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Assessment of Urban Stormwater Quality in Western Australia

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Abstract. The main aim of this study was to understand the impacts of land use on stormwater quality. Stormwater samples have been collected from three main land use areas; residential, commercial and industrial lands around the Town of Victoria Park in Western Australia. Each sample was tested to measure water quality parameters such as total organic carbon (TOC), suspended solids (SS), total nitrogen (TN), Nitrate Nitrogen (NO3-), Nitrite Nitrogen (NO2−), Ammonia Nitrogen (NH3-N) and total phosphorus (TP). Time variation of stormwater flow, rainfall intensity and stormwater quality clearly showed that the highest concentration of pollutants in stormwater occurs during the first flush event. Further analysis shows that the commercial stormwater demonstrated the cleanest appearing stormwater with lowest amounts of suspended solids whereas the industrial stormwater had the dirtiest appearing stormwater quality. Nutrients in the residential stormwater have the lowest nitrate, ammonia and phosphate concentrations. Overall, the industrial land use site recorded the worst stormwater quality. These results of the preliminary study are only a snapshot of the quality of Western Australia's stormwater runoff, but they emphasize the value of further detailed investigations.

Keywords: Stormwater, Land use, Water quality, Contaminants

1. Introduction

Stormwater runoff picks up natural and human-made contaminants that accumulated on surfaces during the dry days and transports them to the receiving waters bodies such as rivers, lakes and ocean. The forms and concentrations of contaminants from runoff are closely related to various types of land use because human activity is different according to land use (Ha and Stenstrom, 2003, Goonetileke et al, 2005). To control stormwater pollution effectively, development of innovative land-use-related control strategies will be required. An approach that could differentiate land-use effects on stormwater would be a first step in solving this problem. Several studies have shown that the contribution of stormwater pollutants must be considered in order to correctly implement an environmental preservation method for a receiving water body A common objective of most urban water quality studies has been to strive to relate land use to pollutant loadings (Hall and Anderson, 1986, Lopes et al., 1995, Parker et al., 2000; Shinya et al, 2000).

Stormwater quality is an issue in Western Australia because the states stormwater typically flows into the state's rivers and ocean or infiltrates back into the groundwater system which is used for drinking in the state. Currently in Western Australia, there are no stormwater quality management procedures in place. Regional reports show that state stormwater may contain different substances including heavy metals, nutrients, petroleum hydrocarbons, suspended solids and microbiological organisms, all depending on the land use of that area. The problem of stormwater pollution is becoming worse because of population growth, which results in increased impermeable surfaces. Perth experienced its highest population growth rate in 2007-2008 of 2.8% (Australian Bureau of Statistics, 2009). With these increases the quality of stormwater is becoming more of an issue around the state as general water quality awareness increases. This study aims to explore the relationship between water quality variables and various types of land use in Western Australia.

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2. Study Area: Town of Victoria Park

The main scopes of this study are; collecting stormwater samples from different land use areas over a period of time during a storm event, identifying the storm water quality for different land use areas by analysing collected samples, studying the temporal variation of stormwater quality during a storm event, developing relationships between stormwater quality versus land use type and developing recommendations and guidelines for stormwater management.

The land use areas focused on in this study include residential, commercial and industrial lands around the Town of Victoria Park in Western Australia. Town of Victoria Park is located 3km southeast of Perth; it has an area of 17.62km2 which consists of mainly commercial and residential areas, also minority of industrial area (Town of Victoria Park, 2009). Five sampling locations with varying land uses have been used for this study; commercial, residential, industrial, and two areas with mix land use patterns (Area #4 consists of 71% of residential and 29% of commercial; area #5 consists of 36% of residential and 64% commercial). Stormwater samples were collected at drainage outlets of the compensation basins of each study area. These outlets were selected based on the surrounding land use, ease of access, site safety and stormwater drainage outlet type so that sample collection would be possible.

3. Methodology

3.1. Sample Collection and Testing

Correct collection of stormwater samples is essential to be able to analyse the stormwater quality in the laboratory facilities. Once a stormwater drainage outlet starts flowing during a storm event, a 1.5 litre sample was taken at ten minute intervals to provide a time related view of the stormwater quality. Each sample was tested within 24hrs of collection. Sample testing was undertaken at the Water Quality laboratory of Curtin University and all testing was conducted according to the test methods specified in APHA, Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Event samples collected at each study location were analysed for total organic carbon (TOC), suspended solids (SS), total nitrogen (TN), Nitrate Nitrogen (NO3-), Nitrite Nitrogen (NO2−), Ammonia Nitrogen (NH3-N) and total phosphorus (TP). An electronic rain gauge with a data logger was used to record the rain intensity for each storm event while the stormwater samples are collected. In addition the volumetric flow rate of the stormwater outlet was also recorded for the duration of the sampling

4. Results and Discussions

4.1. Temporal Variation of Stormwater Quality

Using the sample collected at every 10mins interval, the temporal variation of stormwater quality has been investigated. Figure 1 shows the temporal variation of Nutrients at commercial, residential and industrial land use observation locations. Also the rainfall intensity has been also integrated in the figures to show the responses of rainfall on water quality. The first flush principle is well demonstrated in these figures, when the highest amount of pollutant concentration occurs at the beginning of the storm event. Other peaks in pollutant concentrations occur in correlation with the maximum peaks in rainfall intensity. This demonstrates the amount of pollutants increase in stormwater with relation to intensity of the storm events.

When compare the Nutrient at different land use catchments, commercial land use receives the peak concentration of phosphate 10 minutes after the peak rainfall intensity. Other Nutrients at commercial lands are relatively low compared to phosphate. This is likely to be due to the amount of vehicle use as the majority of this area is used for car parking, contributing to the higher amounts of phosphate. Nutrient concentration levels in the residential land use area also follow the rain intensity pattern by having the highest concentrations recorded simultaneous with the highest rain intensity. Nitrate levels appear to have the opposite occurring by decreasing during the increasing of rain intensity. Ammonia is at its highest concentration with the first flush of stormwater and then only small amounts are recorded afterwards for the remainder of the storm event. Phosphate is the most common nutrient in residential land use stormwater, having a high concentration with the first flush and then remaining high.

In the industrial land use area, Ammonia and phosphate followed the same pattern. In this site, nitrate concentration levels follow the opposite pattern to the ammonia concentration levels. As nitrate levels increase there is a decrease in both ammonia and phosphate concentration levels. The opposite happens when nitrate levels decrease. Nitrate concentrations decreases when rain intensity increases. This site recorded very small concentrations of nitrite for the whole duration of the storm event demonstrating nitrite is not an issue in this industrial land use area.

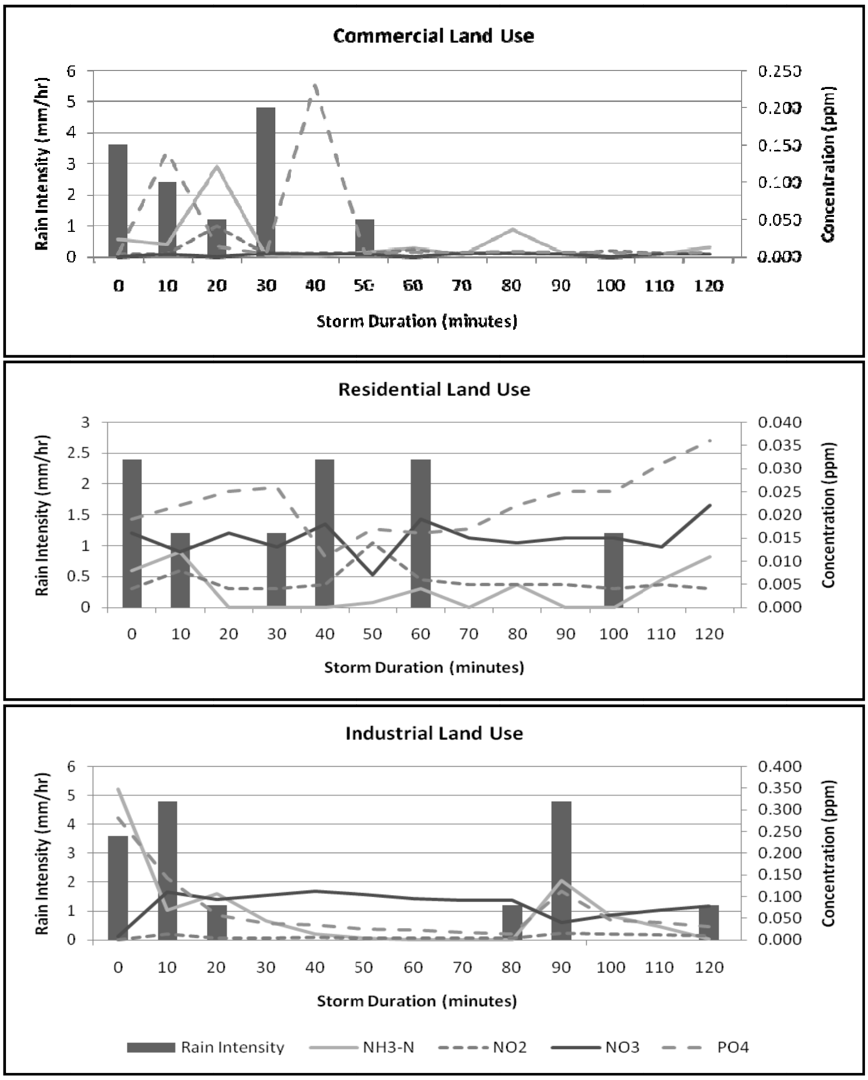

Figure 1: Temporal variation of nutrient concentrations and rain intensity

Suspended solid is one of the main indicators of water quality. Most of pollutants coagulate with suspended solids and shows great relation with it. Time variation of stormwater flow rate and suspended solids is shown in Figure 2. The first flush principle is also demonstrated here. The first flush and other peaks of suspended solids during the storm duration correlate to the increase in stormwater flow at the same time. The highest amount of suspended solids concentration occurs at the beginning of the storm event. Other peaks in suspended solids concentrations occur in correlation with the maximum flow.

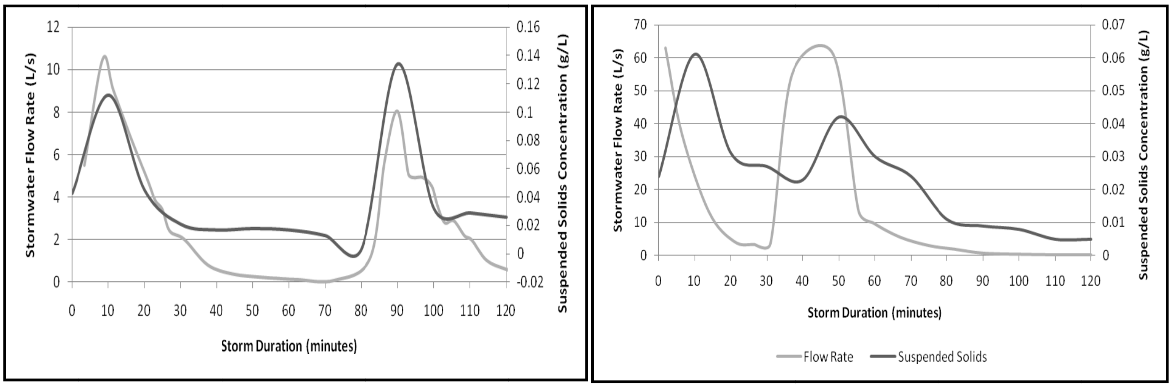

Figure 2: Flow Rate vs. Suspended Solids for Two Sampling Locations

4.2. Land use versus Stormwater Quality

Analysing the pollutant distribution in all collected samples, the average pollutant concentration (pH, suspended solids, Turbidity, Nitrate, Nitrite, Ammonia and Phosphate) in stormwater in each land use area is tabulated in Table 1. Stormwater in commercial land use area demonstrated the cleanest appearing stormwater with lowest average amounts of suspended solids within the stormwater. This land use sampling location also had other physical traits. It recorded the turbidity of all the different land use sites and lowest turbidity variance of all the different land use sites. With a low variance for suspended solids and turbidity, commercial sites are reasonably predictable and the results also demonstrate that there is a link between suspended solids and turbidity within stormwater. Also the lowest nitrate and the highest nitrite concentration are recorded in commercial areas. Nitrite recorded the highest variance indicating that parameter can be unpredictable concentration in the stormwater. Residential land was demonstrated low levels of ammonia present in the stormwater at some point in time while also recording the lowest minimum phosphate concentration in the stormwater samples collected.

Residential stormwater resulted in containing low nitrate concentration and recorded low nitrate concentration. The residential site was one of many sites that demonstrated zero levels of ammonia present in the stormwater at some point in time. This site also recorded the lowest concentration of ammonia in stormwater. This indicates that the presence of ammonia in residential stormwater is usually predictable and in low amounts.

The industrial stormwater sampling location also had the dirtiest appearing stormwater quality. This is due to recording the highest amounts of suspended solids in the stormwater when compared to the other land use locations results. The results also demonstrate that there is a link between suspended solids and turbidity within stormwater. The nutrient amounts in industrial sampling location also showed some features unique to the industrial site. This is the only site to record a zero concentration of nitrate in the stormwater at some point in time. The industrial location also recorded the highest nitrate, ammonia and phosphate over all the stormwater sampling locations.

Table 1: Average Stormwater Quality Results

Land use	pH	SS	Turbidity (NTU)	Nitrite (ppm)	Nitrate (ppm)	Ammonia (ppm)	Phosphate (ppm)
Commercial	5.74	0.007	1.164	0.008	0.003	0.019	0.034
Residential	6.73	0.016	1.900	0.006	0.015	0.004	0.022
Industrial	6.49	0.039	1.762	0.007	0.081	0.063	0.066

5. Conclusions

To understand the impacts of land use pattern on stormwater quality, stormwater samples have been tested in three main land use areas; residential, commercial and industrial lands around the Town of Victoria Park in Western Australia. The results show very interesting patterns. Time variation of stormwater flow, rainfall intensity and stormwater quality clearly showed that the highest peak in stormwater contaminants occurs after the beginning of the storm event which is referred to as the first flush event, where the majority of pollutants are washed down with the initial precipitation runoff. The highest nitrite concentration was recorded in commercial lands. The industrial stormwater had the dirtiest appearing stormwater quality showing the highest amounts of suspended solids. Residential stormwater shows the lowest nitrate, ammonia and phosphate concentrations.

A general recommendation concluded from this study is that pollutant traps be incorporated into Western Australia's drainage network by incorporating some new infrastructure into the current drainage networks. Compensation basins can improve quality of the stormwater entering it using items purposely designed with the intension of improving the stormwater quality including sedimentation ponds, litter traps or wetlands. Also, the first flush of stormwater is diverted away from natural waterways as the results indicated that the initial first flush of stormwater that contains higher levels of both physical and chemical contaminates. Another general recommendation is that industrial land use areas stormwater do not enter natural waterways as the results of this project demonstrate that the industrial land use sites have the worst storm water quality.

6. Acknowledgements

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