CHARACTERIZATION OF URBAN STORM WATER RUNOFF

P.E. Zope* and P. H. Sawant

Department of Civil with Environment, S.P.C.E, Andheri, Mumbai (INDIA)

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ABSTRACT

Runoff volumes and pollution loads increase considerably when a catchment is urbanized. Storm water runoff from urban surfaces often contains elevated levels of toxic pollutants when discharged directly into water bodies. These pollutants degrade water quality and impact aquatic life and human health and have potential for carcinogenic, mutagenic and allergic effects.

The area selected for the case study was Milan subway at western suburb of Mumbai which is the chronic flooding spot for so many years. Increased quantity of runoff has increased the pollutant impact risk in the vicinity of the area.

This paper presents the analysis of the pollutants in the surface runoff, estimation of the pollutant loads to find out the pollutant impact and thereby attempting to provide the basic data to establish a proper treatment processes and best management practices to reduce the pollutant impact at the catchment area of the Milan subway, Mumbai. As per the analysis of storm water samples from site, the average event mean concentrations (EMCs) of DO, BOD, TSS, COD, O and G, chlorides, and TDS were 3.89 mg/ L, 18.33 mg/ L, 312.67 mg/ L, 59.67 mg/ L, 5.85 mg/ L, 34.37 mg/ L, and 245.5 mg/ L respectively. Also the unit pollutant loading rates of DO, BOD, TSS, COD, O and G, chlorides, and TDS were 78.71, 370.87, 6326.28, 1207.31, 118.36, 695.41 and 4967.22 kg/ha/yr respectively. The concentration of the total suspended solids is more than the permissible standard limits and requires controlling the source of suspended solids at their source only. The Best Management Practices are proposed to control the suspended solids at source only.

Key Words : Runoff, Pollution load, Best management practices, Pollutant impact, Non point sources, Unit pollutant loading rate.

INTRODUCTION

The sources of urban pollutants are diverse and associated with both natural and human activities. They can be broadly categorized into point sources (PS) and non point sources (NPS) pollution. The effluent of pollutants from non point source resulting from rainfall not only contains various kinds
of pollutants but also carries a large pollutant load so that it exerts a great influence on receiving waters. The key contaminant parameters in terms of receiving water pollution potential are total suspended solids (TSS), biological oxygen demand (BOD), bacteria, heavy metals (particularly zinc, lead and cadmium), herbicides and polyaromatic hydrocarbons (PAH). In addition, nutrients can be a problem where urban surface waters discharge to already nutrient-rich water bodies. Storm event sampling programme and runoff quality analysis are fundamental for estimating pollutant mass loads in both natural and distributed ecosystem.

Pollution prevention promotes continuous improvement through operational and behavioral changes. Pollution prevention is a shared responsibility among governments and individuals, industrial, commercial, institutional, and community concerns. Pollution prevention provides a means of reducing pollutant resulting in an associated benefit to water quality. Pollution prevention is generally achieved by controlling pollutants at the source so that they do not enter the flow of water. Pollution prevention can also be achieved through the reduction of flows or diverting the flow from pollutant source.

The area selected for the case study was Milan subway at western suburb of Mumbai which is the chronic flooding spot for so many years. Increased quantity of runoff has increased the pollutant impact risk in the vicinity of the area. This paper aims for the analysis of the pollutants in the surface runoff, estimation of the pollutant loads to find out the pollutant impact and to suggest the best management practices and control measures so that the pollutants can be controlled at source only and the storm water quality can be maintained properly.

**METHODOLOGY**

**Site Description**

The study site Milan subway is located (Fig: 1) at the western suburb at Santacruz in Mumbai city, Maharashtra state in India. Milan subway is the connecting part of the east and west area of the Santacruz city in Mumbai having heavy vehicular traffic.

The catchment area of the Milan subway (Fig. 1) consist of the slum area, residential area, commercial area, temple marble making shops, tabelas, recreation ground, garages, automobile workshops, open spaces and lawns. The pollutant source from the
catchment area is mainly from the automobile workshops, shops of marble commercial areas, construction sites and slum area. The total catchment area of the Milan subway is 11.7256 ha.

**Climatic conditions**

The yearly mean precipitation of the Mumbai city is 2129.8 mm, ninety percent of which is concentrated within four months from June to end of September.

**Identification of Pollutant Sources**

The identified sources of pollutants at catchment of Milan subway are enlisted as under:

- Vehicular traffic and automobile workshops.
- Lawn and garden maintenance.
- Air pollution: Fall out of suspended solids from traffic, industrial source and wind erosion.
- Municipal maintenance activities.
- Industrial and commercial activities.
- Illegal connections of sanitary services from slum area.
- Illegal disposal of household hazardous wastes.
- Transportation spills.
- Construction activity.
- Pet faeces and litter.
- Waste from marble shops.
- Runoff from residential driveways and parking areas.

![Fig. 2: Plan showing pollutant source areas at catchment area of Milan Subway.](image)

**Pollutant Analysis**

The storm water samples were tested from the catchment area of the Milan subway during the flooding periods to analyze the impact of pollutants. Table 1 shows the results of the storm water samples at Milan subway site.

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH</td>
</tr>
<tr>
<td>Max</td>
<td>7.35</td>
</tr>
<tr>
<td>Min</td>
<td>6.62</td>
</tr>
<tr>
<td>Avg</td>
<td>7.04</td>
</tr>
<tr>
<td>Standard limit</td>
<td>5.5</td>
</tr>
</tbody>
</table>
From the above table it can be observed that the concentration of TSS is very high as compared to the permissible standard limits.

**Unit Pollutant Loading Rates :**

The unit pollutant loading rates are calculated by the following equation:

\[
L = \frac{1}{100}(Cv \times AR \times EMC)^3;
\]

Where;

- \( L \) = Unit pollutant loading rate (Kg/ha/year);
- \( Cv \) = Co-efficient of runoff;
- \( AR \) = Annual rainfall (mm/year);
- \( EMC \) = Event mean concentration (mg/l).

In this study the value of \( Cv \) was taken 0.95, the average of the measured value during the rainfall, and that of the \( AR \) to be 2129.8 mm/yr, the yearly mean precipitation of the sampling sites. The calculated unit pollutant loading rates for the study site are summarized in **Table 3.** In general, the unit pollutant load of residential area is higher than industrial area.

**Table 2 : Unit Pollutant Loading for catchment area of Milan subway (Unit: kg/ha/yr)**

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>DO</th>
<th>Chlorides</th>
<th>TSS</th>
<th>COD</th>
<th>BOD</th>
<th>O and G</th>
<th>TDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit pollutant loading</td>
<td>78.71</td>
<td>695.41</td>
<td>6326.28</td>
<td>1207</td>
<td>370.9</td>
<td>118.36</td>
<td>4967.22</td>
</tr>
</tbody>
</table>

The unit pollutant loading of TSS is very high as compared to the standard limits and it is necessary to control the suspended solids entering in runoff at their source only.

**RESULTs AND DISCUSSION**

The use of storm water practices to control and manage the quality and quantity of urban runoff has been labeled as best management practices (BMPs). BMPs may be classified as structural or non structural.

**Non Structural BMPS :**

Non-structural storm water quality best management practices (non-structural BMPs) are institutional. Among a variety of practices, non-structural BMPs include:

- Town planning controls : Using town planning instruments to promote Water Sensitive Urban Design [WSUD] principles in new
developments, such as decreasing the area of impervious surfaces.

- The adoption and implementation of building and site development codes to encourage or require the installation of structural BMPs for a new development and significant redevelopment projects.
- Adoption and implementation of site disturbance/erosion control programs.
- Public education on the proper uses and disposal of potential pollutants such as household chemicals, paints, solvents, motor oils, pesticides, herbicides, fertilizers, and antifreeze.
- Effective street sweeping and leaf pickup and efficient street deicing programs.
- Detection and elimination of illicit discharges from wastewater lines to separate storm sewers.

### Structural BMPs

Structural BMPs are designed to function without human intervention at the time wet weather flow is occurring, thus they are expected to function unattended during a storm and to provide a passive treatment. Structural BMPs may be viewed as reactive approaches to storm water quality management, in that they seek to reduce peak runoff rates, reroute flows, and/or improve storm water quality during runoff event.

#### Table 3: BMP pollutant removal ranges in percent.

<table>
<thead>
<tr>
<th>Type of Practice</th>
<th>TSS</th>
<th>Total P</th>
<th>Total N</th>
<th>Zinc</th>
<th>Lead</th>
<th>BOD</th>
<th>Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porous Pavement</td>
<td>80-95</td>
<td>65</td>
<td>75-85</td>
<td>98</td>
<td>80</td>
<td>80</td>
<td>n/a</td>
</tr>
<tr>
<td>Grass Buffer Strip</td>
<td>10-20</td>
<td>0-10</td>
<td>0-10</td>
<td>0-10</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Grass Lined Swale</td>
<td>20-40</td>
<td>0-15</td>
<td>0-15</td>
<td>0-20</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Infiltration Basin</td>
<td>0-98</td>
<td>0-75</td>
<td>0-70</td>
<td>0-99</td>
<td>0-99</td>
<td>0-90</td>
<td>75-98</td>
</tr>
<tr>
<td>Percolation Trench</td>
<td>98</td>
<td>65-75</td>
<td>60-70</td>
<td>95-98</td>
<td>n/a</td>
<td>90</td>
<td>98</td>
</tr>
<tr>
<td>Retention Pond</td>
<td>91</td>
<td>0-79</td>
<td>0-80</td>
<td>0-71</td>
<td>9-95</td>
<td>0-69</td>
<td>n/a</td>
</tr>
<tr>
<td>Extended Detention</td>
<td>50-70</td>
<td>10-20</td>
<td>10-20</td>
<td>30-60</td>
<td>75-90</td>
<td>n/a</td>
<td>50-90</td>
</tr>
<tr>
<td>Wetland Basin</td>
<td>40-94</td>
<td>(-4)-90</td>
<td>21</td>
<td>(-29)-82</td>
<td>27-94</td>
<td>18</td>
<td>n/a</td>
</tr>
<tr>
<td>Sand Filters</td>
<td>14-96</td>
<td>5-92</td>
<td>(-129)-84</td>
<td>10-98</td>
<td>60-80</td>
<td>60-80</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Pollutant removal efficiency in percentage of individual BMP is enlisted as shown in above Table 1. At study site of the Milan subway catchment, from analysis of storm water samples (Table 1), the concentration of TSS is very high as compared to the standard results. Therefore it is necessary to control the suspended solids entering in runoff at their source only. As given in Table 3, the BMPs to control the suspended solids at source are recommended as porous pavements at road surfaces, and sand filters, infiltration basins (Fig. 5), percolation trenches, retention ponds (Fig. 4), wetland basins. The main source of the suspended solids is from the runoff from construction sites. The BMPs to reduce the concentration of suspended solids in surface runoff from construction sites are enlisted below.
BMPs to control pollutants at source from runoff at construction sites

The two most common sources of the storm water pollution problems associated with construction activities are erosion and sedimentation. Failure to maintain adequate erosion and sediment controls at construction sites often results in sediment discharges into the storm water drainage system and creating multiple problems once it enters local waterways.

Construction site planning BMPs at the beginning

- Prepare the complete storm water pollution prevention plan (SWPPP).
- Plan the development to fit the topography, soils, drainage pattern and natural vegetation of the site.
- Avoid construction on steep slopes.
- Minimize cut and fills.
- Develop and implement an effective combination of erosion and sediment controls for the construction site.
- Align temporary and permanent roads and driveways along slope contours.

BMPs during progress of the work

- Protect all storm drain inlets and streams located near the construction site to prevent sediment-laden water from entering the storm drain system. Construct sediment traps.
- Limit access to and from the site. Stabilize construction entrances/ exits to minimize the track out of dirt and mud onto adjacent streets. Conduct frequent street sweeping.
- Protect stockpiles and construction materials from winds and rain by storing them under a roof, secured impermeable tarp or plastic sheeting.
- Avoid storing or stockpiling materials near storm drain inlets, gullies or streams. Construct detention/retention structures or ponds (Fig: 4) at key outfall areas to capture rainwater and allow it to percolate into the ground rather than drain from the site.
- Phase grading operations to limit disturbed areas and duration of exposure.
- Perform major maintenance and repairs of vehicles and equipment off site.

Fig. 4 : Retention Pond.

Fig. 5 : Infiltration Basins
• Wash out concrete mixers only in designated washout areas at the construction site.
• Setup and operate small concrete mixers on tarps or heavy plastic drop cloths.
• Keep construction sites clean by removing trash, debris, wastes, etc. on a regular basis.
• Clean up spills immediately using dry clean up methods (e.g., absorbent materials such as cat litter, sand or rags for liquid spills; sweeping for dry spills such as cement, mortar or fertilizer) and by removing the contaminated soil from spills on dirt areas.
• Prevent erosion by implementing any or a combination of soil stabilization practices such as surface roughening, and temporary silt fencing.
• Maintain all vehicles and equipment in good working condition. Inspect frequently for leaks, and repair promptly.
• Practice proper waste disposal. Many construction materials and wastes, including solvents, water-based paint, vehicle fluids, broken asphalt and concrete, wood, and cleared vegetation can be recycled. Materials that cannot be recycled must be taken to an appropriate landfill or disposed of as hazardous waste.
• Cover open dumpsters with secured tarps or plastic sheeting. Never clean out a dumpster by washing it down on the construction site.
• Arrange for an adequate debris disposal schedule to insure that dumpsters do not overflow.
• Infiltration basins (Fig: 5).
• Porous pavements.
• Sand Filters.

CONCLUSION

The average EMCs of the total suspended solids is 312.7 mg/l which is very high from the standard permissible limits. The average EMC of the dissolved oxygen is marginally higher than the permissible limits and this may be due to the increased concentration of the total suspended solids. The unit pollutant loading of the total suspended solids is higher than the allowable permissible limits. Storm water quality should be protected by implementing the proper pollution prevention plans, reduction of pollutant concentrations at their source. Best management practices such as porous pavements, grass buffers and swales, stream buffers and greenways, extended detention basins, wet detention ponds, constructed wetlands, spill containment facilities should be adopted to reduce flow rates and constituent concentrations. Non structural BMPs such as institutional and educational practices for producing behavioral changes should be implemented effectively so that pollutant load can be decreased and quantity and quality of storm water runoff can be maintained. The proper BMPs should be adopted at construction sites to reduce the impacts of solids in surface runoff from construction sites.

REFERENCES


