mg/L	Fe mg/L	Cu mg/L
1	6.62	19.40	0.00	0.0	0.55	26	3	118.11	25.00	0.00	0.07
1	6.63	21.60	0.00	0.0		26	3	209.01	30.00		0.08
3	6.75		0.00	3.0	0.80	25.5	3	232.75	0.00	0.00	0.06
3	6.70	27.20	0.00	7.0		25.5	3	232.75	0.00	0.00	0.07
5	6.70	36.00	0.00	1.0	1.00	25	3	224.07	0.00	0.00	0.06
5	6.69	34.00	0.00	1.0		25	3	224.07	0.00	0.00	0.06
8	6.74	5.00	0.00	1.0	0.40	26.5	3	217.83	17.90	0.00	0.04
8	6.73	6.00	0.00	1.0		26.5	3	228.20	0.00	0.00	0.04
11	6.72	6.00	0.00	1.0	0.40	24	3	222.99	0.00	0.00	0.07
11	6.70	6.00	0.00	1.0		24	3	228.43	33.18	0.00	0.06
18	6.70	7.00	0.01	1.0	0.80	26.5	3	230.55	28.36	0.00	0.06
18	6.68	8.00	0.01	2.0		26.5	3	239.47	27.36	0.00	0.07
32	6.70	16.00	0.00	5.0	0.60	26.6	3	225.43	70.08	0.00	0.15
32	6.68	16.00	0.00	5.0		26.6	3	215.84	18.69	0.00	0.15
64	6.61	8.00	0.01	3.0	0.80	20.5	3	330.30	69.12	0.00	0.07
64	6.64	8.00	0.01	5.0		20.5	3	308.44	0.00	0.00	0.07
242	6.67	16.90	0.00	2.0	0.00	22	3	331.93	0.00	0.00	0.01
242	6.68	17.20	0.00	3.0	0.00	22	3	331.93	0.00	0.00	0.02

UWRAA RESEARCH REPORTS

Report Number	Title	Author
1	Trickling filter – solids contact process: Pilot plant studies.	M. Laginestra
2	A model of water pricing for Melbourne, Sydney and Perth	P. B. Dixon P. M. Norman
3	Taste generation associated with chloramination	M. Kerslake
4	Bacterial regrowth in water supplies	K. Power L. A. Nagy
5	Leakage management: Assessing the effect of pressure reduction on losses from water distribution systems	B. Horvath
6	Improving communication with the public on water industry policy issues	B. E. Nancarrow G. J. Syme
7	Water use efficiency of domestic appliances	I. J. Beith D. J. Horton
8	Sewage fermentation units to increase degradable COD fraction	P. J. Bliss D. Barnes P. R. Evans I. Law
9	Review of artificial destratification of water storages in Australia	T. F. McAuliffe R. S. Rosich
10	Taste thresholds of mono-chloramine and chlorine in water	R. O'Halloran C. Veres
11	Chromatographic analysis of chloramines using electrochemical detection	R. O'Halloran Hai Lin Ge P. Spizziri
12	Glass reinforced plastic bore casing for large diameter and deep bores	R. Bowyer
13	A guide to improving communication with the public on water industry policy issues	B. E. Nancarrow G. J. Syme
14	Fouling and cleaning of fine bubble ceramic dome diffusers	K. J. Hartley
15	Chloramination of Water Supplies	P. M. Thomas (ed)
16	The 1988 Australian Winter Storms Experiment: Report on aircraft observations	J. B. Jensen
17	Pipeline assets: Life cycle management and economic life	R. Vass M. Anderson R. Lewis D. Samson
18	Development of empirical model for tradewaste discharges to small treatment plants	Camp Scott Furphy
19	PRELIM users guide (Amended): Australian Version	Camp Scott Furphy
20	Chemical regeneration of activated carbon: Preliminary studies	G. Newcombe
21	Management and display of dam surveillance data	D. M. Stirling G. L. Benwell A. B. Murnane
22	Evaluation and demonstration facilities for primary sensors	J. A. Lanaway M. Cavey
23	Modelling and design of reservoir aeration destratification systems	D. P. Lewis J. C. Patterson J. Imberger R. P. Wright S. G. Schadlow
24	Modelling optimum conditions for reservoir destratification using mechanical mixers	R. M. A. Velzeboer J. A. Cugley J. C. Patterson
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26	Toxic cyanobacteria in water supplies: Analytical techniques	D. J. Flett B. C. Nicholson
27	Tracing toxic discharges to sewers by analysis of biofilms	D. Oliver T. Watson
28	Electronic meter reading: Link between water meter and house	P. J. Reid J. S. Renwick M. F. Prior
29	Identification of common noxious cyanobacteria: Part 1 – Nostocales	P. Baker
30	Forecasting water demand using weather data	M. N. Viswanathan
31	Effects of controls on water consumption	M. N. Viswanathan
32	Biological removal of iron from groundwater: Preliminary studies	M. N. Viswanathan
33	Statistical modelling of water main failures	E. Tsui G. Judd
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36	Microbiological studies on enhanced removal of phosphates from sewage	R. C. Bayly J. W. May G. Vasiliadis G. N. Rees
37	Magnetite and microwaves in sewage effluent treatment	D. R. Dixon A. J. Ware
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39	Current cost asset valuation: Methodology	J. Dyke

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42	Coagulants for water treatment: A generic guide	ACWQR
43	Optimal prices for urban water: A general equilibrium model applied to Melbourne	P.B. Dixon D.J. Baker
44	Applications of the Streaming Current Detector in water treatment	W. Barron D. R. Dixon M. Pascoe
45	Sydney coastal stormwater study	W. G. Rowlands et al.
46	Identification of common noxious cyanobacteria: Part 2 – Chroococcales and Oscillatoriales	P. Baker
47	Levelling using the Global Positioning System	A. P. Armstrong P. A. Collier F. J. Leahy
48	Allocation of sewerage costs to customer segments	R. Hood P. Geary
49	Impact of urban lawns on nutrient contamination of an unconfined aquifer	M. L. Sharma D. E. Herne P. G. Kin J. D. M. Byme
50	Early warning system for hazardous substances in sewage	R. O'Halloran B. A. Sexton N. H. Pilkington
51	Management model for trade waste discharges to small treatment plants (including PRELIM VERSION 4.0 Users Guide)	Camp Scott Furphy
52	Automatic meter reading: Link between meters and billing centre (Combined utilities trial)	B. Phey A. Leong Z. Balazic
53	Prediction of perceived odour strength and type from composition of sewage odour mixtures	D. G. Laing A. Eddy D. J. Best
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55	Development of a water quality analyser suitable for unattended use in rivers and streams	G. W. Skyring I. A. Johns J. A. Cugley
56	Enhancement of nitrification in wastewater lagoons	P. M. Gross
57	Identification of critical water supply assets	PPK Consultants
58	Water in Our Environment: Education Project	H. Breidahl D. Cliffe H. Henderson
59	Electronic household water meter: Investigation into a cost effective design	Z. Balazic A. Leong
60	Domestic greywater reuse: Preliminary evaluation	B. Jeppesen
61	Chemical regeneration of activated carbon: A feasibility study	G. Newcombe
62	Tracing toxic discharges to sewers by analysis of biofilms (Stage 2)	W. H. Lock
63	Production of Jerusalem artichoke hybrids under irrigation using urban wastewater	M. Parameswaran
64	Control of pitting corrosion of copper tubes in potable waters	R. J. Taylor P. H. Cannington
65	Measurement of Total Factor Productivity in major water utilities: Melbourne case study	I. Manning E. Molyneux
66	Assimilable organic carbon as a measure of bacterial growth potential in water supplies	K. C. Tapang M. Drikas L. E. Bennett
67	Simultaneous peak water demands in residential areas	J. Henstridge G. J. Syme B. E. Nancarrow
68	Installation damage: Effect on lifetimes of uPVC pipes subjected to cyclic pressure	L. S. Burn
69	Safety aspects of the design of roadways as floodways	R. J. Keller B. Mitsch
70	Regional development implications of wastewater reuse: Werribee case study	D. Hunter W. Smith L. Nagy P. Jacob
71	Treatment of electroplating wastes using new-generation membrane technology	A. G. Fane Y. R. Shen
72	Stochastic economic approach to headworks augmentation timing	G. Kuczera W. S. Ng
73	Domestic greywater reuse: Overseas practice and its applicability to Australia	B. Jeppesen D. Solley
74	Decision support systems for the water industry: An Object-Oriented approach	J. M. Edwards
75	Chemical characterisation and olfactometric measurement of odours from sewage treatment process units	R. Kaye N. Mulhem D. Stone
76	Utilisation of sewage sludge for minesite rehabilitation: Rix's Creek Mine Trial	C. P. Phillips
77	A benchmarking methodology for the Australian water industry	I.R.C. Eggleton
78	Water quality effects of aeration/ destratification at Harding Reservoir, W.A.	R.S. Rosich T.A. McAuliffe

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79	Heavy metals and organics in domestic wastewater	W. H. Lock
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117	Water Sensitive Urban Design: A Tool for Urban Integrated Catchment Management - a Case Study of Bayswater	M Mouritz P Newman
118	An Evaluation of an Integrated Urban Water Management System: Palmyra Case Study	M Mouritz P Newman
119	Critical Evaluation of Domestic Irrigation Equipment	The Australian Irrigation Technology Centre
120	New Concepts in Sludge Dewatering	P Scales S Johnson D Labbett D Dixon

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200	Review of Drinking Water Treatment Coagulants	Gutteridge Haskins & Davey
201	Biological Aspects of Aluminium in Food and Water Supply	F Cumming
	Occasional Papers	
No 1	Water Pricing and the Marginal Cost of Water	R Warner
No 2	Systematic Environmental Management in the Water Industry: Toward Best Practice	S Mills
	A Guide to Wetland Invertebrates of Southwestern Australia	J Davis