



Focus on Wastewater-to-Energy Applications

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ABSTRACT

Water, food and energy securities are emerging as increasingly important and vital issues for India and the world. Most of the river basins in India and elsewhere are closing or closed and experiencing moderate to severe water shortages, brought on by the simultaneous effects of agricultural growth, industrialization and urbanization. Current and future fresh water demand could be met by enhancing water use efficiency and demand management. Thus, wastewater/low quality water is emerging as potential source for demand management after essential treatment. An estimated 38354 million litres per day (MLD) sewage is generated in major cities of India, but the sewage treatment capacity is only of 11786 MLD. Similarly, only 60% of industrial waste water, mostly large scale industries, is treated. Performance of state owned sewage treatment plants, for treating municipal waste water, and common effluent treatment plants, for treating effluent from small scale industries, is also not complying with prescribed standards. Thus, effluent from the treatment plants, often, not suitable for household purpose and reuse of the waste water is mostly restricted to agricultural and industrial purposes. Wastewater- irrigated fields generate great employment opportunity for female and male agricultural labourers to cultivate crops, vegetables, flowers, fodders that can be sold in nearby markets or for use by their livestock. However, there are higher risk associated to human health and the environment on use of wastewater especially in developing countries, where rarely the wastewater is treated and large volumes of untreated wastewater are being used in agriculture.

I. WATER AVAILABILITY AND USE:

India accounts for 2.45% of land area and 4% of water resources of the world but represents 16% of the world population. Total utilizable water resource in the country has been estimated to be about 1123 BCM (690 BCM from surface and 433 BCM from ground), which is just 28% of the water derived from precipitation. About 85% (688 BCM) of water usage is being diverted for irrigation (Figure 1), which may increase to 1072 BCM by 2050. Major source for irrigation is groundwater. Annual groundwater recharge is about 433 BCM of which 212.5 BCM used for irrigation and 18.1 BCM for domestic and industrial use (CGWB, 2011). By 2025, demand for domestic and industrial water usage may increase to 29.2 BCM. Thus water availability for irrigation is expected to reduce to 162.3 BCM. With the present population growth-rate (1.9% per year), the population is expected to cross the 1.5 billion mark by 2050. Due to increasing population and all round development in the country, the per capita average annual freshwater availability has been reducing since 1951 from 5177 m³ to 1869 m³, in 2001 and 1588 m³, in 2010. It is expected to further reduce to 1341 m³ in 2025 and 1140 m³ in 2050. Hence, there is an urgent need for efficient water resource management through enhanced water use efficiency and waste water recycling.

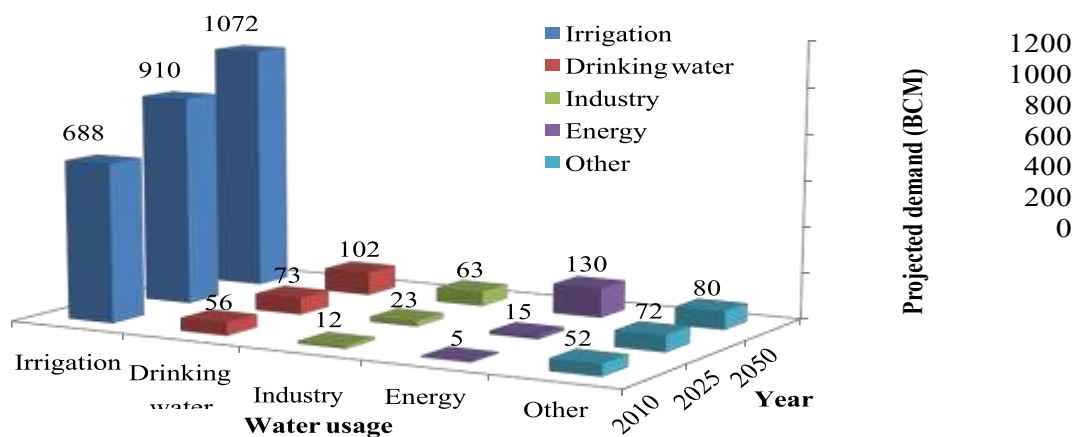


Figure 1: Projected water demand by different sectors (CWC, 2010)



II. WASTEWATER PRODUCTION AND TREATMENT:

With rapid expansion of cities and domestic water supply, quantity of gray/wastewater is increasing in the same proportion. As per CPHEEO estimates about 70-80% of total water supplied for domestic use gets generated as wastewater. The per capita wastewater generation by the class-I cities and class-II towns, representing 72% of urban population in India, has been estimated to be around 98 lpcd while that from the National Capital Territory-Delhi alone (discharging 3,663 mld of wastewaters, 61% of which is treated) is over 220 lpcd (CPCB, 1999). As per CPCB estimates, the total wastewater generation from Class I cities (498) and Class II (410) towns in the country is around 35,558 and 2,696 MLD respectively. While, the installed sewage treatment capacity is just 11,553 and 233 MLD, respectively (Figure 2) thereby leading to a gap of 26,468 MLD in sewage treatment capacity. Maharashtra, Delhi, Uttar Pradesh, West Bengal and Gujarat are the major contributors of wastewater (63%; CPCB, 2007a). Further, as per the UNESCO and WWAP (2006) estimates (Van-Rooijen *et al.*, 2008), the industrial water use productivity of India (IWP, in billion constant 1995 US\$ per m³) is the lowest (i.e. just 3.42) and about 1/30th of that for Japan and Republic of Korea. It is projected that by 2050, about 48.2 BCM (132 billion litres per day) of wastewaters (with a potential to meet 4.5% of the total irrigation water demand) would be generated thereby further widening this gap (Bhardwaj, 2005). Thus, overall analysis of water resources indicates that in coming years, there will be a twin edged problem to deal with reduced fresh water availability and increased wastewater generation due to increased population and industrialization.

In India, there are 234-Sewage Water Treatment plants (STPs). Most of these were developed under various river action plans (from 1978-79 onwards) and are located in (just 5% of) cities/ towns along the banks of major rivers (CPCB, 2005a). In class-I cities, oxidation pond or Activated sludge process is the most commonly employed technology, covering 59.5% of total installed capacity. This is followed by Up-flow Anaerobic Sludge Blanket technology, covering 26% of total installed capacity. Series of Waste Stabilization Ponds technology is also employed in 28% of the plants, though its combined capacity is only 5.6%. A recent World Bank Report (Shuval *et al.* 1986) came out strongly in favour of stabilization ponds as the most suitable wastewater treatment system in developing countries, where land is often available at reasonable opportunity cost and skilled labour is in short supply.

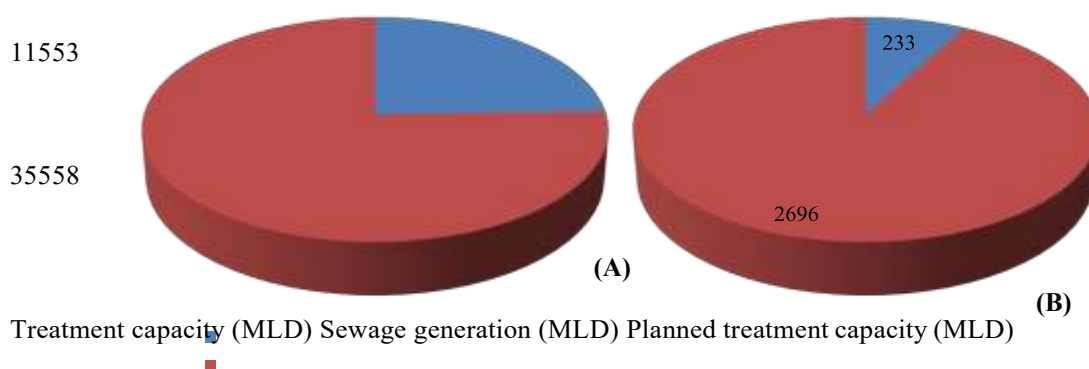


Figure 2: Sewage generation and treatment capacity in 498 Class I cities and 410 class II towns in India. (CPCB, 2009)

Apart from domestic sewage, about 13468 MLD of wastewater is generated by industries of which only 60% is treated. In case of small scale industries that may not afford cost of waste water treatment plant, Common Effluent Treatment Plants (CETP) has been set-up for cluster of small scale industries (CPCB, 2005b). The treatment methods adapted in these plants are dissolved air floatation, dual media filter, activated carbon filter, sand filtration and tank stabilization, flash mixer, clariflocculator, secondary clarifiers and Sludge drying beds, etc. Coarse material and settleable solids are removed during primary treatments by screening, grit removal and sedimentation. Treated industrial waste water from CETPs mixed disposed in rivers. For example, 10 CETPs from Delhi with capacity of 133 MLD dispose their effluent in Yamuna River.

Being flared and not being utilized. One of the major problems with waste water treatment methods is that none of the available technologies has a direct economic return. Due to no economic return, local authorities are generally not interested in taking up waste water treatment. A performance evaluation of STPs carried out by CPCB in selected cities has indicated that out of 92 STPs studied, 26 STPs had not met prescribed standards in



respect to BOD thereby making these waters unsuitable for household purpose. As a result, though the waste water treatment capacity in the country has increased by about 2.5 times since 1978-79 yet hardly 10% of the sewage generated is treated effectively, while the rest finds its way into the natural ecosystems and is responsible for large-scale pollution of rivers and ground waters (Trivedy and Nakate, 2001).

Table 1: Economics of different levels of treatments through conventional measures

Particulars	Primary treatment system	Primary + ultra-filtration system	Primary + ultra-filtration system + reverse osmosis
Capital cost (Rs lakhs)	30.0	90.64	145
Annualized capital cost (@15% p.a. interest & depreciation)	5.79	18.06	29.69
Operation and maintenance cost (lakhs/annum)	5.88	7.04	12.63
Annual burden (Annualized cost +O&M cost) Rs. Lakhs	11.85	27.1	42.5
Treatment cost Rs./kl (Without interest and depreciation)	34.08	52.40	73.22

III. WASTEWATER USE/ DISPOSAL:

Insufficient capacity of waste water treatment and increasing sewage generation pose big question of disposal of waste water. As a result, at present, significant portion of waste water being bypassed in STPs and sold to the nearby farmers on charge basis by the Water and Sewerage Board or most of the untreated waste water end up into river basins and indirectly used for irrigation. In areas like Vadodara, Gujarat, which lack alternative sources of water, one of the most lucrative income-generating activities for the lower social strata is the sale of wastewater and renting pumps to lift it (Bhamoriya, 2004). It has been reported that irrigation with sewage or sewage mixed with industrial effluents results in saving of 25 to 50 per cent of N and P fertilizer and leads to 15-27 % higher crop productivity, over the normal waters (Anonymous, 2004). It is estimated that in India about 73,000 ha of (Strauss and Blumenthal, 1990) per-urban agriculture is subject to wastewater irrigation. In peri-urban areas, farmers usually adopt year round, intensive vegetable production systems (300-400% cropping intensity) or other perishable commodity like fodder and earn up to 4 times more from a unit land area compared to freshwater (Minhas and Samra, 2004). Major crops being irrigated with waste water are:

Wastewater- irrigated fields generate great employment opportunity for female and male agricultural laborers to cultivate crops, vegetables, flowers, fodders that can be sold in nearby markets or for use by their livestock. In downstream rural areas of Vadodara in Gujarat, wastewater supports annual agricultural production worth Rs. 266 million. It has been estimated that in India sewage waters can annually irrigate about 1 Mha (Sengupta, 2008) to 1.5 M-ha of land area and have a potential to contribute about one million tonnes of nutrients and 130 million man-days of employment (Minhas and Samra, 2004). However, there are a number of limitations *w.r.t.* waste water treatment and reuse in agriculture, such as the production of waste water when the crops do not require irrigation water, the location of the plants compared to the land requiring irrigation, the match between the waste water fertilizer content and the crop requirements, the risk of over-application, vigorous incidence of weeds and insect pests due to, in general, low uses of pesticides in agro-forestry systems and early dropping and softening of fruits, etc. Intensive land application has indeed shown accumulation of salts in the soil, odour problems, salt and colour leaching affecting groundwater and downstream water quality, etc. (Satyawali and Balakrishnan, 2008).

IV. POLICIES AND INSTITUTIONAL SET-UP FOR WASTEWATER MANAGEMENT:

Presently there are no separate regulations/ guidelines for safe handling, transport and disposal of wastewater in the country. The existing policies for regulating wastewater management are based on certain environmental laws and certain policies and legal provisions viz. Constitutional Provisions on sanitation and water pollution; National Environment Policy, 2006; National Sanitation Policy, 2008; Hazardous waste

Creation of sewerage infrastructure for sewage disposal is responsibility of State governments/urban local bodies,



though their efforts are supplemented through central schemes, such as National River Conservation Plan, National Lake Conservation Plan, Jawaharlal Nehru National Urban Renewal Mission, and Urban Infrastructure Scheme for Small and Medium Towns (MoEF, 2012). However, operation and maintenance of sewerage infrastructure including treatment plants are responsibilities of State governments/urban local bodies and their agencies. As per Water Act 1974, State Pollution Control Boards possesses statutory power to take action against any defaulting agency. Water Act 1974 also emphasizes utilization of treated sewage in irrigation, but this issue has been ignored by the State Governments.

Ministry of Environment and Forests (MoEF), Govt. of India initiated a technical and financial support scheme to promote common facilities for treatment of effluents generated from SSI units located in clusters. Under the Common Effluent Treatment Plant (CETP) financial assistance scheme, 50% subsidy on project capital cost - 25% share each of Central and State Governments - was provided. As a result, 88 CETPs having total capacity of 560 MLD have been set up throughout India covering more than 10,000 polluting industries (CPCB, 2005b).

V. RESEARCH/PRACTICE ON DIFFERENT ASPECTS OF WASTEWATER:

Wastewater treatment systems

Bio-refineries wastewater treatment

Bio-refineries for the production of fuel ethanol produce large volumes of highly polluted effluents. Anaerobic digestion is usually applied as a first treatment step for such highly loaded wastewaters. At present, the anaerobic biological treatment of bio-refinery effluents is widely applied as an effective step in removing 90% of the Chemical Oxygen Demand (COD) in the effluent stream. During this stage, 80–90% BOD removal takes place and biochemical energy recovered is 85–90% as biogas (Pant and Adholeya, 2007; Satyawali and Balakrishnan, 2008). To reduce the BOD to acceptable standards, the effluent from an anaerobic digestion step requires further aerobic treatment. However, biological treatment processes alone are not sufficient to meet tightening environmental regulations (Pant and Adholeya, 2007). A proper choice of tertiary treatment can further reduce color and residual COD.

Yet another approach is to use algae. The advantage of wastewater treatment using algae is that one can reduce the organic and inorganic loads, increase dissolved oxygen levels, mitigate CO₂ pollution and generate valuable biomass by sequential use of heterotrophic and autotrophic algal species and the generated biomass can be an excellent source of ‘organic’ fertilizers. As documented in studies on eutrophication, algae are known to thrive under very high concentrations of inorganic nitrates and phosphates that are otherwise toxic to other organisms. This particular aspect of algae can help remediate highly polluted wastewaters.

Municipal wastewater treatment using constructed wetlands

Constructed wetlands (CWs) are a viable treatment alternative for municipal wastewater, and numerous studies on their performance in municipal water treatment have been conducted. A good design constructed wetland should be able to maintain the wetland hydraulics, namely the hydraulic loading rates (HLR) and the hydraulic retention time (HRT), as it affects the treatment performance of a wetland (Kadlec and Wallace, 2009). Indian experience with constructed wetland systems is mostly on an experimental scale, treating different kinds of wastewater (Juwarkar et al., 1995; Billore et al., 1999, 2001, 2002; Jayakumar and Dandigi, 2002). One of the major constraints to field-scale constructed wetland systems in developing countries like India is the requirement of a relatively large land area that is not readily available. Subsurface (horizontal/ vertical) flow systems, generally associated with about a 100 times smaller size range and 3 times smaller HRTs (generally 2.9 days) than the surface flow systems (with about 9.3 days HRT, Kadlec, 2009), are therefore being considered to be the more suitable options for the developing countries. Shorter HRTs generally translate into smaller land requirement. Batch flow systems, with decreased detention time, have been reported to be associated with lower treatment area and higher pollutant removal efficiency (Kaur et al., 2012a, b). Thus, batch-fed vertical sub-surface flow wetlands seem to have an implication for better acceptability under Indian conditions.

Wastewater application methods

Farm workers and their families practicing furrow or flood waste water irrigation techniques are at the highest risk. Spray/sprinkler irrigation leads to the highest potential deposit of the salts, pathogens and other pollutants on the crop surfaces and affects nearby communities. Drip irrigation is the safest irrigation method but suffers from clogging of the emitters, depending on the wastewater total suspended solid concentrations. Use of appropriate filters such as gravel, screen and disk filters in combination with drip systems has been observed to tremendously reduce the clogging and coliform incidence (Tripathi *et al.*, 2011).



Post-harvest interventions

Post-harvest interventions are an important component for health-risk reduction of wastewater-irrigated crops and are of particular importance to address possible on-farm pre-contamination, and also contamination that may occur after the crops leave the farm. The health hazards could be markedly lowered with adoption of some of the low cost practices such as repeated washings, exposure of the produce to sunlight and raising the crops on beds, removing the two outmost leaves of cabbage and also, cutting above some height from ground level (0.10 m; Minhas *et al.*, 2006).

VI. STATUS AND NEED FOR THE KNOWLEDGE AND SKILLS ON THE SAFE USE OF WASTEWATER

Wastewater is more saline due to dissolved solids originating in urban areas, and concentrated further through high evaporation in arid and tropical climates. Heavy use of wastewater in agriculture may cause salinity problem and can decline the land productivity. Excessive industrial release to the environment can lead to a buildup of toxic pollutants, which can in turn encourage the overgrowth of weeds, algae, and cyanobacteria and deteriorate groundwater and downstream water quality.

VI. CONCLUSIONS AND/OR IMPORTANT INFORMATION ON THE SUBJECT NOT COVERED ABOVE:

In developing countries like India, the problems associated with wastewater reuse arise from its lack of treatment. The challenge thus is to find such low-cost, low-tech, user friendly methods, which on one hand avoid threatening our substantial wastewater dependent livelihoods and on the other hand protect degradation of our valuable natural resources. The use of constructed wetlands is now being recognized as an efficient technology for wastewater treatment. Compared to the conventional treatment systems, constructed wetlands need lesser material and energy, are easily operated, have no sludge disposal problems and can be maintained by untrained personnel. Further these systems have lower construction, maintenance and operation costs as these are driven by natural energies of sun, wind, soil, microorganisms, plants and animals.

Hence, for planned, strategic, safe and sustainable use of wastewaters there seems to be a need for policy decisions and coherent programs encompassing low-cost decentralized waste water treatment technologies, bio-filters, efficient microbial strains, and organic / inorganic amendments, appropriate crops/ cropping systems, cultivation of remunerative non-edible crops and modern sewage water application methods