# Impact of Land Use Characteristics on Urban Storm Water Quality in Rajshahi City

**P. CHAKRABORTY[1], A. CHOWDHURY[2]**

[1*]Department of Civil Engineering, RUET, Rajshahi, Bangladesh (protikchakraborty77@gmail.com)

[2]Department of Civil Engineering, RUET, Rajshahi, Bangladesh (anupam.19ce@gmail.com)

**Abstract**

Land use characteristics such as urban form, impervious cover significantly impact the water environments with increased runoff and the degradation of water quality. Hence, stormwater management becomes prime concern to safeguard the receiving water quality of the surrounding environment. The main focus of this paper is to investigate the impact of land use characteristics on the variability of urban stormwater quality in Rajshahi City. Stormwater runoff samples were collected from three different land use areas such as residential (Aloker mor, new market), commercial (Zero point, Shaheb Bazar) and industrial (Visic, Sapura) in Rajshahi City, Bangladesh. Collected samples were tested in the laboratory to determine the physical (temperature, pH, turbidity, electrical conductivity) and chemical parameters (total suspended solids (SS), biological oxygen demand (BOD)) using standard quality control and test methods specified in APHA 1999. The test result shows that the residential stormwater demonstrated the cleanest appearing with lowest value of Turbidity, suspended solids whereas the industrial had recorded the worst stormwater quality comparing to other. On the other hand, Biological oxygen demand (BOD) was found highest in commercial land use area. The study results will provide guidance to stormwater management of natural treatment systems for treating the stormwater pollutants for specific land use.

***Keywords:*** *stormwater runoff, land use, stormwater quality, Rajshahi city*

## 1. Introduction

The impact of urbanization is the important concern that significantly alters the catchment hydrology such as increase the peak flow, runoff volume and decreases the infiltration rate, runoff retention time and base flow. The quality of urban runoff in terms of the amount and types of pollutants generated and transported varies depending on land usage and the activities carried out on the land (Arnold et al., 1996). Urban runoff quality and pollutants loading has been shown to have a high variability among different land use such as residential, industrial, commercial, agricultural, and land for recreational purpose (Egodawatta et al., 2007).
Rajshahi is one of the developing cities in Bangladesh and characterized by rapid urbanization. Large tracts of land are converted to residential, commercial and industrial developments (RCC Website, 2018). The aim of the study is to investigate the impact of land use characteristics on the variability of urban storm water quality in Rajshahi City.

## 2. Study Areas and Sample Collection

Rajshahi is the 4$^{th}$ largest among the eight divisions in Bangladesh that covered the area of 18,153.08 sq. km (RCC Website, 2018). The study areas were selected at three different land uses such as residential, commercial and industrial in Rajshahi City Corporation as shown in Figure 1. Storm water sample was collected from three roads surface runoff such as Aloker mor, new market (site 1- residential), Visic, Sapura (site 2- industrial) and Zero point, Shaheb Bazar (site 3- commercial) in Rajshahi City (Figure 1). The details characteristics of these study areas are discussed below.

**Site 1:** Residential Area (Aloker mor, new market) was an access road located in a typical suburban residential area with detached family houses (Figure 1). The site was chosen due to its typical suburban characteristics. The road system is primarily used by residents for access. It was also found that street sweepers operate in the area every four weeks, which may influence the availability of pollutants on the road surface at certain times.
**Site 2:** Industrial area (Visic, Sapura) was located in a light industrial area. The site was chosen because of the diversity of industries located along the road (Figure 1). Compared to the residential site, the street surface was significantly degraded.
**Site 3:** Commercial area (Zero point, Shaheb Bazar) was a crowded market area and is considered to be one of the busiest in that region (Figure 1). The condition of the place was found to be fair but with a coarse texture.
Sample collection was undertaken based on the standard procedure recommended by EPA, 1992. Sample was collected three times from one location at different rainfall events to understand the effect of dry periods on variability of storm water quality. After sample collection the bottle was properly sealed and leveled for future identification.


Figure 1: Location of study areas and sample collection points

## 3. Methodology

The collected samples were tested in the laboratory to determine the physical and chemical parameters using standard quality control and test methods specified in APHA 1999. The physical parameters includes temperature, pH, turbidity, electrical conductivity where chemical parameters are total suspended solids (SS), BOD. In order to investigate the relationship between land use characteristics and water quality, univariate (mean, median, standard deviation) techniques were applied

### 3.1 Sample testing

The physical parameters such as temperature, pH, turbidity, electrical conductivity were tested instant after collect the sample. Then the chemical parameters were tested within 24 hours of collection. Sample testing was undertaken at the Environmental Engineering laboratory of Rajshahi University of Engineering and Technology. Standard quality control and test methods specified by APHA were followed to undertake the laboratory test (APHA, 1999).

### 3.2 Univariate and multivariate analysis tools

**MEAN:**
The mean is the average of a set of data points. Mean can be calculate from the ratio of sum of data values to the total number of data points. The mathematical expression of the mean is shown in Equation (1).

$$\bar{X} = \frac{\sum x_n}{N} \text{ ---------- (1)}$$

Here, $\sum x_n$= sum of data values.
N = total number of data points.
$\bar{X}$ = mean

**Standard deviation:**
Standard deviation is the measure of dispersion of a set of data from its mean. It measures the absolute variability of a distribution; the higher the dispersion or variability, the greater is the standard deviation and greater will be the magnitude of the deviation of the value from their mean. The mathematical expression of the standard deviation is shown in Equation (2).

$$\sigma = \sqrt{\frac{\sum(x-\bar{X})^2}{N-1}} \text{ ---------- (2)}$$

Here, x= individual data points
$\bar{X}$=mean/average of the data points
N = total number of data points
$\sigma$= standard deviation

**The coefficient of variation (CV):**
The coefficient of variation (CV) is the ratio of the standard deviation to the mean. The higher the coefficient of variation, the greater the level of dispersion around the mean. It is generally expressed as a percentage. The lower the value of the coefficient of variation, the more precise the estimate. The mathematical expression of the coefficient of variation is shown in Equation (3).

$$\text{CV}= \frac{\sigma}{\bar{X}} \text{ ---------- (3)}$$

Here, $\sigma$= Standard deviation.
$\bar{X}$=mean

## 4. Results and Discussions

Table 1 shows the summary of the analysis results for selected stormwater quality parameters for each individual land use category. It can be seen that these pollutants concentrations vary considerably for each land use, which indicates that pollutant distribution throughout the catchment is highly dependent on the land use. Suspended solids is one of the main indicators of water quality. Most of the pollutants absorbed by suspended solids and transport by stormwater runoff. (Ranjan et al., 2011).
Storm water in residential area demonstrated the cleanest appearing storm water with lowest average amounts of Suspended Solids within the storm water. With a low variance for Suspended solids and turbidity, Residential sites are cleanest among the other sites.
The stormwater quality in industrial area was found highly polluted than other land use. This is due to recording the highest amounts of Suspended Solids and Turbidity in the storm water when compared to the other land use. The industrial location also recorded the higher BOD value than the Residential sites. Presence of organic matter in industrial waste is the reason, for that result shows the BOD is higher in industrial area than residential one.
Commercial storm water resulted in containing low concentrations of Suspended solids and turbidity value then industrial sites. But commercials are recorded the highest BOD value than the other sites. As commercial area produces the highest organic waste that decomposed on road surfaces.

Table 1: Average pollutant loading for each specified land use

| Land use type | pH | | | TURBIDITY (NTU) | | | CONDUCTIVITY (mg/L) | | | SUSPENDED SOLIDS (mg/L) | | | BOD (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MEAN | SD | CV (%) | MEAN | SD | CV (%) | MEAN | SD | CV (%) | MEAN | SD | CV (%) | MEAN | SD | CV (%) |
| Residential | 6.90 | 0.18 | 1.95 | 10.00 | 0.38 | 3.58 | 1066.67 | 115.47 | 10.82 | 115.73 | 10.84 | 9.39 | 2.22 | 0.04 | 1.82 |
| Commercial | 6.57 | 0.10 | 1.64 | 8.52 | 0.13 | 1.54 | 1433.33 | 57.74 | 4.02 | 189.99 | 4.30 | 2.26 | 8.23 | 0.25 | 3.06 |
| Industrial | 6.42 | 0.05 | 0.80 | 13.17 | 0.90 | 6.85 | 1533.33 | 57.72 | 3.76 | 394.45 | 4.32 | 1.09 | 3.17 | 0.28 | 9.11 |

Table 2: Comparison of study results with EPA guideline

| Water Quality Parameters | Study Results | | | EPA Guidelines (EPA, 2001) |
|---|---|---|---|---|
| | Residential | Commercial | Industrial | |
| pH | 6.90 | 6.57 | 6.42 | 5.5-8.5 |
| Turbidity | 10.0 | 8.52 | 13.17 | 1-50 NTU |
| Conductivity | 1066.67 | 1433.33 | 1533.33 | 1000-2500 mg/L |
| Suspended Solids | 115.73 | 189.99 | 394.45 | 100 – 400 mg/L |
| BOD | 2.22 | 8.23 | 3.17 | < 20 mg/L |

Data of average concentrations (pH, Turbidity, Conductivity, SS, BOD) of stormwater in each land use area and the EPA standard guideline value for stormwater are shown in Table 2. Table-2 shows that the highest pH value was found 6.90 at residential area, lowest is 6.42 at industrial site. EPA denotes 5.5-8.5 as standard pH value for stormwater. Also highest value for conductivity, Turbidity, Suspended Solids were found in industrial land use type which are in acceptable level. Standard BOD value is less than 20 mg/L. study result shows the highest BOD 8.23 at commercial area that are also in acceptable value.

Figure 1 to 5 are shows the average pollutant concentrations of storm water for each land use. Also it shows the temporal variation of concentrations of pollutants at residential, commercial and industrial land use.

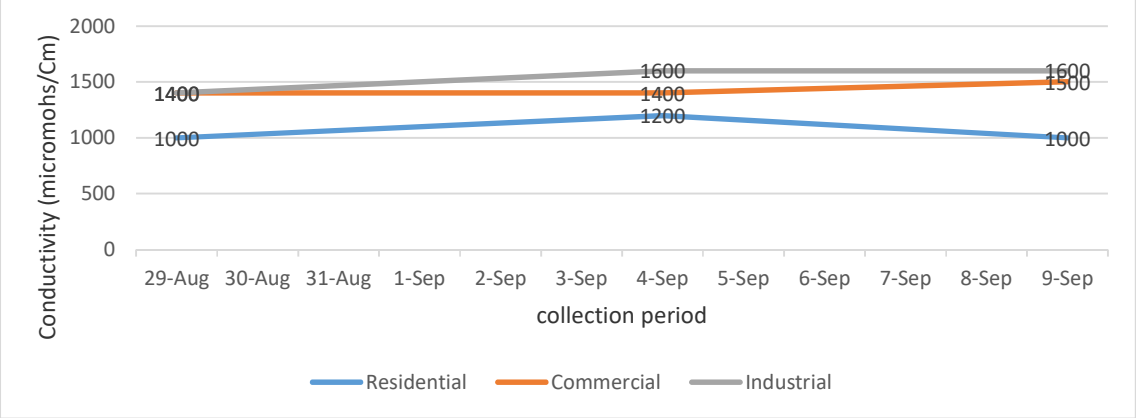


Figure 1: Variation of conductivity value in 3 different land uses

The variation of Electric Conductivity shown in figure 1. As seen in figure 1, Industrial area have the higher Conductivity than other. This can be due to the reaction of chemical or metal substances with the water flowing from the runoff area. Residential have the lower value compared to other because there are the presence of chemical or metal substances.

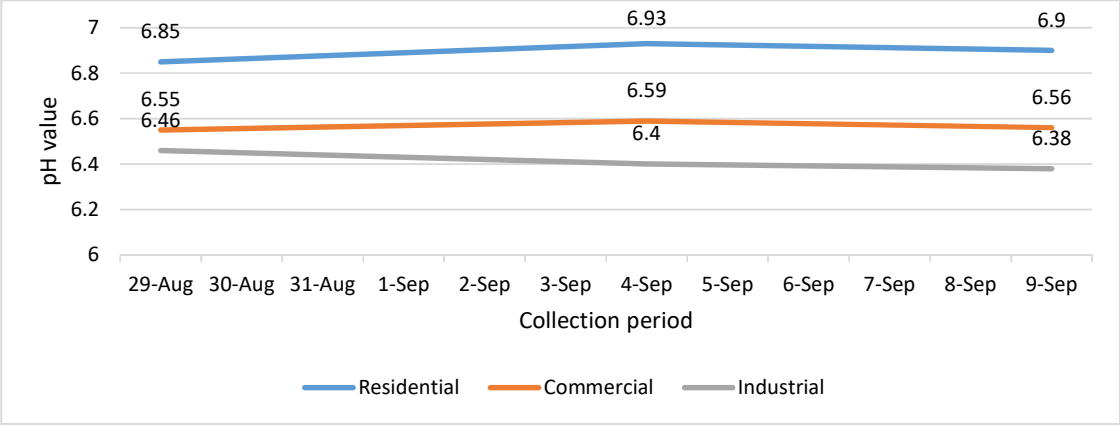


Figure 2: Variation of pH value in 3 different land uses

As shown in figure 2, pH value was found similar for both industrial and commercial areas. This can be due to the presence of chemical and metal that reacts with water and decrease the pH value. In contrast, higher pH was found for residential area due to the decomposition of organic substances such as plant leaves, vegetation etc.

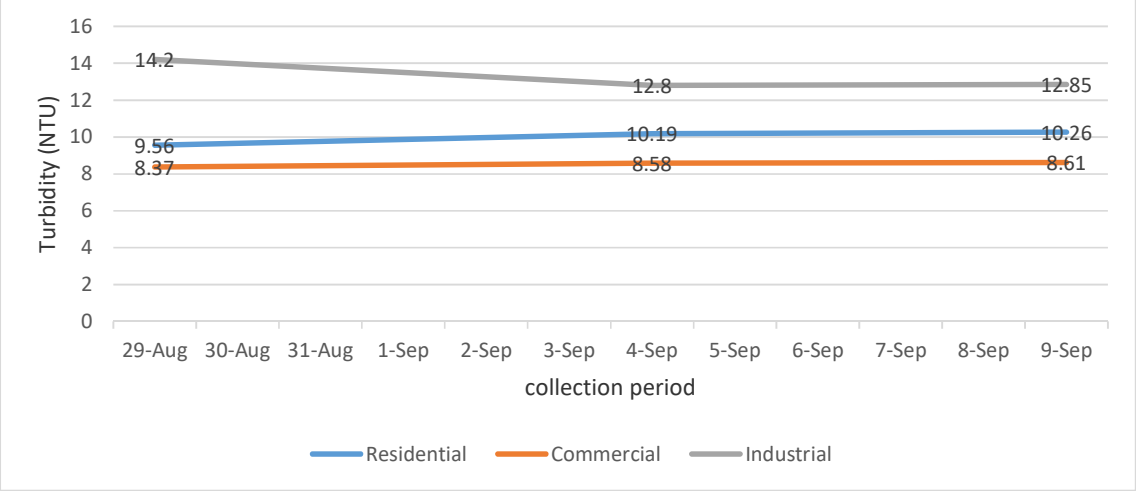


Figure 3: Variation of Turbidity value in 3 different land uses

Variation of Turbidity for different dry period is shown in figure 3. Turbidity in water arises from the presence of very finely divided solids (which are not filtrable by routine methods). As seen in figure 3, the highest Turbidity was found in Industrial area. This can be due to the presence of fine particles from different production processes and distributed on the road surface by traffic, wind, workers during loading and unloading time.

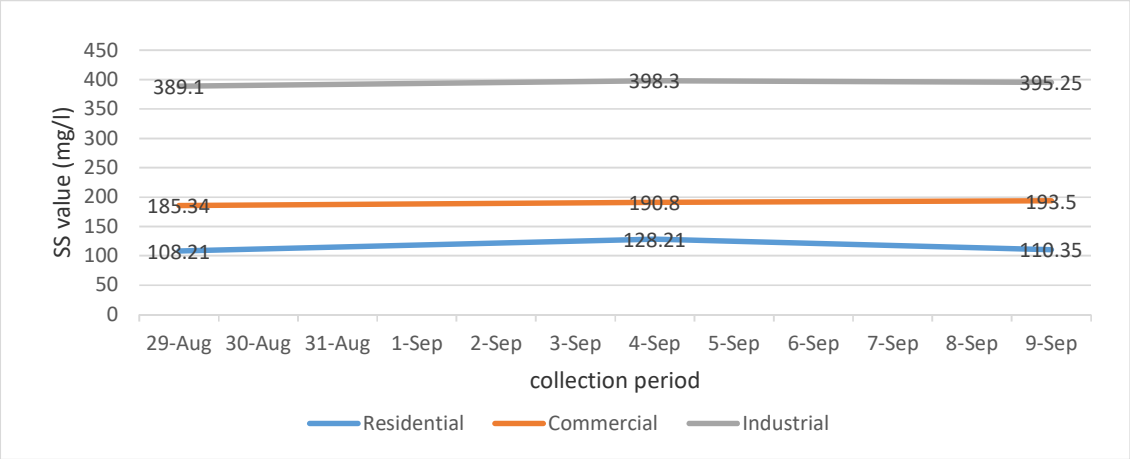


Figure 4: Variation of Suspended solids in 3 different land uses

The variation of suspended solids is shown in Figure 4. As seen in figure 4, the residential area have lower SS value compared to other land uses in study area. This can be due to the periodic cleaning of road surfaces by sweepers. It can be seen that the average concentration of SS in industrial areas was almost two and a half times the values for residential areas. The commercial and industrial area produces high level of SS. This is due to the high population density, traffic density and various anthropogenic activities occur by human and distribute by traffic and wind.

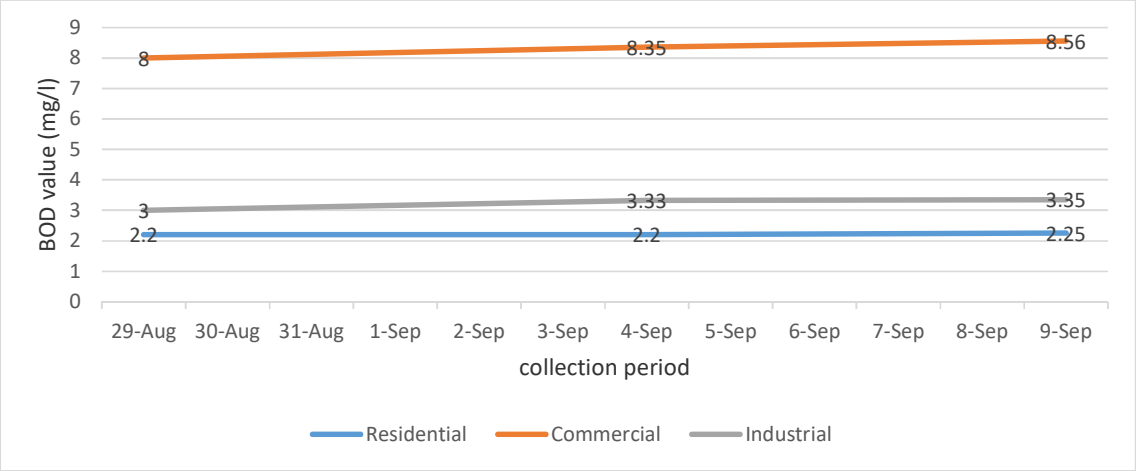


Figure 5: Shows the variation of BOD value in 3 different land uses

Variation of BOD value is shown in figure 5. As seen in figure 5, the residential area have the lower BOD compared to industrial and commercial areas. As we know, BOD value measure the amount of dissolve oxygen to biologically decompose the organic matters. The presence of organic matter is higher in commercial area that produces from local fruit seller, decomposed fruit bunch and vegetable waste. In contrast, residential area produce small amount of organic waste that's why the value is lowest among the others.

## 5. Conclusions

To understand the impacts of land use pattern on storm water quality, storm water samples have been tested in three main land use areas; residential, commercial, industrial lands in Rajshahi city. The results show very interesting patterns. Turbidity value of industrial area is comparatively higher than the other areas. Excessive use of chemical, industrial production, heavy use of machine increases the value of water quality parameters such as Turbidity, Conductivity in industrial area. The highest BOD value was recorded in commercial lands. The industrial storm water had the dirtiest appearing storm water quality showing the highest amounts of Suspended Solids. Residential storm water shows the lowest concentrations.

The study results will provide clear idea about storm water pollutants generating from commercial, industrial and residential areas. In addition, this study will provide guidance to the storm water management authority for development of natural treatment systems for treating the storm water pollutants for specific land uses to safeguard the receiving water quality and aquatic ecosystem.

## References

APHA (1999). Standard methods for the examination of water and wastewater. Washington, DC: American Public Health Association

APHA (1999). Standard methods for the examination of water and wastewater. Virginia, USA: American Water Works Association, Water Environment Federation. CDROM

Arnold, C. L., & Gibbons, C. J. (1996). Impervious surface coverage- The emergence of a key environmental indicator, Journal of the American Planning Association, American Planning Association, 62(2), 243–258

Egodawatta, P., Thomas, E. and Goonetilleke, A., 2007, 'Mathematical interpretation of pollutant wash-off from urban road surfaces using simulated rainfall', Water Research, Vol. 41(13), pp. 3025-3031.

'Parameters of water quality, Interpretation and Standards', Environmental Protection Agency, Ireland (2001).

Ranjan Sarukkalige, Shane Priddle (2011), Assessment of Urban Stormwater Quality in Western Australia, 2nd International Conference on Environmental Engineering and Applications, IPCBEE vol.17 (2011) © (2011) IACSIT Press, Singapore

RCC Website (2018). Rajshahi City Corporation. Assessed at 3rd November, 2018. Available at: https://erajshahi.portal.gov.bd/