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Reuse of treated sewage in Delhi city: Microbial evaluation of STPs and reuse options

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ABSTRACT

Microbiological quality of the treated wastewater is an important parameter for its reuse. The data on the Fecal Coliform (FC) and Fecal Streptococcus (FS) at different stages of treatment in the Sewage Treatment Plants (STPs) in Delhi watershed is not available, therefore in the present study microbial profiling of STPs was carried out to assess the effluent quality for present and future reuse options. This study further evaluates the water quality profiles at different stages of treatment for l6 STPs in Delhi city. These STPs are based on conventional Activated Sludge Process (ASP), extended aeration, physical, chemical and biological treatment (BIOFORE), Trickling Filter and Oxidation Pond. The primary effluent quality produced from most of the STPs was suitable for Soil Aquifer Treatment (SAT). Extended Hydraulic Retention Time (HRT) as a result of low inflow to the STPs was responsible for high turbidity, COD and BOD_5 removal. Conventional ASP based STPs achieved 1.66 log FC and 1.06 log FS removal. STPs with extended aeration treatment process produced better quality effluent with maximum 4 log order reduction in FC and FS levels. "Kondli" and "Nilothi" STPs employing ASP, produced better quality secondary effluent as compared to other STPs based on similar treatment process. Oxidation Pond based STPs showed better FC and FS removals, whereas good physiochemical quality was achieved during the first half of the treatment.

Based upon physical, chemical and microbiological removal efficiencies, actual integrated efficiency (IE_a) of each STP was determined to evaluate its suitability for reuse for irrigation purposes. Except "Mehrauli" and "Oxidation Pond", effluents from all other STPs require tertiary treatment for further reuse. Possible reuse options, depending upon the geographical location, proximity of facilities of potential users based on the beneficial uses, and sub-soil types, etc. for the Delhi city have been investigated, which include artificial groundwater recharge, aquaculture, horticulture and industrial uses such as floor washing, boiler feed, and cooling towers, etc.

1. Introduction

Delhi, capital city of India is about 1485 km^2 in area, out of this approximately 63% is urbanized. River Yamuna serves about 75% of the total population of the watershed. Problem of water shortage in Delhi has been exacerbated as a result of high natural population growth, urbanization, industrialization and migration. Consequently, Delhi is facing a future of very limited water resources. About 30% of the total water demand in Delhi watershed is met by groundwater sources. Consequently, due to overexploitation, the groundwater level in Delhi city has declined to 10–20 m below ground level and the deepest water level is about 40 m below ground level in south Delhi region.

Wastewater reuse has recently been looked up as a potential option to cope up with the increasing water stress. Reclaimed water is suitable for many applications, such as irrigation, toilet flushing, cleaning, industrial reuse and environmental enhancement (El-Gohary et al., 1998; Scott et al., 2003; Jimenez et al., 2001; Jimenez and Chavez, 2002; Chang et al., 2007; Chiou et al., 2007). Because of its stable quantity, reclaimed water from domestic Sewage Treatment Plants (STPs) could be a reliable alternative water resource.

Delhi city has 17 STPs located in the outskirts and along the banks of river Yamuna. City generates 2.98×10^6 cubic meter sewage per day (m^3/d). The actual treatment capacity of STPs of Delhi watershed is 1.44×10^6 m^3/d, thus around 50% of the total wastewater generated gets treated that can be reused. STPs are usually designed to efficiently remove organic matter (suspended and dissolved) and nutrients, but seldom have they been planned specifically to remove pathogenic microorganisms from wastewater. Thus, reuse of treated wastewater from such STPs needs careful evaluation.

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The removal efficiency of pathogenic and indicator microorganisms in conventional STPs vary according to the characteristics of influent sewage, type of treatment process, Hydraulic Retention Time (HRT), biological flora present in treatment plants, pH, temperature and the efficiency in removing suspended solids (Jimenez et al., 2001; Koivunen, 2003; Chuang et al., 2005; Zhang and Farahbakhsh, 2007). Though conventional STPs have been reported to reduce the numbers of enteric microbes but as reductions in treatment processes vary extensively depending on the above listed factors, effluents still contain high Fecal Coliforms (FC) levels (Mara, 2001; Abdel-Shafy et al., 2004; Foppen and Schijven, 2005).

The reuse options depend on the quality of effluent produced after the treatment of the sewage (Megdal, 2006; Chiou et al., 2007). At present the data regarding organic load, i.e., BOD_5 and COD removal is available for the STPs in Delhi. The absence of microbial data for these STPs restricts the wastewater reuse options. Besides, the level of tertiary treatment shall also depend on the FC and FS levels in the secondary effluent.

Improper planning of wastewater reuse may expose large number of people including workers, and farmers to pathogenic microorganisms thus posing a high risk to public health (Friedler et al., 2006; Zaidi, 2006). Keeping in view the interest of public health, National River Conservation Directorate (NRCD, 2005) in India has reviewed the wastewater standards with special reference to the levels of microbial load.

In the present study, microbial quality of wastewater for all 17 STPs at different stages of treatment has been studied. A number of different biological treatment processes are employed at STPs. Effluent quality has been related with the type of treatment process. Reuse options are evaluated with respect to the local conditions and applicability of specific reuse options in conformity with the local geographical, hydrological, and accessibility issues. Evaluation of STPs employing different technologies is carried out with special reference to FC and Fecal Streptococcus (FS) removal at different stages of treatment. The study focuses on the wastewater reuse options for STPs taking public health into consideration.

2. Methodology

In this study all 17 STPs located in Delhi were sampled (Table 1). Water quality was analyzed at the influent, after primary treatment and after secondary treatment.

2.1. Sampling

The sampling campaigns for all STPs were carried out for a period of 12 months, i.e., from November 2005 to November 2006. Samples were collected at after every treatment step from all STPs. During the evaluation period, each STP was sampled four times. Samples were collected at every stage of the treatment (Figs. 1–6). The influent samples were collected from the sump constructed to hold the water after pumping the sewage from open drains or sewerage system. In all, 234 samples were collected and analyzed.

2.2. Physiochemical and bacteriological analysis

Samples were preserved at 4 °C during transportation to laboratory. They were immediately analyzed for FC, FS, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_5), pH and turbidity. All the analyses were carried out as per the Standard Methods (APHA, 1998).

FC and FS were enumerated using Most Probable Number method (MPN). For the enumeration of FC and FS, samples were suitably diluted using sterile de-ionized water before inoculation in appropriate medium. Enumeration of FC was carried out by direct inoculation technique using A1 broth (Difco) as per Standard Methods. FS were recovered on Azide dextrose broth (HiMedia) at an incubation temperature of 35 ± 0.5 °C for 48 h. All positive tubes were subjected to the confirmation test by using Pfizer selective enterococcus Agar (HiMedia).

2.3. Treatment process description

All the STPs investigated consisted of either single stage treatment (secondary) or two stage treatment (primary and secondary). Different types of primary and secondary treatment processes were employed in these STPs (Table 1).

2.3.1. Primary treatment processes

Figs. 1–6 present the process flow diagram of different STPs in Delhi city. In conventional ASP, the Primary Settling Tank (PST) is employed to remove the suspended particles. The designed HRT for PST was 2.5 h. The PST for all STPs employing ASP was of circular cross-section (Figs. 1–2). In Trickling Filter process recirculation ratio was 1:1, so as to dilute the effluent after Primary Settling Tank and thereby improving the total treatment efficiency (Fig. 3).

Table 1
Wastewater treatment plant characteristics.

Sewage Treatment Plant	Technology	Design flow (MLD)	Hydraulic retention time (h)				Utilization (%)
			PST/physical treatment	Biological reactor/chemical treatment	SST/biological treatment	Total HRT	
Kondli (KND)	ASP	204	7.33	17.33	7.33	32.00	30.00
Yamuna Vihar (YV)	ASP	91	7.33	17.33	7.33	32.00	30.00
Rithala I (RIT I)	ASP	182	3.83	9.04	3.83	16.70	57.50
Coronation pillar (CP I)	ASP	136	4.40	10.40	4.40	19.20	50.00
Okhla (OKH)	ASP	636	2.93	6.93	2.93	12.80	75.00
Nilothi (NIL)	ASP	182	17.60	41.60	17.60	76.80	12.50
Keshopur (KSH)	ASP	327	4.40	10.40	4.40	19.20	50.00
Papankallan (PPK)	ASP	91	4.89	11.56	4.89	21.33	45.00
Vasant Kunj I (VKI)	Extended aeration	14	–	30.00	3.30	33.30	66.67
Mehrauli (MEH)	Extended aeration	23	–	58.82	6.47	65.29	24.00
Nazafgarh (NAZ)	Extended aeration	23	–	83.33	9.17	92.50	24.00
Coronation pillar CP (TF)	Trickling Filter	45	3.75	5.00	3.75	12.50	40.00
Rithala II (RIT II)	High rate aeration	182	3.20	2.26	3.20	8.66	66.25
Oxidation Pond Timarpur (OP)	Oxidation Pond	27	–	433.90	33.33		
Delhi gate[a] (DG)	Biofore	10	2.50	4.00	2.50	9.00	100.00
Sen nursing[a] home (SNH)	Biofore	10	2.50	4.00	2.50	9.00	100.00

[a] Physical, chemical and biological treatment (BIOFORE).