ISSN 2250-3153

Variability of pollutant build-up parameters in different land uses of Guwahati City, Assam, India

Abeda Khatun[*], Krishna Gopal Bhattacharyya[**], Hari Prasad Sarma[**]

[*]Department of Environmental Science, Gauhati University, Guwahati-781014, Assam, India
[**]Department of Chemistry, Gauhati University, Guwahati-781014, Assam, India
[**]Department of Environmental Science, Gauhati University, Guwahati-781014, Assam, India

Abstract- Urban stormwater runoff carries pollutants that collect on impervious surfaces such as oil, dirt, chemicals, and lawn fertilizers directly to receiving water bodies (surface water, seepage water and ground water), where they seriously harm water quality. This study investigated the variability of pollutant build-up parameters in five different land use types. For this purpose stormwater samples were collected from five different land use types; residential, commercial, recreational, heavy traffic and industrial, around Guwahati city, Assam (India) and analysed to measure different build-up parameter. It was found that distribution of stormwater pollutants is highly influenced by the surrounding land use type. Coefficient of variation (CV) is derived for each of the selected build-up parameters for the different land uses. Industrial land uses showed relatively higher values of CV, indicating the highly variable nature of the pollutant build-up parameters within the same land use.

Index Terms- Coefficient of variation, Impervious surfaces, Pollutant build-up, Urban stormwater runoff.

I. INTRODUCTION

Build-up is the process by which dry deposition accumulates on impervious surfaces. Urban land use plays an important role in stormwater quality by influencing pollutant generation, build-up and wash off (Liu et al., 2012). 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 (Goonetilleke et al., 2005). In literature, urban areas have been classified 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. Hvitved-Jacobsen et al. (2010) divided them into six specific groups, depicted in Table 1.

It has been proved that, site specific, climatic and other local variables play an important role in stormwater characterization (Barbosa et al., 2012). As precipitation washes and transports the pollutants away, the stormwater flow quantity is characterized by the frequency, intensity, duration, amount and pattern of the precipitation (Hvitved-Jacobsen and Yousef, 1991). The build-up of pollutant depends on several factors such as- antecedent dry periods, land use, traffic, population density, street cleaning practices etc. In this study the variability of pollutant build-up parameters are considered with respect to different land uses.

The main objective of the present study was to investigate the variability of pollutant build-up parameters in different land uses and thus to find out the influence of land use in urban stormwater pollution.

Table 1. Characterization of stormwater pollutants

Pollutant group	Parameter	Sources	Comments
Solids (suspended solids, SS)	TSS	Pavement wear; construction sites or rehabilitation works; atmospheric fallout; anthropogenic wastes, etc.	60-80% of SS in stormwater could be less than 30 mm diameter. Other sewer solids are present in CSO. Solids also accumulate within the sewer system and may be discharged at different times. Heavy metals and PAHs are bond to the smaller particles (e.g.: 100-250 mm)
Heavy metals	Cu, Zn, Cd, Pb, Ni and Cr	Vehicles parts and components; tire wear; fuel and lubricating oils; traffic signs and road metallic structures. Industries may also be an important source of heavy metals.	They are relevant because of toxic effects. Generally the focus is on copper (Cu), zinc (Zn); cadmium (Cd) and lead (Pb). The relevance of Pb is minor in countries using unleaded gasoline
Biodegradable organic matter	BOD5 and COD	Vegetation (leaves and logs) and animals such as dogs, cats and birds (either fecal contributions or dead bodies)	Organic matter (OM) from stormwater is less biodegradable (dominated by plant material), therefore is also less problematic for the environment than the OM. from CSO.
Organic micropollutants	They are numerous. Among them: PAHs, PCBs, MTBEs, endocrine disrupting chemicals	e.g.: PAH: incomplete fossil fuel combustion; abrasion of tire and asphalt pavement, etc. Phthalate esters: urban construction plastic materials	Presently, a large number of compounds (over 650 identified) are discharged in trace concentrations and sometimes there is no accurate chemical determination method available for them.
Pathogenic microorganisms	e.g.: Total coliforms; Escherichia coli	Contributions from cats, dogs and birds	Stormwater sources are much different than domestic wastewater contribution in the case of CSOs
Nutrients	Nitrogen and Phosphorous (e.g.: total Kjeldahl N; NO2+NO3; total-P; soluble-P)	Fertilizers and atmospheric fallout	Nutrients can cause not only eutrophication problems but also water discoloration, odors, toxic releases and overgrowth of plants.

(Hvitved-Jacobsen and Yousef, 1991; Wanielista and Yousef, 1993; Burton and Pitt, 2002; Bjo¨ rklund, 2011; Eriksson et al., 2005; Lau and Stenstrom, 2005; McCarthy et al., 2008; Hvitved-Jacobsen et al., 2010; Barbosa et al., 2012).

II. METHODOLOGY

A. 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 (Borthakur and Nath, 2012). 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.

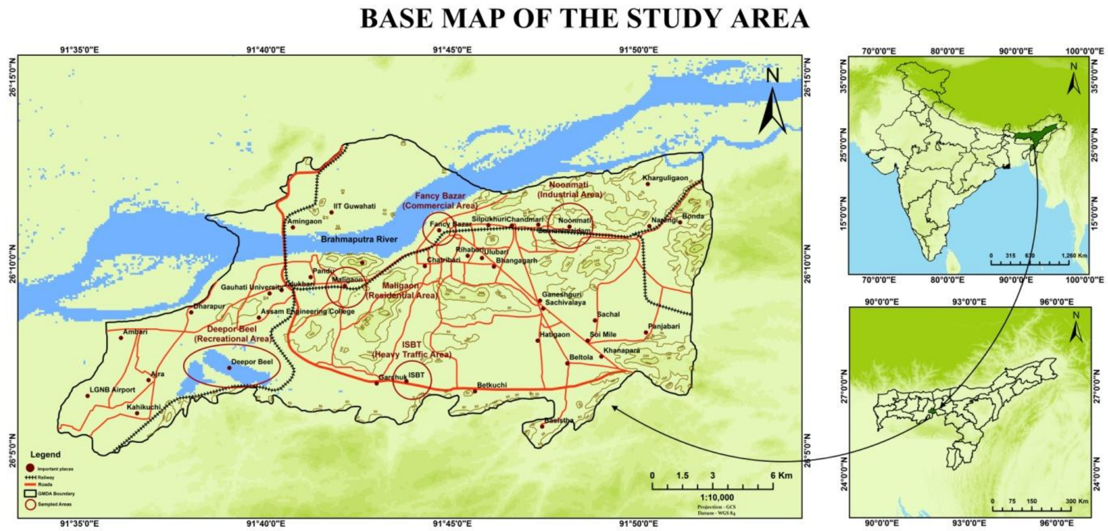

Fig. 1. Location map of the study area

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 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.

B. Sampling and analysis

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 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 the Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Samples collected at each study location was analysed for Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^{+}), Chloride (Cl^{-}), Sulphate (SO_4^{2-}), Total Suspended Solids (TSS), Nitrate-Nitrogen (NO_3-N), and Phosphate (PO_4^{3-}).

C. Analysing the Variability of Build-up Parameters

Variability of build-up parameters is expressed by using the coefficient of variation (CV). CV describes the variation of dataset. A high CV value represents a high variation in the dataset and vice versa. CV is obtained by the standard deviation being divided by mean of the dataset. It is denoted as a percentage (Hamburg, 1994).

III. RESULTS AND DISCUSSION

After analyzing the pollutant build-up parameters and their distribution in all samples collected from the different land uses, the average pollutant concentration for each land use type was determined (Table 2). It is observed that the pollutant concentrations vary considerably with land use pattern which indicates the influence of land use in stormwater pollution.

Results show a higher concentration of Calcium (Ca^{2+}) and Sulphate (SO_4^{2-}) in industrial land use areas comparing to other land uses. Sulphate 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. Point sources include sewage treatment plants and industrial discharges such as tanneries, pulp mills, and textile mills (Bhattacharjee and Bhattacharyya, 2010). Higher concentration of Magnesium (Mg^{2+}) and Chloride (Cl^{-}) are found in recreational areas compared to other land uses. The main sources of Magnesium in natural water are rocks, sewage and industrial wastes. Sources of Chloride are atmospheric precipitation, sedimentary rocks and industrial and domestic sewages. The high chloride content may lead to high blood pressure for people who use it, may harm metallic pipes and structures as well as growing plants (Ramadevi et al., 2009).

Table 2. Average Stormwater Quality parameters

Land use	Parameters (mg/L)							
	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	K^+	NO_3^--N	PO_4^{3-}	TSS
Residential	15.76	6.97	22.96	12.41	20.08	11.43	0.18	1671
Commercial	19.87	7.50	23.86	27.05	13.47	11.12	0.13	5119
Industrial	21.03	11.34	23.43	66.43	26.35	15.30	0.31	8365
Heavy Traffic	20.34	7.27	22.28	19.31	10.33	2.57	0.12	3763
Recreational	18.33	12.09	29.96	13.71	13.01	4.65	0.15	987

The results of the study demonstrated higher concentration of Nitrate nitrogen (NO_3-N) in the industrial zone followed by residential and commercial zones, sources of which 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 wastewater, industrial emission, nitrogen containing raw materials and industrial processes in the industrial zone. Nitrification is the major source of nitrate in the environment. Nitrate nitrogen (NO_3-N) levels exceed Indian National Standards (EPA, 1986) in some of the land use locations. Highest concentrations of Phosphate (PO_4^{3-}) and Total Suspended Solids (TSS) are found in industrial areas. TSS values also exceed Indian National Standards (EPA, 1986) 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 areas into the runoff. The comparison of maximum, minimum and average recorded concentrations for each of the pollutants build-up parameters are shown in the Fig. 2.

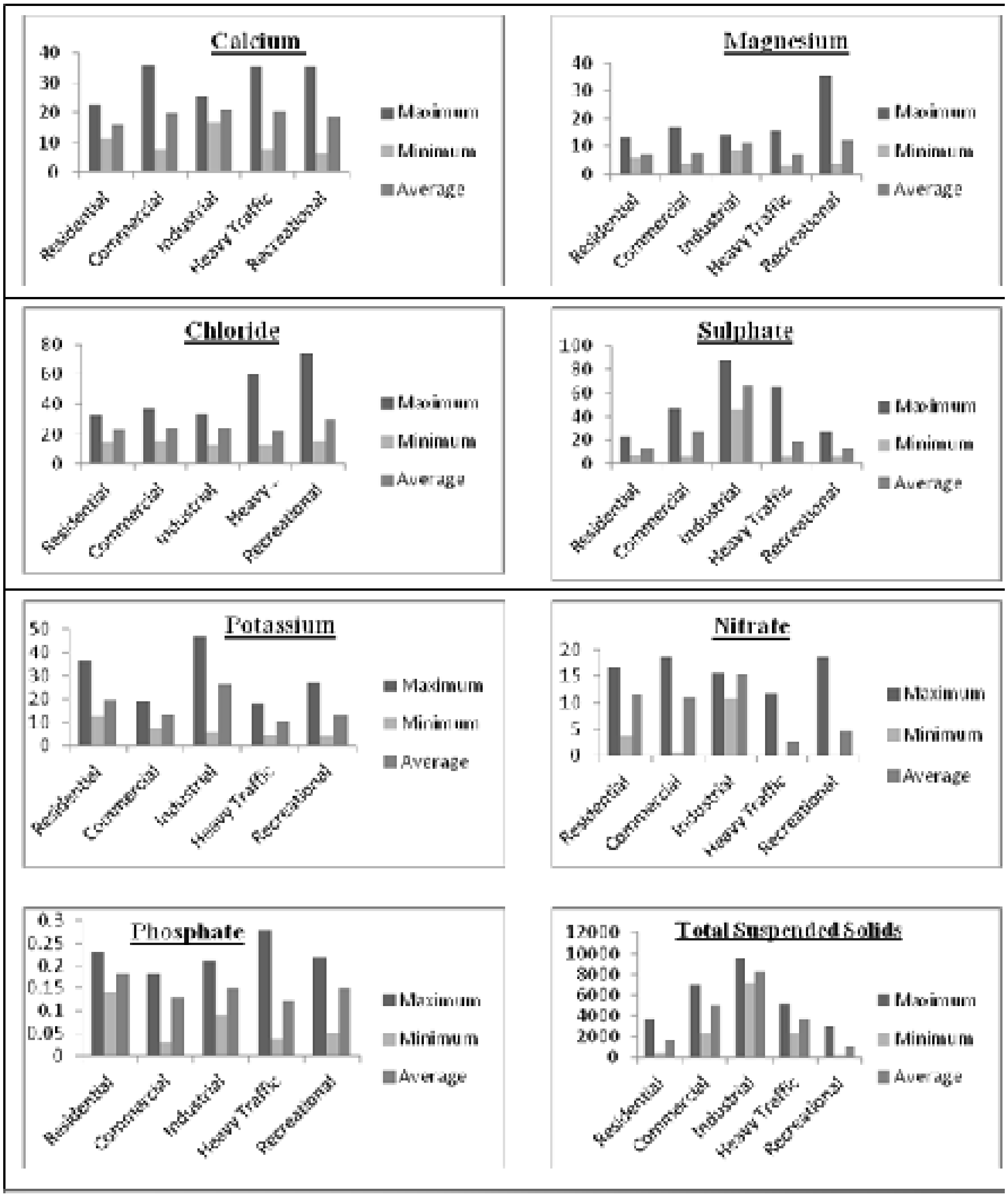

Fig. 2. Comparison of water quality parameters in different land use

A. Comparison of variability in pollutant build-up parameters

Three selected main land use patterns; residential, industrial and commercial, were considered for comparison of variability. CV of the pollutant build-up parameters are derived for these three main land uses. Fig. 3 gives a comparison between the CV values of build-up parameters for different land uses. Except for Calcium in residential and in industrial land uses and phosphate in residential land use, all other build-up parameters show relatively higher CV values (greater than 30%). As per reference, a dataset with CV greater than 10% is considered as having a high variation (Hamburg 1994). This confirms the high variation of build-up parameters even within the same land use. Potassium (K^+) in industrial land use displays the highest CV value (more than 100 %) and thus, the stormwater has the maximum variability of potassium.

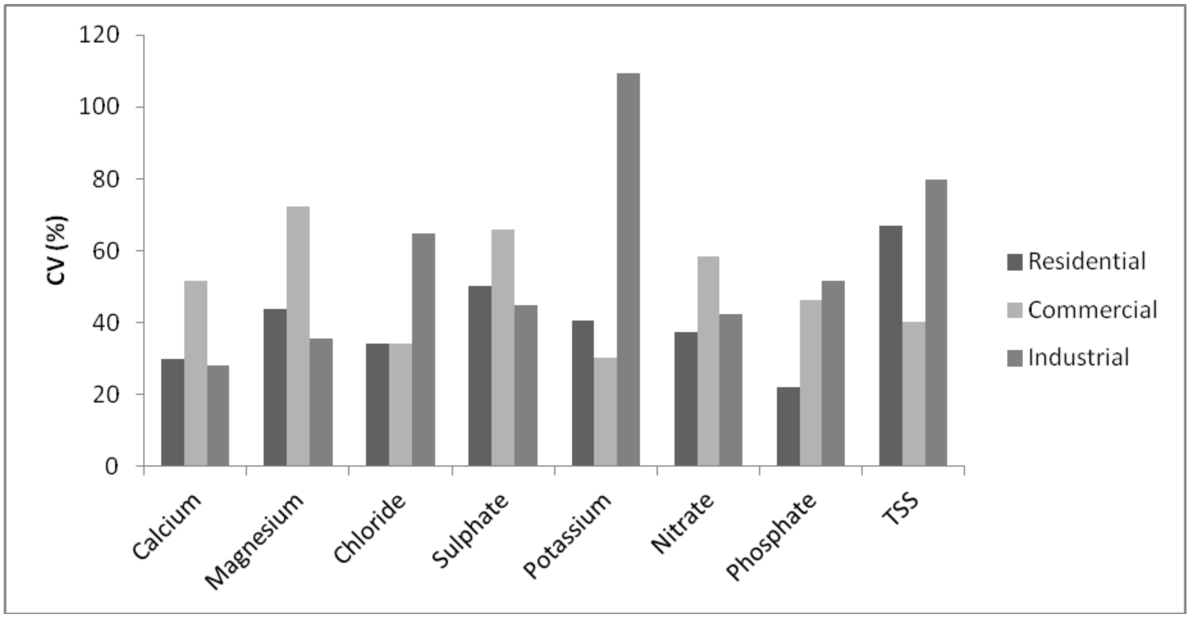

Fig. 3. CV of different build up parameters

IV. CONCLUSION

This study was undertaken to investigate the variability of pollutant build-up parameters in five different land uses of Guwahati city, Assam (India). From the study, following conclusions are derived:

(i) Pollutant build-up varies considerably with land use pattern which indicating influence of surrounding land use in stormwater pollution.

(ii) Pollutant build-up parameters vary even within the same land use which confirms the highly variable nature of build-up not only with land use but also due to site specific characteristics.

(iii) Nearly all pollutant build-up parameters have relatively higher variability and build-up rate in Industrial land use than the other land uses. However, commercial land use shows higher variability of Ca^{2+}, Mg^{2+}, SO_4^{2-} and NO_3^- than other land uses but their build-up rate is higher in Industrial land uses.

(iv) Industrial land use could be identified as the areas of critical pollution and hence these areas should be treated as important for applying best management practices (BMPs).

ACKNOWLEDGMENT

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.

REFERENCES

[1] APHA, Standard methods for examination of water and wastewater, *American Public Health Association, Washington, DC 21st Edn.*, (2005)

[2] Barbosa, A.E.; Fernandes, J.N. and David, L.M. 2012. Key issues for sustainable urban stormwater management. Water Research, 46 (2012) 6787-6798

[3] Bhattacharjee, K.K. and Bhattacharyya, K.G. Baseline study of Siang River water in Pasighat, Arunachal Pradesh, India, J. Environ. Science & Engg. (NEERI), 2010, 52 (2),121-130

[4] Bjorklund, K., 2011. Sources and fluxes of organic contaminants in urban runoff. Thesis for the degree of Doctor in Philosophy, Department of Civil and Environmental Engineering, Chalmers University of Technology, Gothenburg, Sweden, 63 pp.

[5] Borthakur, M., Nath, B.K., A Study of Changing Urban Landscape and Heat Island Phenomenon in Guwahati Metropolitan Area, International Journal of Scientific and Research Publications, 2 (11), 1-6 (2012)

[6] Burton Jr., G.A., Pitt, R.E., 2002. Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists, and Engineers. Lewis Publishers, 911 pp.

[7] EPA (1986) General Standards for discharge of Environmental Pollutants, Environmental Protection Act, Schedule VI, Ministry of Environment and Forest, GoI, New Delhi

[8] Eriksson, E., Baun, A., Mikkelsen, P.S., Ledin, A., 2005. Chemical hazard identification and assessment tool for evaluation of stormwater priority pollutants. Water Science and Technology 51 (2), 47-55.

[9] Goonetilleke, A., Thomas, E., Ginn, S., Gilbert, D., Understanding the role of land use in urban stormwater quality management, *J. Env. Manage.*, 74(1): 31-42 (2005)

[10] Hamburg M. (1994), Statistical analysis for decision making, The Dryden Press, Harcourt Brace College Publishers, Philadelphia.

[11] Hvitved-Jacobsen, T., Vollertsen, J., Nielsen, A.H., 2010. Urban and Highway Stormwater Pollution. Taylor & Francis Inc, 347 pp.

[12] Lau, S., Stenstrom, M.K., 2005. Metals and PAHs adsorbed to street particles. Water Research 39 (17), 4083-4092.

[13] Liu, A., Goonetilleke, A., Egodawatta, P., Inadequacy of Land Use and Impervious Area Fraction for Determining Urban Stormwater Quality, *Water Resour. Manage.*, 26, 2259–2265(2012)

[14] McCarthy, D.T., Deletic, A., Mitchell, V.G., Fletcher, T.D., Diaper, C., 2008. Uncertainties in stormwater E. coli levels. Water Research 42 (6-7), 1812-1824.

[15] P. Ramadevi, G. Subramanian, V. Pitchammal and R. Ramanathan, The study of water quality of Ponnamaravathy in Pudukkottai district,

Tamilnadu, *Nature Environment and Pollution technology*, 2009, **8** (1), 91-94

[16] Wanielista, M.P., Yousef, Y.A., 1993. Stormwater Management.John Wiley & Sons, Inc., 579 pp.

AUTHORS

First Author – Abeda Khatun, Department of Environmental Science, Gauhati University, Guwahati-781014, Assam, India, Corresponding author; E-mail: itsmeabida@gmail.com
Second Author – Krishna Gopal Bhattacharyya, *Department of Chemistry, Gauhati University, Guwahati-781014, Assam, India
Third Author – Hari Prasad Sarma, Department of Environmental Science, Gauhati University, Guwahati-781014, Assam, India