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Archives of Applied Science Research, 2014, 6 (5):96-100
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0975-508X
CODEN (USA) AASRC9

Levels of pollutants in runoff water from different land uses in Guwahati City, Assam, India

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ABSTRACT

Levels of pollutants in urban stormwater runoff are closely related to various types of land use because human activity is different according to land use. This study assesses the impacts of land use on stormwater quality. Stormwater samples were collected from five different land use types; residential, commercial, recreational, heavy traffic and industrial, around Guwahati city, Assam (India). Each of the collected samples was analysed to measure important water quality parameters such as suspended solids (SS), total residual chlorine, oil and grease, nitrate-nitrogen (NO_3-N) and phosphate (PO_4^{3-}). The analysis shows that the spatial variation in the distribution of pollutants in stormwater was highly influenced by the land use type. In industrial and commercial land use, the pollutants exceeded the guideline values as per Indian National Standards. Overall, the industrial land use site produces the worst quality stormwater. The study also provides recommendations for improvement and management of storm water quality in the city.

Keywords: Stormwater, land use, Guwahati city, water quality, pollutants.

INTRODUCTION

Urban expansion transforms the local 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 both the quantity as well as quality characteristics of the water environment. Modification of land use associated with urbanisation includes removal of vegetation, expansion of impervious areas and modifications of drainage channels which result in changes to the characteristics of the surface runoff hydrograph [1] with increased runoff volume and peak flows. Impervious surfaces reduce rainwater infiltration and increase stormwater runoff which results 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 [2]. Concentrations of pollutants from urban stormwater runoff are closely related to various types of land use because human activity is different according to land use [1]. Urban areas have been classified in the literature into main roads (including parking lots and airports), roofs, residential areas, commercial areas, industrial areas, parks and lawns, and open, undeveloped areas, all of which generate stormwater of different quality which transports different pollutants. Researchers have divided them into six specific groups such as Solids (suspended solids,SS), Heavy metals (Cu, Zn, Cd, Pb, Ni and Cr), Biodegradable organic matter (BOD_5 and COD), Organic micropollutants (PAHs, PCBs, MTBEs etc.), Pathogenic microorganisms (total coliforms & E. coli) and Nutrients [3]. As urban stormwater is comprised of many individual flow components draining various areas, the 'mix' at the outlet depends on the characteristics of those areas, pollutant wash-off potentials and the features (i.e. frequency, intensity, duration and pattern) of the specific rain event [4]. In summary, deterioration of water quality, degradation

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of stream habitats, and increase in flesh flood are the most common impacts of urbanisation. Several authors have reported alternate methods for treatment of polluted runoff water and reuse of stormwater [5,6,7,8].

The present study aims to identify different pollutants of stormwater assess the impacts of land use on stormwater quality and developing recommendations and guidelines for stormwater management.

MATERIALS AND METHODS

Study area

This study was carried out in Guwahati city, Assam, India, located approximately along $26^0 11^/$ N latitude and $92^0 49^/$ E longitude. The city covers an area of 216 km^2 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 [9]. 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.

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 gets 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 flesh 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.

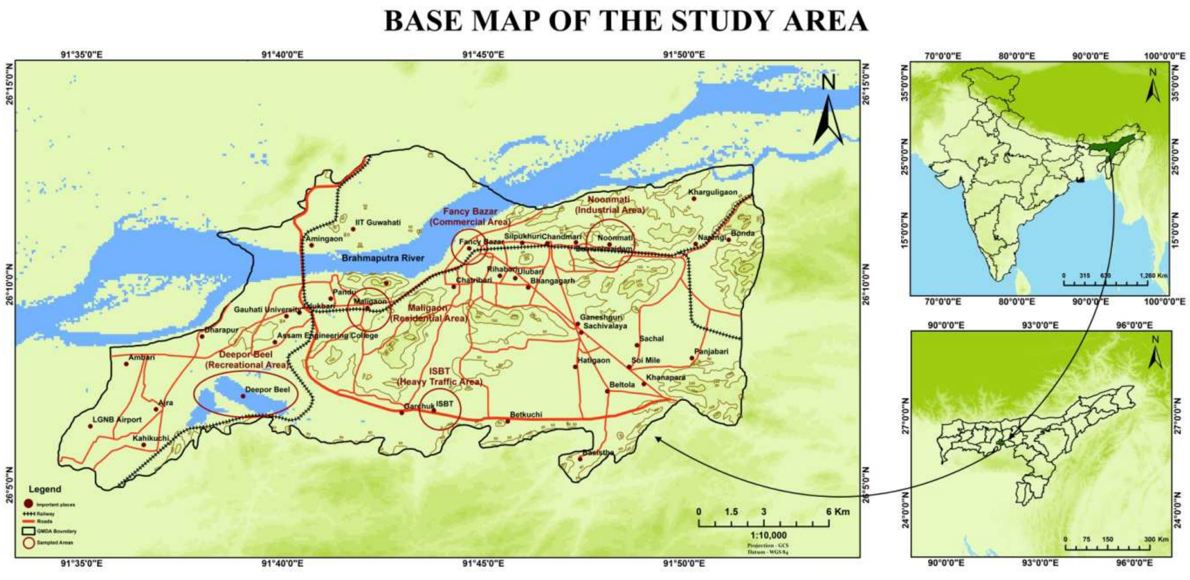

Fig-1: Location map of the study area

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 h of collection and all testing was conducted according to the test methods specified in APHA, Standard Methods for the Examination of Water and Wastewater [10].

Samples collected at each study location were analysed for pH, Total Suspended Solids (TSS), Total Residual Chlorine (TRC), Oil & Grease (O&G), Nitrate-Nitrogen (NO3-N), and Phosphate (PO_4^{2-}).

RESULTS AND DISSCUSSION

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. For all the five land uses, except Phosphate (PO_4^{3-}) all other parameter values in stormwater runoff displays high standard deviation which indicates a high variability of stormwater quality from the same urban land use. This confirms the highly variable nature of build-up not only with land use but also due to site specific characteristics.

Table 1. Mean and standard deviation of pollutant concentrations in each specified land use site of Guwahati city

Land use		Parameter					
		pH	*TRC (ppm)	Oil & Grease (ppm)	NO3—N (ppm)	PO43- (ppm)	TSS (ppm)
Residential	Mean SD	7.40 0.40	2.58 2.38	9.20 3.03	11.43 4.27	0.18 0.04	1671.33 1120.13
Commercial	Mean SD	6.76 0.15	8.61 9.70	10.12 3.87	11.12 6.51	0.13 0.06	5118.60 2059.30
Industrial	Mean SD	7.12 0.19	6.00 3.67	10.65 5.80	15.30 6.49	0.31 0.08	8365.00 530.33
Heavy Traffic	Mean SD	7.43 0.52	12.05 11.91	11.6 3.84	2.57 3.93	0.12 0.04	3763.38 905.84
Surface water	Mean SD	7.59 0.73	3.64 2.49	1.35 1.16	4.65 6.91	0.15 0.05	987.00 987.07

**TRC= Total Residual Chlorine*

Commercial land use shows relatively higher standard deviation of pollutants and thus variable nature of stormwater runoff than the other four land uses. The results display higher concentration of NO_3-N in the industrial zone followed by residential and commercial zone. Nitrate nitrogen (NO_3-N) levels also exceed Indian National Standards in some of the land use locations. The plausible source of NO_3-N can be domestic effluent, sewage/sludge disposal, pet waste, use of fertilizer in gardening and small agriculture, in the residential zone, nitrogen based commercial fertilizers, decay of vegetables fruits residue and animal matter in the commercial zone and industrial discharges, nitrogen containing raw materials and industrial processes, refuge dump leachates, etc. in the industrial zone. 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 [11].

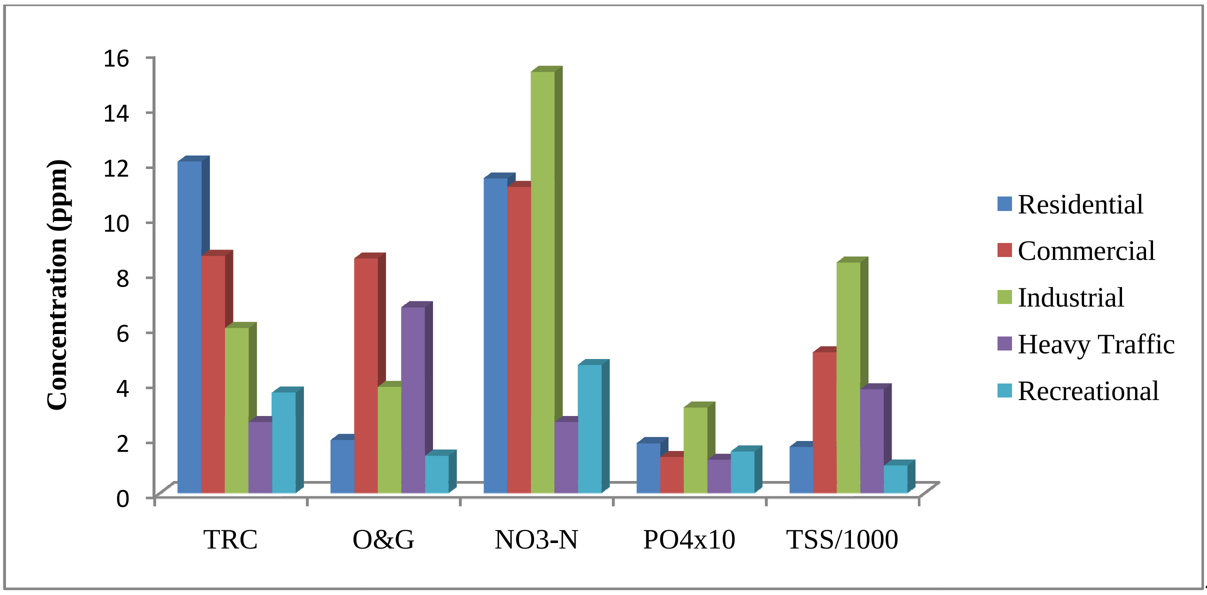

Fig-2: Variation of pollutants in different land use

Total Residual Chlorine (TRC) is found highest in residential area and then in commercial, industrial and heavy traffic area respectively. Sources of residual chlorine in storm water are municipal drinking water, chemical treatment facilities, food and paper industries etc. Residual Chlorine in surface water is acutely toxic to many aquatic species at concentrations below 1mg/l. Highest concentration of Oil and Grease (O&G) is found in commercial area source of which are automobile crankcase oil and automobile exhaust particulates. Concentrations of O&G are found within permissible limit prescribed by Indian National Standards. Highest concentration of Phosphate (PO_4^{3-}) and Total Suspended Solids (TSS) are found in industrial area. TSS values also exceed Indian National Standards which 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 assess the impacts of land use on stormwater quality stormwater samples were collected from five different land use types; residential, commercial, recreational, heavy traffic and industrial, around Guwahati city, Assam (India). Each of the collected samples was analysed to measure important water quality parameters such as suspended solids (SS), total residual chlorine, oil and grease, nitrate-nitrogen (NO_3-N) and phosphate (PO_4^{3-}). Results of the study show that pollutant distribution in the storm water is highly dependent on the surrounding land use type and 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. Pollutants like nitrate nitrogen (NO_3-N) and Total suspended solids (TSS) are exceeding the Indian National Standards. Residential, commercial and industrial areas contribute to NO_3-N in the storm water. Industrial land use has relatively 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 Stormwater Best Management Practices (BMP) such as incorporation of pollutant traps at selected locations having high contamination levels of stormwater 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.

Acknowledgement
One of the authors (AK) is grateful to the Department of Science and Technology (DST), Government of India for financial support under INSPIRE programme to carry out this work.

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