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COMMENTARY

Reclamation and reuse of treated municipal wastewater: an option to mitigate water stress

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Growing population, industrialization, agricultural practices and urbanization have increased the water demand and hence the quantity of wastewater (ww). Availability of drinking water, including different components of daily per capita demand in developing countries, is becoming a serious issue to manage. To fight with growing water stress, reclamation and reuse of treated ww for various day-to-day uses except for drinking purpose is necessary. Reuse of ww in Indian cities, not a substantial but a small fraction, may bridge the gap between supply and demand of water in the future. This also deals with a viable technological option for reuse of ww.

With growing population, advanced agricultural practices, industrialization, urbanization and multiple use of water have increased the demand for water. Climate change leads to major impacts on regional water resources, affecting both groundwater and surface water supply for domestic and industrial uses. These impacts will be more severe in the developing world, because of their poor capacity to cope with and adapt to climate variability. India also comes under this category. Natural bodies of surface water, such as lakes, rivers, reservoirs and other impounding structures are major sources of raw water which is used for community water supply after necessary treatment. The increasing water demand will lead to a clear stress on these water bodies. In future, treatment of raw water would become more cumbersome and costly due to contamination, which is to be brought down to permissible limits.

Due to daily human activity and also various agricultural and industrial operations, wastewater (ww) is produced in enormous quantity. Due to lack of management and treatment facilities most of the municipal ww generated in Indian cities is discharged into aquatic systems without treatment, making the receiving body unfit for its desired use in the years to come. Inadequate treatment facilities for sewage have deteriorated the water quality of aquatic resources. The latest study carried out by the Central Pollution Control Board (CPCB) indicates that about 26,254 million litres per day (Ml/d) of ww is generated in the 921 Class I cities and Class II towns in India (housing more than 70% of urban population). The municipal ww treatment capacity developed so far in India is about 7044 Ml/d – accounting for 27% of ww generation in these two classes of urban centres. Table 1 presents a scenario of ww generated and treated for the year 2001 for the Indian states. The table clearly shows inadequate treatment facility and management. The situation is much worse because most of the states show that ww generated is directly discharged into the nearby surface water.

There is an urgent need to plan strategies and give thrust to policies with equal importance for the development of ww treatment facilities and reuse. The future of urban water supplies for potable uses will grossly depend on efficient ww treatment systems and reuse, as the treated ww of upstream urban centres will be the source of water for downstream cities.

Reclamation and reuse of ww – a case study

In India, where ww treatment facilities in Class II cities are in the developmental stage, reuse of treated water is still a distant dream. However, in bigger cities (metros), reuse of ww may be made mandatory. In cities like Delhi, where ww treatment is more stringent and a major portion of the waste is treated, the reuse facility may be implemented effectively. A case study of Delhi is given below. Based on this study, a scheme may be proposed for other big cities also as an option to meet their future water requirement and to mitigate water stress.

Delhi is experiencing increasing pressure to meet its demand for its water resources. Growing urbanization, improvement in living standards and exploding

Table 1. State-wise domestic waste generation and treatment (2001)

State	Wastewater generation (Ml/d)	Wastewater treated (Ml/d)	Untreated wastewater (Ml/d)
Maharashtra	4692	499	4193
West Bengal	2113	372	1741
Uttar Pradesh and Uttarakhand	2292	772	1520
Bihar and Jharkhand	1363	135	1228
Andhra Pradesh	1271	208	1063
Rajasthan	1055	27	1028
Gujarat	1709	701	1008
Madhya Pradesh and Chhattishgarh	1159	227	932
Tamil Nadu	1094	290	804
Delhi	2700	1927	773
Karnataka	1036	387	649
Punjab	616	0	616
Kerala	428	0	428
Orissa	374	0	374
Assam	222	0	222
Chandigarh	272	91	181
Puducherry	36	0	36
Meghalaya	30	0	30
Haryana	330	303	27
Manipur	24	0	24
Tripura	22	0	22
Goa	20	0	20
Himanchal Pradesh	20	0	20
Nagaland	13	3	10
Andaman & Nicobar	8	0	8
Mizoram	4	0	4
India	22,903	5942	16,961

Source: Central Pollution Control Board, Ministry of Environment and Forests, Govt of India.

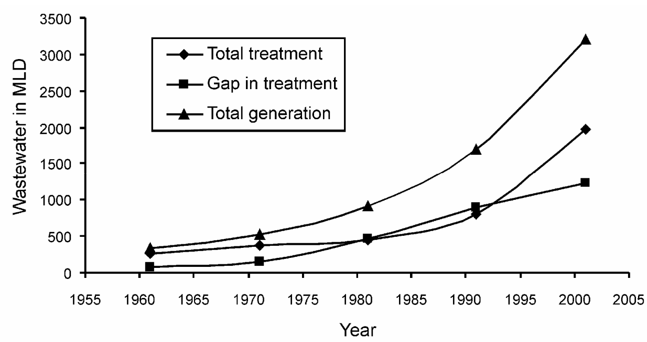

Figure 1. Decadal growth of wastewater (ww) treatment and gap in treatment for Delhi city.

population are just some of the contributing factors. The population of Delhi is expected to reach 22 million by the year 2021. According to the manual of the Central Public Health & Environmental Engineering Organization (CPHEEO), Ministry of Urban Development, the per capita per day water requirement is 274 lpcd (litres per capita per day). The city experiences an unequal supply – 29 lpcd of water in some areas, compared to 509 lpcd in other areas. With the projected population, the expected[1] rise in water demand will be 4370 Ml/d (excluding losses) by end of 2021.

Even though Delhi is one of the first Indian cities to have paid attention to city planning with the first master development plan of 1962, the infrastructure for public utilities is proving to be inadequate, especially under the burden of the growing population. Figure 1 shows a decadal growth of ww generation in Delhi with total treatment and gap in treatment of the generated ww. Figure 1 also shows an exponential growth in ww generation over the decade. While during the period 1961–81 the amount of ww treatment was almost constant, there was significant increase after 1981. The gap in treatment shows a linear increasing trend over a period of time.

The projected ww generation (assuming 80% of the demand) in Delhi will be 3500 Ml/d by 2021, with an estimation that 3150 out of 3500 Ml/d will reach the sewage treatment plants (STPs). The shortfall in the water supply may be reduced by reusing the treated ww and supplying it to the city by imparting necessary treatment. Even 20–40% reuse of treated ww may reduce the shortfall in the city water supply substantially. Reuse of only 20% treated ww (nearly 630 Ml/d) will fulfil the need of 10% of the city's population at an average of 274 lpcd in the projected scenario. Water may be reused for various purposes like recreation, cleaning, toilet flushing and other uses where meeting the drinking water criterion is not mandatory. No doubt, reuse of treated water needs infrastructure facility, space at the treatment site and treatment technology to meet the intended criteria. Forty per cent may be an ambitious target to achieve, but starting with even 20–25% will lessen the burden of raw water supply sources in the future projected scenario.

There are several advantages involved in this plan. This will reduce the pressure on existing raw water sources and bridge the gap between city water supply demand and availability. Pollution due to discharge of ww effluent will reduce significantly, enabling it fit for future use. Pressure on groundwater sources, which contributes a major percentage of the city's water supply, will drop substantially. This will create positive hydrological balance leading to increase in the productivity of the wells, decreasing pumping costs and energy requirement.

Viable technological option for reuse of treated ww

Here the purpose of reuse of ww is not to make it useful for drinking purpose, which requires thorough treatment and may not be aesthetically acceptable to the community at large. A partial treatment by ensuring complete removal of suspended matter, organic matter, colour and bringing down excessive contaminants to non-objectionable levels is sufficient for this purpose. If we consider the ww treatment scenario of Delhi, it has 30 STPs, all of which are based on conventional treatment processes. A survey conducted to evaluate the performance of STPs by CPCB during November–December 2006, found influent and effluent quality as listed in Table 2.

The performance of all STPs shows excellent removal of total suspended solid (TSS), chemical oxygen demand (COD) and biochemical oxygen demand (BOD_5) with 85–93%, 75–85% and 83–98% efficiency respectively, and effluent quality is within permissible limits for the aquatic body disposal. With the above effluent quality, it may not be difficult to impart further treatment, so as to make it fit for reuse.

Before giving any viable solution for ww reuse, we shall take a look at the existing Indian ww treatment technology. STPs in India are mostly based on conventional processes (activated sludge process (ASP) followed in a few cases by bio-filters and extended aeration modification). Conventional treatment processes are effective but are often chemically, energetically and operationally intensive, focused on large systems and require considerable infusion of capital, engineering expertise and infrastructure. When making the technology or process more energy-efficient and – there is global pressure on India to reduce carbon emission in view of climate change scenario – a paradigm shift from conventional to biological treatment of ww is an urgent need. National River Conservation Directorate (NRCD), a national agency under the Ministry of Environment and Forests, Govt of India took the initiative to improve the quality of the major freshwater sources in the country, through implementation of pollution abatement schemes[2]. Under this initiative, 20 STPs based on the Up-Flow Anaerobic Sludge Blanket (UASB) process were constructed as a choice of technology with the same number in the pipeline throughout the country. Unlike the ASP, the UASB process does not effectively remove the biological pollution of ww (Table 3). But it offers an advantage in terms of low energy for operation and low initial capital requirement, making it attractive and appropriate for direct treatment of sewage in countries like India, where energy is a scarce resource.

Table 2. Influent and effluent quality in sewage treatment plants

	pH	TSS	COD	BOD_5
Influent	6.4–7.8	142–647	172–615	48–323
Effluent	6.9–8.1	11–93	26–153	1–55

All figures are in mg/l, except pH.
TSS, Total suspended solid; COD, Chemical oxygen demand; BOD_5, Biochemical oxygen demand.

Table 3. Performance comparison between conventional and UASB processes

	Removal efficiency (%)			
Process	TSS	BOD_5	COD	Microbes
Conventional (ASP)	85–93	83–98	75–85	60–90
UASB	60–75	65–75	60–80	Negligible

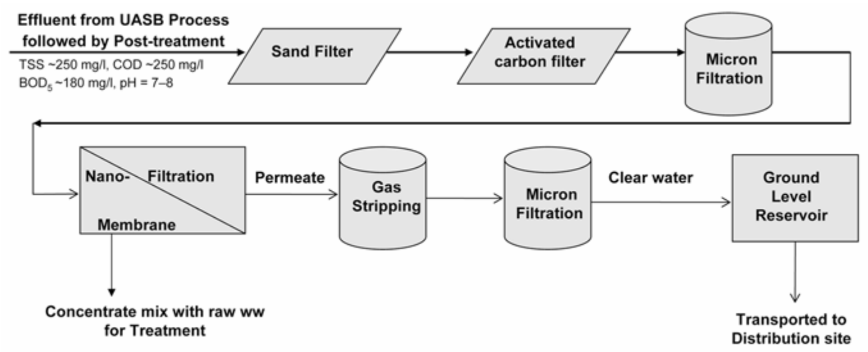

Figure 2. Schematic diagram for reuse of ww after UASB followed by post-treatment.

Table 3 provides a comparison of the performance of both conventional and UASB processes[3,4].

To improve effluent quality, the UASB process is mostly followed by post-treatment processes like extended aeration lagoon, stabilization pond, biological activated sludge, physical sand filtration to remove macronutrients, pathogens and organic materials, which is a limitation of the UASB process[5]. The performance of a few UASB-based STPs under the Yamuna Action Plan (YAP)[6] is presented in Table 4.

In the Indian scenario, performance of UASB followed by post treatment shows considerably good results, with an average removal efficiency of BOD, COD and TSS up to 70%, 75% and 74% respectively. No doubt, the conventional treatment offers an advantage in terms of efficient treatment but looking into the economy, energy consumption, land requirement and ease of handling, a set of treatments is proposed in the Indian context for ww reuse (Figure 2).

In general, TSS, BOD and COD levels in raw municipal sewage range between 100 and 600 mg/l, 150 and 600 mg/l, and 40 and 300 mg/l respectively. The effluent quality (input stage) in Figure 2 for reuse is taken on the higher side considering the worse performance condition by the UASB followed by post-treatment processes. The final water obtained through the proposed set of arrangements (Figure 2) will have the quality of water that is needed for day-to-day use, except for drinking (BOD_5 <3 mg/l, turbidity <2 NTU, and colliform <1 log). The UASB process has advanced over a period of time and has promising potential to treat ww in countries like India, with further treatment for reuse of treated ww (Figure 2). The widespread application of membranes has made ww reuse at an affordable cost, offering an effective solution for the removal of most of the impurities along with microbes. Another major advantage is that the clean water obtained for reuse can be utilized for back washing (a process to clean filter media

Table 4. Performances of few UASB STPs under YAP[6]

		Removal efficiency (%)					
		BOD		COD		TSS	
Location	Capacity (Ml/d)	UASB[a]	Total[b]	UASB[a]	Total[b]	UASB[a]	Total[b]
Faridabad Zone-II	45	45–57	70–77	58–67	72–81	57–69	64–67
Faridabad Zone-III	50	51–67	65–78	66–73	69–83	71–78	70–84
Gaziabad Cis	70	53–66	64–76	69–78	65–88	64–73	67–78
Gaziabad Trans	56	57–64	65–72	58–79	66–81	59–70	64–81
Gurgoan	30	61–69	62–72	61–68	63–81	66–73	67–80

[a]Per cent removal by UASB only.

[b]Per cent removal by the plant is followed by post-treatment (final polishing pond).

by subjecting opposite water flow direction) of different units, flushing of membrane surface, and for other onsite cleaning purposes.

One of the important issues in ww reclamation and reuse is how to store and supply the treated ww. It may be difficult to store and supply the treated ww because all the houses in major cities are connected through piped water supply from water-treatment plants. While ground-level reservoirs (GLR) may be considered the best option to store the treated ww at site, introducing dual water-supply system (two separate distribution networks for potable and non-potable water) in the city will ease the problem of distribution and consumption of treated ww. In many cities worldwide, dual water supply system is in operation satisfactorily[7]. Hong Kong is the best example of dual water supply system[8], which has been running successfully and effectively since the 1950s. In the dual scenario, GLR-stored treated ww may be chlorinated (to prevent bacterial growth) and transported to the city water supply (in non-potable distribution network), from where it is supplied to the consumers or the same water may be used when the city is facing shortage of supply. Blending treated ww with the non-potable distribution network will reduce the burden of the water treatment plant during peak hours, as non-potable water consists of a major portion in the city's water supply. The cost of treatment will also reduce by reducing the treatment process, as producing non-potable water does not need a thorough treatment which is necessary in the case for water of potable quality. However, there is also the chance of growth of bacteria while transporting such water to the distribution point if the ww treatment plant is far away from the distribution point. In such a case the transported water may be passed through (at the distribution site) a chlorination chamber again to kill the bacteria.

Conclusion

Here an option to reuse ww to mitigate water stress is discussed, which will arise in future with increasing demand for water for multiple uses. It will not only reduce the burden on existing water sources, but also reduce the load of pollution in the receiving body due to effluent discharge. It is time that other states should also think and take the initiative in this direction, when water supply is a scarce resource. However, in India where most of the cities have no master plans for development, setting up a water supply system for treated ww for community use will be a major challenge. There is a task ahead before environmental engineers and city planners as to how to reclaim and reuse municipal ww with growing demand and bridge the gap between supply and demand. We must explore the possibilities in the near future to locate ww treatment plants in the near vicinity from where city water is supplied. It is time to replace all conventional STPs by UASB process-based systems followed by post-treatment to make them energy-efficient and economical. Choice of the reuse technology suggested here may vary according to geographical conditions. The government must make reuse of ww mandatory in every city from municipal ww treatment plants and also include this provision in the national water policy. The future of water supply lies in how effectively a nation uses its ww.

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