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Stormwater runoff quality in Malabe, Sri Lanka

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Abstract

Stormwater runoff is the primary nonpoint source that pollutes all water resources. Stormwater pollution at a sewage outfall is a mixture of different kinds and strengths of pollutants from different surfaces. It is essential to understand typical pollutants from each of several impervious surfaces of a specific suburbanized area in order to properly analyze and design water quality improvement systems. Two types of impervious surfaces, roads and pavement, of two catchments in northern and southern Malabe, a western suburb of Colombo, were studied to determine the physicochemical characteristics of their stormwater runoff pollutants. For each surface type from each catchment, the first flush was sampled using a sheetflow technique. Five pollution paramters, i.e., pH, turbidity, colour, electrical conductivity (EC), and nitrate content, were analyzed and compared with that of the rain water. The pavement surfaces showed higher values of turbidity, colour, and nitrate, while EC was higher for road surfaces. The turbidity and colour values were higher in the northern catchment than that in the southern one while EC values were opposite. The nitrate concentration values of pavements were consistently higher than that of the roads for both catchments, which were not much higher than that of rain water. The pH value was consistently neutral for both surface types while rain water was slightly acidic.

Keywords: Contaminants, Impervious layer, Malabe, Stormwater runoff, Urbanization

1. Introduction

Stormwater runoff flows from different land-uses including residential, commercial, industrial areas, roads, highways and bridges, among others, flows to receiving water bodies (rivers, lakes and other bodies of water). A portion of precipitated water flows on as stormwater runoff [1]. Its amount is directly related to the amount of water absorbed by the ground as surface infiltration. The slope of the land, degree of saturation of soil, porosity of the soil, vegetation on the surface and land-use are few examples of the factors affecting the infiltration capacity of surfaces, and thus indirectly affects surface runoff [2].

However, urbanization adversely impacts infiltration, thus increases the runoff [3]. Urbanization increases impervious surfaces and therefore, the total pervious area is reduced. Therefore, stormwater that would have previously infiltrated now is stormwater runoff. Stormwater, generally, is not an issue as it is a significant component of the water cycle. However, excessive stormwater causes many environmental issues. It has become a major problem in today's world. Day by day, the world's pervious areas are converted to impervious ones. Therefore, stormwater management is a challenge [4]. Urbanization takes place in almost all countries. Therefore, stormwater management is not confined to specific countries, but is a global issue. The Environmental Protection Agency in the United States [5] identified three categories of adverse impacts associated with stormwater discharges upon receiving waters. They are: 1) short-term changes in water quality during and after storm events, including temporary increases in the concentrations of one or more pollutants, toxins or bacteria levels, 2) long-term water quality impacts caused by the cumulative effects associated with repeated stormwater discharges from a number of sources, and, 3) physical impacts due to erosion, scour, and deposition associated with increased frequency and volume of runoff that alters aquatic habitat.

Stormwater management is directly related to flood mitigation. Floods are the quantitative adverse impacts of excessive stormwater. In contrast, the qualitative adverse impact is the water quality aspects of the stormwater, which has not received much attention in developing countries. The deposited pollutants on impervious surfaces wash into receiving water even during a minor rainfall. Therefore, the urban stormwater wash off has been recognized as a "non-point" pollution source causing deterioration of water quality of surface water. [6].

Stormwater is easily contaminated by various pollutants. Therefore, stormwater flows along roads are contaminated. People never consider the adverse impacts of this in south Asian countries. The general public thinks that it is completely natural to have floods of

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contaminated stormwater during rainy events. However, this contamination is a major cause of waterborne diseases after a flood. This not only causes health issues but also creates issues related to aesthetics. However, the attention of planners and researchers is minimal regarding the qualitative aspects of stormwater when compared to floods and related issues. As previously stated, most developing countries worry about the infrastructure damage caused by floods. Therefore, they look for remedial measures to minimize floods. Therefore, there is a clear research gap regarding the water quality constituents that flow in stormwater. Additionally, urbanization changes land-use and it creates new pollutants in runoff. For example, a forest converted to an agricultural area has increased nitrogen and phosphorus in its stormwater. It would be similar if the land-use is converted to an industrial zone from a forest. The runoff would contaminated by industrial pollutant, like heavy metals. The same result would be observed had it was changed to an industrial area. Land-use has subsequently become one of the major factors that affects the types and levels of pollutant generation [7]. Therefore, the pollutants that flow in stormwater are adversely changed with urbanization.

The concentrations of pollutants are very high, especially during the first rain event after a dry period. The first flush has a significant contribution to nearby receiving waters because it contains most of the pollutants. Pollutographs show a sudden incremental changes in water quality constituents during the first flush and the concentration levels adversely impact the aquatic life in receiving waters. Additionally, the biodiversity in the receiving waters is endangered. Previous researchers [8-10] generated pollutographs for several constituents in stormwater. They showed the variability of concentrations with respect to varioius land-uses. However, they were developed using hypothetical data. Therefore, it is very important to acquire physicochemical pollutant data of stormwater runoff for different land-uses to develop predictive models for urban water systems [11-13]. Insufficient data and improper sampling of stormwater leads to uncertainties in stormwater modelling [13]. However, monitoring water quality is not an easy task [14]. More specifically, the collection of stormwater from various impervious surfaces is rather difficult. Therefore, a special technique called “sheetflow sampling” has been used in most of monitoring processes [15-17].

Many researchers tried to identify the most influenual surfaces in stormwater contamination. Road surfaces, roofs and parking areas have been identified as some of them. Therefore, the pollutant concentration that wash off due to impermeable roads and parking surfaces are significant compared to other impervious surfaces. This varies with traffic density, and wind drift as well as the duration and intensity of stormwater events [18].

Malabe, Sri Lanka has been under rapid development and urbanization during the past decade. It is interesting to analyze the quality of stormwater runoff in the area. Therefore, this paper presents an initial analysis of the quality of stormwater around the SLIIT campus in Malabe. As a rapid growing city, the analysis would give insights to carry out a detailed water quality analysis in the area. This would further identify the necessity of such a detailed study in an event like the floods that occurred in May, 2016. Additionally, similar studies in trophic climates are limited. Therefore, this research work addresses a gap and adds information about the tropical climate.

2. Study area

Malabe is around 15 km driving distance from the Sri Lanka’s capital, Colombo. It is in the wet zone of Sri Lanka and receives an average of 2120 mm of rainfall annually [19]. The southwestern monsoon brings the majority of the rainfall during the months of May to September. However, inter-monsoon rains can bring some rainfall during the months of November and December. Since Malabe is in the wet zone, the humidity is quite high. The temperatures are around 27 ^{0}C-33 ^{0}C during the day and 22 ^{0}C-25 ^{0}C at night [19].

The SLIIT higher education institute is located along the Malabe-Kaduwela Road. The institution has a capacity of 8000 students. The surrounding area is heavily urbanized. The statistics obtained from divisional secretariat, Kaduwela, show the rate of population change from 2001 to 2012 in the area (Table 1). During this time, there was a 27% increase in the population of Malabe. This suggests that the rate of urbanization is high and thus, has increased areas of impervious land.

Table 1 Population of Malabe, Sri Lanka

Division	Year 2001	Year 2012	Percentage Increment
Malabe, north	5653	7680	36%
Malabe, east	3963	5958	50%
Malabe, west	5050	5141	2%
Hokandara, north	5057	6238	24%
Total	19723	25017	27%

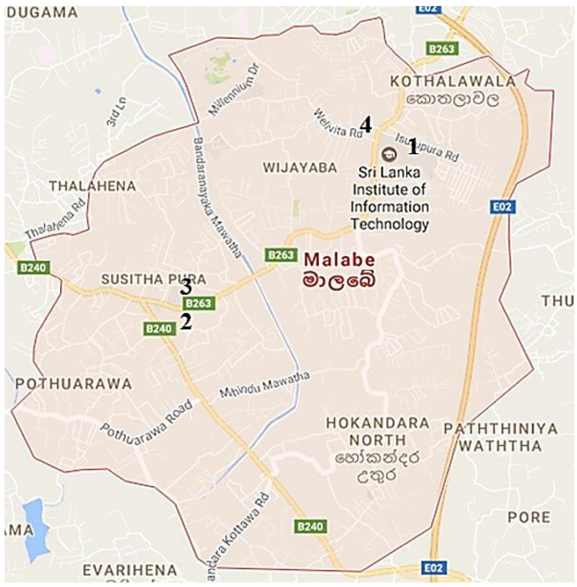

Figure 1 Sample locations in Malabe, Sri Lanka (Google Maps)

Several sample locations were identified in the Malabe area (Figure 1). They are (1) the impervious pavement surface of the SLIIT Malabe campus, (2) impervious road surfaces in Malabe town, (3) impervious pavement surface in Malabe town, and (4) impervious road surfaces along Walivita Road in Malabe. These four locations lie in a relatively flat region. Most of this area has open drains to collect stormwater runoff. However, due to improper maintenance, these open drains are often blocked. The sampling locations are within

2 km of the Environmental Engineering Laboratory of SLIIT campus. We believe these locations are representative of the Malabe area and can be used in an initial study.

The sampling areas are impervious areas. Location 1 is a concrete bricked area and the other locations (2, 3, 4) are covered by asphalt. Topographical map analysis using image processing (data not presented) showed about a 13% increase in impervious area in Malabe from 2004 to 2016. This clearly shows the influence of urbanization.

3. Data collection and analysis

Stormwater samples were collected in November 2016. Malabe and surrounding areas had not had any rainfall for around 2-3 months. We caught the first rainfall event after a significant dry period. Four groups rushed to these locations at the same time (given in Figure 1) to collect the stormwater runoff. We were able to collect 3 samples at each location over a week. The sheet flow sampling method was used. First, a plastic sheet was laid on the impervious surface a all locations, and then, two sand bags were placed on top of each sheet to create a funneling effect. Next, a metal bar was placed under the plastic sheet just downstream of the sand bags to collect the stormwater. A plastic bag was filled several times and emptied into a sample bottle until 1 liter of stormwater was collected. The bottle was labeled with the place, date and time of collection. After that, the bottle was put into a resealable plastic bag and kept in a cooler for transport to the laboratory.

All of the samples were collected during the first flush, i.e., within the first 5-10 minutes of the rainfall. It is well established that the first flush occurs during the first 10 minutes of a rainfall [20]. Sampling was done to collect as many as impurities and other particles from various surfaces before they washed away.

It was assumed that the accuracy of the tests for water quality would be increased because of the increased number of the samples. Additionally, a sample of rainwater was collected from each location to analyze and compare it against the stormwater quality. A clean wide pan was used to collect rainwater without touching any other surfaces.

The water samples were tested at the Water and Environmental Engineering Laboratory, Faculty of Engineering, on the SLIIT Malabe Campus. We measured their pH values, turbidity, colour, conductivity, nitrate, total solids using the available resources. These included a *EUTECH 700* pH meter, *HACH 2100* turbidity meter, *HACH R2800* spectrophotometer and *SensION EC71 GLP* electrical conductivity meter.

Due to the limited resources, we could not measure the oil and grease levels in the stormwater samples. It is highly recommended that these experiments be conducted in a future study for sound conclusions.

4. Results and discussion

Table 2 presents the average values of the measures of physicochemical pollutants in the collected stormwater samples. The pH values of the tested stormwater samples were comparable to rainwater (slight variations). The pH values for stormwater samples were approximately 7. Most aquatic life is sensitive to lower pH values. However, the measured pH values are within the allowable upper and lower limits [21] Therefore, significant impact upon the aquatic life in receiving waters would not be expected on the basis of pH alone. The pH value of the corresponding rainwater was about 6.27. The impurities in the stormwater increased the pH values of the rainwater.

The turbidity values of the stormwater samples showed that the turbidity values are much higher in samples from pavement surfaces than from roads. Additionally, the turbidity value was higher for impervious surface 1 at the Sri Lanka Institute of Information Technology than for impervious surfaces in Malabe town. The abnormal increment in the level of turbidity in the runoff water collected at Location 1 (pavement in the SLIIT car park) can be due to the heavy dust accumulation in the interlocked pavement. Additionally, a nearby construction site increased dust in the parking area.

However, samples taken from Locations 2 and 4 showed acceptable levels of turbidity. Additionally, the turbidity levels were solely due to the pollution loads on the impervious surfaces as the collected rainwater was not turbid. Nevertheless, high turbidity can significantly reduce the aesthetic quality of lakes and streams, harmfully impacting recreation and tourism. Furthermore, it can increase the cost of drinking water treatment and adversely impact aquatic life. Additionally, the aesthetics of water bodies are affected by water colour. The colour of the water bodies directly impacts absorption of solar radiation and can influence the growth of water plants. Water turbidity and colour can impact water in the same way.

Electric conductivity of stormwater samples showed no significant differences in any of the four locations. Location 4 showed a little higher electric conductivity. However, these EC values were slightly higher than for rainwater.

Additionally, the nitrate concentrations of the stormwater samples were well below the upper limits. However, concentrations from the various payments were slightly higher than for road surfaces. These results are from an initial study. Extended research is proposed.

5. Summary

Urbanization is unstoppable. Therefore, urban water runoff continually increases. The urban runoff carries many pollutants. We conducted an initial water quality analysis of stormwater runoff in a suburbanized area, Malabe,

Table 2 Summary of average values of physicochemical parameters

Surface type	**Parameter**				
	pH	**Turbidity (NTU)**	**Colour (Pt/Co)**	**EC (μS/cm)**	**Nitrate (mg/L)**
Impervious Pavement (1)	6.91	319	2784	56.8	9.2
Impervious Pavement (3)	7.03	167	657	58.9	9.4
Impervious Road (2)	7.04	16.95	77	66.6	4.8
Impervious Road (4)	6.9	39.7	197	136	5
Rainwater	6.27	1.52		34	3.95
Allowable limit	5.5-9.0	<50		<2250	<45.0

Sri Lanka. Some of the collected runoff sample parameters clearly had values above the desired maximum limits. The runoff generated in Malabe flows into Kelani River and the Thalangama canal, which are habitats to a wide range of species. This study gives some initial test results for stormwater quality in the area. However, an extended stormwater quality analysis is proposed with an increased number of samples and sampling locations.

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