IMPACT OF LAND USE ON URBAN STORM WATER QUALITY WITH RESPECT TO NUTRIENTS AND SUSPENDED SOLID LOADS

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ABSTRACT

The change in land use due to urbanisation significantly impacts water environments with increased run-off and degradation of water quality. The aim of this study was to understand the impact of land use on urban stormwater quality and to identify the areas of critical pollution. These areas can then be treated as important for applying Best Management Practices (BMPs). Stormwater samples were collected from five different land use areas, residential, commercial, recreational, heavy traffic and industrial lands around Guwahati city, Assam (India) and analysed. From the analysis, it was found that the stormwater quality varies with land use type. In industrial and commercial land use the pollutants exceeded the guideline values as per Indian National Standards. The spatial variation of the distribution of pollutants in stormwater was highly influenced by the surrounding land use type. Overall, the industrial land use site was identified as the site that produces the worst quality stormwater.

Key Words: Land use, Stormwater, Water quality, Pollution, BMPs

INTRODUCTION

Urbanisation produces numerous changes in the natural environment as it replaces the existing land use pattern. Changes associated with urbanization in a catchment due to any type of activity will have a direct impact on the quantity and quality characteristics of the water environment. Modification of land use associated with urbanisation results in changes to the hydrological characteristics of the surface runoff with increasing runoff volume and peak flows and reducing time to peak. Impervious surfaces such as buildings, roads and other paved areas reduce rainwater infiltration and increase stormwater runoff resulting in the reduction of ground water storage due to decreased rate of recharge. Urban form also plays an important role in storm water quality by influencing pollutant generation build-up and wash off.1 Anthropogenic activity in urban areas generates wastes and pollutants on the catchment surfaces that may be washed out to water bodies during storms.2 As the human activity is different according to land use, concentrations of pollutants in urban stormwater runoff also differs according to various types of land use. Therefore land use is frequently referred to as the most relevant factor affecting stormwater runoff characteristics.3 Urban areas have been classified in the literature into main roads (including parking lots and airports), residential areas, commercial areas, industrial areas, parks and lawns and open, undeveloped areas, all of which generate stormwater of different quality. Roads, parking lots and gas stations have been known to contribute a large variety of contaminants, directly related to vehicles such as hydrocarbons, oxides of nitrogen, sulphur and lead. The quality of stormwater from industrial areas is highly dependent upon the type of industry and the conditions at the specific site. Studies indicated that stormwater runoff from industrial areas were potentially significant sources of pollution.4 Residential areas may contain some contaminants, including detergents, plant related nutritional materials and fertilizers, herbicides and insecticides. In summary, deterioration of water quality, degradation of stream habitats and increase in flesh flood are the most common

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impacts of urbanisation. Several authors have reported alternate methods for treatment of polluted runoff water and reuse of stormwater. The stormwater improvement strategies include different Best Management Practices (BMPs) which can be structural, such as rainwater retention or non-structural, such as pollution prevention or street cleaning. This approach deals with stormwater taking into account both future needs and the protection of natural resources.

AIMS AND OBJECTIVES
The present study aims to identify different pollutants of stormwater and to establish the possible correlation of the pollutants with different land uses. The main scopes of this study are (a) collecting stormwater samples from different land use areas over a period of time during a storm event (b) identifying the stormwater quality for different land use areas by analysing collected samples, developing relationships between stormwater quality versus land use type and developing recommendations and guidelines for stormwater management.

METHODOLOGY
Study area
This study was carried out in Guwahati city, Assam, India located approximately along 26°11' N latitude and 92°49' E longitude. The city covers an area of 216 km² consisting of mainly commercial and residential areas and some amount of industrial area. The population of Guwahati has increased from 809,895 in 2001 to 963,429 in 2011 with an increase in population density from 3736 persons per sq. km. to 4445 persons per sq. km. respectively. The climate of the city for most part of the year is hot and wet, with a dry winter and a rainy season from April to mid October. The mean annual rainfall is nearly 160 cm. The location map of the study area is presented in Fig.1.

Fig. 1 : Base map of the study area

Guwahati being the gateway of North East region is undergoing rapid urbanisation and the urban population is increasing day by day. The problem of stormwater pollution is becoming worse because of population growth, which results in increased impermeable surfaces. One of the most horrible problems in the city is the lack of proper drainage and sewerage system. The drains are not properly constructed and maintained. Some of them are linked with the waste water outlets of the residential units by small drains. In most part of the city, the important roads are lined by inadequate open surface drains and in many places there are no drains at all. During the rainy season, most parts of the city remain submerged under water and thus, the surface water of the city get polluted by stormwater. Throughout the city, no proper planning has been introduced in residential, commercial, industrial, public and semi-public areas and due to this, the water environment of the city is severely affected. Occurrences of
landslide and flash flood are more common in the area due to improper construction work and tree-felling. Besides these, there are no facilities for groundwater recharge, rainwater harvesting and have no channel characterisation throughout the city. Currently, there are no stormwater quality management procedures in place.

**Sampling and analysis**

The value of any laboratory analysis and test depends upon the method of sampling. Correct collection of stormwater samples is therefore essential to be able to analyse the stormwater quality in the laboratory facilities. Sampling sites were selected on the basis of surrounding land use and land cover in five land use zones namely, industrial, commercial, recreational, residential and heavy traffic zones. Grab samples of runoff were manually collected from the downstream direction of the road runoff in the designated sampling sites in the respective zones during the rainfall event. Each sample was tested within 24 hr of collection and all testing was conducted according to the test methods specified in APHA, Standard Methods for the Examination of Water and Wastewater. Samples collected at each study location were analysed for pH, total suspended solids (TSS), total dissolved solids (TDS), sulphate (SO$_4^{2-}$), nitrate-nitrogen (NO$_3$-N), phosphate (PO$_4^{3-}$) and potassium (K$^+$).

**RESULTS AND DISCUSSION**

From Table 1, it can be observed that the pollutant concentrations vary considerably with land use pattern which indicates that pollution distribution in the storm water is highly influenced by the surrounding land use type. Pollutant build-up characteristics vary even within the same land use. This confirms the highly variable nature of build-up not only with land use but also due to site specific characteristics. pH of all the samples were within the permissible limit of WHO (6.5-8.5) for drinking water. Pollutants like nitrate nitrogen (NO$_3$-N) and Total Suspended Solids (TSS) are exceeding Indian National Standards. Sources of nitrates in water are use of fertilizer in gardening and small agriculture, decayed vegetables and animal matter, domestic effluent, sewage/sludge disposal, industrial discharges, refuge dump leachates, etc. Nitrification is the major source of nitrate in the environment. Nitrates can be readily converted to nitrites inside the body and the nitrites can give rise to the carcinogenic nitrosamines. Drinking water that gets contaminated with nitrates can prove fatal especially to infants, because in their intestinal tract, nitrates are reduced to nitrites which may cause methemoglobinemia (Blue Baby Syndrome). It is also linked to digestive tract cancers. It causes algae to bloom resulting in eutrophication in surface water.

**Table 1**: Mean and standard deviation of pollutant concentrations in each specified land use site of Guwahati city, Assam (India)

<table>
<thead>
<tr>
<th>Land use</th>
<th>Parameter</th>
<th>pH</th>
<th>SO$_4^{2-}$ (mg/L)</th>
<th>NO$_3$-N (mg/L)</th>
<th>PO$_4^{3-}$ (mg/L)</th>
<th>K$^+$ (mg/L)</th>
<th>TSS (mg/L)</th>
<th>TDS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Mean</td>
<td>7.40</td>
<td>12.41</td>
<td>11.43</td>
<td>0.18</td>
<td>20.08</td>
<td>1671.33</td>
<td>191.17</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.40</td>
<td>6.25</td>
<td>4.27</td>
<td>0.04</td>
<td>8.18</td>
<td>1120.13</td>
<td>107.33</td>
</tr>
<tr>
<td>Commercial</td>
<td>Mean</td>
<td>6.76</td>
<td>27.05</td>
<td>11.12</td>
<td>0.13</td>
<td>13.47</td>
<td>5118.60</td>
<td>316.00</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.15</td>
<td>17.86</td>
<td>6.51</td>
<td>0.06</td>
<td>4.06</td>
<td>2059.30</td>
<td>161.84</td>
</tr>
<tr>
<td>Industrial</td>
<td>Mean</td>
<td>7.12</td>
<td>66.43</td>
<td>15.30</td>
<td>0.31</td>
<td>26.35</td>
<td>8365.00</td>
<td>335.00</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.19</td>
<td>29.92</td>
<td>6.49</td>
<td>0.08</td>
<td>0.56</td>
<td>530.33</td>
<td>55.15</td>
</tr>
<tr>
<td>Heavy traffic</td>
<td>Mean</td>
<td>7.43</td>
<td>19.31</td>
<td>2.57</td>
<td>0.12</td>
<td>10.33</td>
<td>3763.38</td>
<td>280.38</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.52</td>
<td>19.30</td>
<td>3.93</td>
<td>0.04</td>
<td>4.83</td>
<td>905.84</td>
<td>87.43</td>
</tr>
<tr>
<td>Surface water</td>
<td>Mean</td>
<td>7.59</td>
<td>13.71</td>
<td>4.65</td>
<td>0.15</td>
<td>13.01</td>
<td>987.07</td>
<td>35.81</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.73</td>
<td>8.18</td>
<td>6.91</td>
<td>0.05</td>
<td>8.05</td>
<td>987.07</td>
<td>41.06</td>
</tr>
</tbody>
</table>
Sulphate and phosphate values are found within the WHO permissible limit of drinking water. Sulphate and phosphate can be obtained naturally or as a result of municipal or industrial discharges. When naturally occurring, they are often the result of the breakdown of leaves that fall into a stream of water passing through rock or soil containing gypsum and other common minerals or of atmospheric deposition. Point sources include sewage treatment plants and industrial discharges such as tanneries, pulp mills and textile mills.\textsuperscript{14-18}

The results show higher concentration of NO\textsubscript{3}-N in the residential zone followed by commercial and industrial zone. The plausible source of NO\textsubscript{3}-N can be residential sewage, human excreta and pet waste in the residential zone, nitrogen based commercial fertilizers, decay of vegetables and fruits residue in the commercial zone and industrial waste water, industrial emission, nitrogen containing raw materials and industrial processes in the industrial zone. Exceeding levels of TSS may be due to the introduction of rock and soil fragments, dirt and debris, decaying plant and animal matter, industrial wastes and sewage etc. from street, commercial, residential and industrial area.

Industrial land uses have the dirtiest appearing storm water quality. This is due to recording the highest amounts of suspended solids in the industrial land use compared to the other land uses. Industrial land use locations also recorded highest concentration of nitrate-nitrogen and phosphate over all the sampling locations.

**CONCLUSION**

To understand the impact of land use on stormwater quality, stormwater samples were collected and tested in five land use zones, industrial, commercial, recreational, residential and heavy traffic in Guwahati city, Assam, India. Results of the study show that pollutant distribution in the storm water is highly dependent on the surrounding land use type. Pollutants like nitrate nitrogen (NO\textsubscript{3}-N) and total suspended solids (TSS) are exceeding the Indian National Standards. Residential, commercial and industrial areas contribute to NO\textsubscript{3}-N in the storm water.

The main conclusions derived from the study which underlines the uncertainty associated with stormwater quality are (a) pollutant build-up characteristics vary even within the same land use pattern, confirming the highly variable nature of build-up not only with land use but also due to site specific characteristics and (b) industrial land use has relatively higher variability of maximum build-up of pollutants than the other four land uses. The results of the study demonstrate that industrial land use sites have the worst storm water quality.

General recommendation from this study is to implement storm water Best Management Practices (BMP) such as incorporation of pollutant traps at selected locations having high contamination levels of storm water such that the pollutants can be separated for safe disposal. Compensation basin can improve quality of storm water entering into it by implementing BMPs such as wet detention basin (i.e. ponds and lakes), infiltration basin, filter strips and natural and constructed wetlands, etc. Wet detention basin can remove water soluble pollutants, about 90\% of suspended solids, 80\% of metals and 40\% of BOD loads through the natural sedimentation process. Infiltration basin planted with hardy vegetation collects stormwater and uses natural sedimentation to remove pollutants. Filter strips also uses natural sedimentation to filter pollutants. Wetlands are a common measure used to filter runoff and improve downstream water quality.

One other preventive measure that can be undertaken is that stormwater runoff from industrial land use should not enter natural waterways as the study demonstrated that industrial land use sites had the worst stormwater quality. This can be done by implementing bio retention areas which are land devoted to using either soil or plants to filter runoff from developed sites. These areas can naturally control hydrology through infiltration and evapotranspiration. Stormwater flows into the area, ponds on the surface and gradually seeps into the soil bed. The filtered water may be allowed to process naturally through sedimentation or may be collected into an underground drainage area and redirected to the storm drain system.
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REFERENCES