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Point and non-point microbial source pollution: A case study of Delhi

Priyanka Jamwal [a], Atul K. Mittal [b,*], Jean-Marie Mouchel [c]

[a] Environmental Engineering Laboratory, Department of Civil Engineering, Indian Institute of Technology, Delhi, New Delhi 110 016, India
[b] Department of Civil Engineering, Indian Institute of Technology, Delhi, Hauz Khas, New Delhi 110 016, India
[c] Cereve, Ecole nationale des ponts et chaussées, Champs sur Marne, Marne la vallée, Paris 77455, France

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ABSTRACT

The present study identifies major point and non-point sources of microbial pollution during dry and wet weather in Delhi watershed which is the first prerequisite for planning and management of water quality of the river Yamuna. Fecal coliforms (FC) and fecal streptococci (FS) levels were determined from two types of sources – point source (effluent from sewage treatment plants) and non-point source (stormwater runoff during dry and wet weather). FC and FS levels in the river Yamuna were also monitored, which is an ultimate sink for all microbial loads in Delhi watershed.

Effluent from sewage treatment plants (STPs) employing different treatment technologies were evaluated. FC and FS levels greater than the effluent discharge standard (1000 MPN/100 ml) were observed in the effluents from all STPs except "oxidation pond Timarpur". This study also involved field program for characterization of urban runoff from different land-uses. Results indicated that the microbial quality of urban runoff produced during wet weather from different land-uses was similar to that of raw sewage. Sewage overflows along with human and animal sources were responsible for high FC and FS levels in the runoff samples.

Wet weather FC and FS levels in river Yamuna were higher as compared to the dry weather levels suggesting that dilution of the river water during wet weather does not affect its microbiological quality. Thus on the basis of this study it was found that urban runoff also contributes to the microbial quality of the river Yamuna.

1. Introduction

Pollutant sources affecting surface water quality are categorized as point and non-point sources (NPS). The difference in these two types of pollution is that, the impurities from point source enter the water resource at an easily identifiable distinct location though a direct route, e.g., effluent from sewage treatment plants (STPs) whereas in case of non-point source pollution the pollutants enter from unidentified diffused sources and are difficult to control, e.g., stormwater runoff, dry weather runoff from slums, small clusters, etc. Delhi, the capital city of India has significant economic expansion and corresponding high rates of urbanization which have brought rapid changes to this megacity's urban spatial structure. The outcome of this has instigated increase in population, change in landuse pattern (mixed landuse), increase in impervious area and growth of unauthorized settlements in the form of slums, unauthorized colonies, clusters, etc. Increase population due to migration and high birth rate, overstressed the water and sanitation infrastructure. At present nearly 55% of Delhi's 15 million inhabitants are connected to the sewage system and others living in slums and squatter settlements deprive of basic sanitation facilities (YAP, 2008a). The process of urbanization and associated activities increase runoff flows and degrade runoff quality, therefore the wastewater generated from such areas during dry as well as wet weather finds its way directly to river Yamuna.

River Yamuna, which drains an area of approximately 1483 km^2 of Delhi watershed, is the main watercourse through Delhi. It is a source of water supply for downstream population and is also used for various recreational purposes. Various institutional and managerial measures have been taken by the Ministry of Environment and Forests (MoEF) of the Government of India in 12 towns of Haryana, eight towns of Uttar Pradesh, and Delhi under an action plan to improve the water quality of river Yamuna. Under Yamuna action plan (YAP), which is implemented since 1993 by the National River Conservation Directorate (NRCD) of the MoEF, number of sewage treatment plants (STPs) aerobic as well and anaerobic were constructed to treat discharges from point sources, i.e., discharges coming from localities served by proper sewerage system, whereas the non-point sources, i.e., wet and dry weather runoff generated from Delhi city was completely neglected (Sato et al., 2006; YAP, 2008b). In Delhi city, the wastewater generated from slums, unauthorized colonies, clusters, etc. finds its way to the open storm drains which contributes to dry weather runoff. Therefore despite,

* Corresponding author. Tel.: +91 11 26591239; fax: +91 11 26581117.
E-mail address: akmittal@civil.iitd.ac.in (A.K. Mittal).

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a number of STPs in place, published data on river water quality showed no improvement, particularly in microbiological water quality (YAP, 2005; Karn and Harada, 2001; CPCB, 2005a; Sato et al., 2006). At present, the total coliform (TC) and fecal coliform (FC) levels in river are of the order of 10^7/100 ml (YAP, 2005; CPCB, 2005b). FC are the indicator organisms used to evaluate the biological quality of surface waters for different purposes such as drinking, bathing, swimming, etc. High levels of FC indicate presence of pathogens, thus posing health implication to the downstream population. Therefore to meet the surface water quality standards of 500 MPN/100 ml for bathing (NRCD, 2005) proper design of water management and quality restoration policies is required, which in turn depends upon the understanding of the relative importance of sources degrading the microbiological quality of river.

Past studies in developed countries suggested that effluent discharged from STPs was only responsible for the poor biological quality of river water. At present the point source of pollution has been successfully controlled and managed but developed nations continue facing fecal contamination of surface waters. Urban runoff has been found responsible for closure of 32% beaches at least once during summer season in United States (EPA, 2006). Studies also confirmed that dry and wet weather runoff being directly discharged to surface waters was one of the important factor responsible for the poor quality of surface waters (Wenwei et al., 2003; Taebi and Droste, 2004; Petersen et al., 2005; McLeod et al., 2006). Studies were carried out to determine the affect of different factors contributing to the quality of urban runoff. It was concluded that urbanization and industrialization influenced the chemistry of surface water (Al-Kharabsheh, 1999; Karn and Harada, 2001; Wang, 2001; Marsalek et al., 2002; Kelsey et al., 2004), the temperature of urban streams (LeBlanc et al., 1997), the reduction of urban groundwater supplies (Gupta, 2002) and the physico-chemical and biological quality of surface waters (Goda, 1991; Young and Thackston, 1999; Izonfuo and Bariweni, 2001).

Except very few studies carried out on physico-chemical quality of surface waters no data is available regarding the identification of the pollution sources and their respective contribution to the surface water quality in the growing cities of developing countries like India (Trisal et al., 2008). Data regarding the biological quality of urban runoff produced from the watershed with mixed landuse characteristics is still lacking.

Thus, the objective of this study is to identify different sources of pollution in Delhi city and to study their impacts on the biological water quality of river Yamuna, which would lead to the easy control and application of the mitigating measures to restore water quality.

2. Methodology

To achieve the scope of the study, data were collected both from primary and secondary sources. Primary data include analysis of samples from point sources, non-point sources and river Yamuna. Fig. 1 shows the location of STPs, sampling sites during wet weather within Delhi watershed and sampling location on river Yamuna. Whereas, secondary data consist of data on landuse, population, water supply, wastewater treatment capacity and other factors important for the identification of point and non-point sources.

2.1. Primary data

2.1.1. Site selection for non-point source of pollution

In Delhi, during monsoon season, water logging problem is quite common. During rain events, due to poor stormwater drainage network water gets collected in low lying areas causing temporary flood situation. To overcome water logging problem in low lying areas, Municipal Committee of Delhi (MCD) had installed temporary as well as permanent stormwater pumping stations. Stormwater gets collected in underground sumps and is than pumped into adjacent stormwater drains. Data regarding the population density, catchment area, type of landuse, etc. for such sites was available with MCD. To estimate the pollution load in stormwater from diffuse sources of pollution, six sites prone to water logging were selected on the basis of landuse characteristics (see Table 1).

The institutional areas are characterized by planned development pattern, having full sewerage, and minimum pollution from sources like slums, open defecation, and mixing of sewage with the stormwater. Campus of the Indian Institute of Technology Delhi (IITD), provided such a setting, so two sampling sites (stormwater drains) were selected within the IITD campus. At commercial and slum areas, pumps were installed to manage water logging. The commercial sites exhibited high impervious cover, medium population density and were prone to sewage mixing during high intensity rain events. The slum areas had a high population density (0.3 million persons/km^2) and were located on the outskirts of Delhi city, with poor or no sewerage systems.

Samples were collected in a time series (20 min interval) from storm drains and pumping stations at respective sites. At the time of sampling, the runoff flow rates were also measured. Three rain events from June to September, 2006, were sampled at each site except for Gandhi Vihar where only a single rain event was sampled owing to some technical problems. Water quality samples were stored at 4 °C and transported to the Environmental Engineering Laboratory, IITD for analysis. Samples were analyzed with 8 h from the time of collection.

2.1.1.1. Data analysis. The pollutant concentrations often vary by several orders of magnitude during the storm event, a single index known as event mean concentration (EMC) can be used to characterize runoff constituents. The EMC is a flow weighted average of constituent concentrations. The EMC for a storm event is defined as total pollutant load divided by total runoff volume, as follows:

$$\mathrm{EMC} = \frac{\sum_{i=1}^{N} Q_i C_i \Delta t}{\sum_{i=1}^{N} Q_i \Delta t} \qquad (1)$$

where N is the total number of samples taken during storm event, Q_i and C_i are flow rate and pollutant concentration respectively measured at time i, and Δt is the time interval between two measurements. For a specific catchment, the mean of all EMCs, is the site mean concentration (SMC).

2.1.2. Point source of pollution

Delhi watershed is divided into five major zones. Depending upon the population, each zone is served by number of STPs. Total 17 STPs were upgraded and constructed with total treatment capacity of 2.30×10^6 cubic meters per day (m^3/d) (see Table 2). At present only 14 STPs are functional with total treatment capacity of 2.19×10^6 m^3/d. Due to poor sewerage network and unavailability of raw sewage, most of STPs are under utilized having actual treatment capacity of 1.16×10^6 m^3/d. These STPs are fed from the sewerage system and open drains (see Table 3). The details of actual sewage treated and hydraulic retention time (HRT) for all STPs are presented in Table 3. The evaluation of STPs was carried out for a period of 12 months, i.e., from November 2005 to November 2006. Influent sewage samples and effluent samples were collected from all STPs. The influent sewage characteristics varied, depending upon the landuse characteristics and the type of population served.

To determine the contribution of microbial pollution load from the treated wastewater, effluent samples were collected from all the functional sewage treatment plants (STPs). Analysis of microbi-