Wastewater production, treatment and use in India

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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.

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 m^3 to 1869 m^3, in 2001 and 1588 m^3, in 2010. It is expected to further reduce to 1341 m^3 in 2025 and

1140 m^3 in 2050. Hence, there is an urgent need for efficient water resource management through enhanced water use efficiency and waste water recycling.

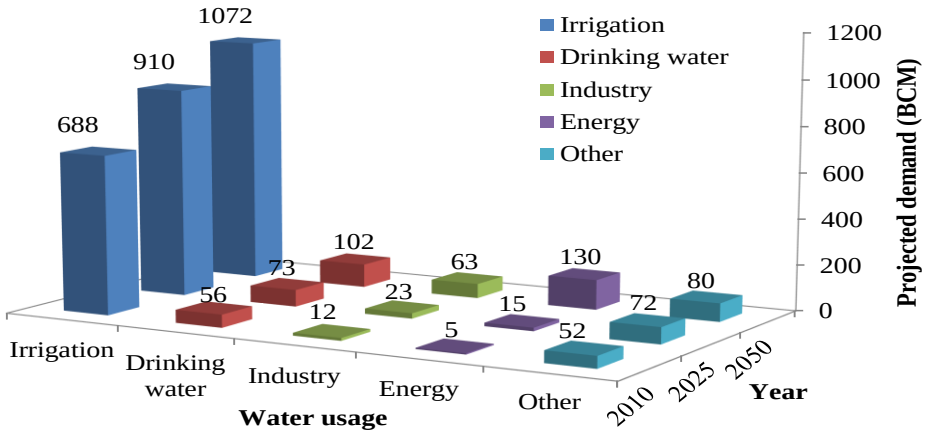

Figure 1: Projected water demand by different sectors (CWC, 2010)

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 m^3) is the lowest (i.e. just 3.42) and about $1/30^{th}$ 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.

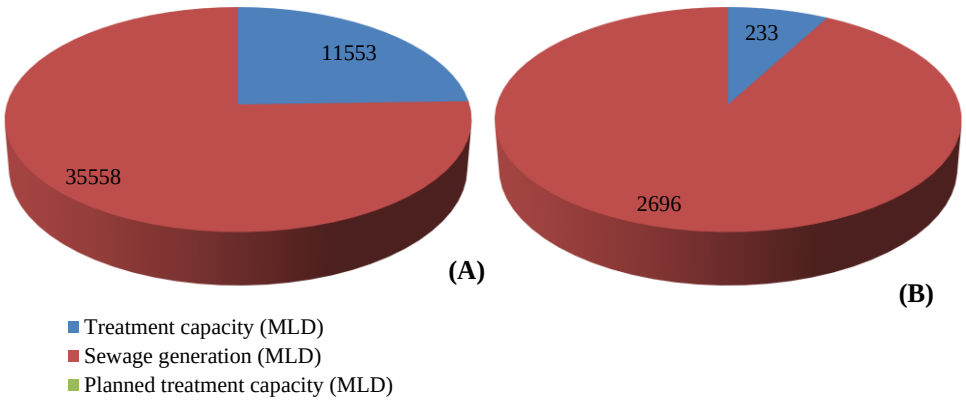

Figure 2: Sewage generation and treatment capacity in 498 Class I cities and 410 class II towns in India. (CPCB, 2009)

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 settable 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.

The conventional wastewater treatment processes are expensive and require complex operations and maintenance. It is estimated that the total cost for establishing treatment system for the entire domestic wastewater is around Rs. 7,560 crores (CPCB, 2005a), which is about 10 times the amount which the Indian government plans to spend (Kumar, 2003). Table 1 illustrates the economics of different levels of treatments through conventional measures (CPCB, 2007b). The sludge removal, treatment and handling have been observed to be the most neglected areas in the operation of the sewage treatment plants (STPs) in India. Due to improper design, poor maintenance, frequent electricity break downs and lack of technical man power, the facilities constructed to treat wastewater do not function properly and remain closed most of the time (CPCB, 2007b). Utilization of biogas generated from UASB reactors or sludge digesters is also not adequate in most of the cases. In some cases the gas generated is

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

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:

- Cereals: Along 10 km stretch of the Musi River (Hyderabad, Andhra Pradesh) where wastewater from Hyderabad is disposed-off, 2100 ha land is irrigated with waste water to cultivate paddy. Wheat is irrigated with waste water in Ahmedabad and Kanpur.
- Vegetables: In New Delhi, various vegetables are cultivated on 1700 ha land irrigated with wastewater in area around Keshopur and Okhla STPs. Vegetables like Cucurbits, eggplant, okra, and coriander in the summers; Spinach, mustard, cauliflower, and cabbage in the winters are grown at these place. In Hyderabad, vegetables are grown in Musi river basin all year round which includes spinach, amaranths, mint, coriander, etc.
- Flowers: Farmers in Kanpur grow roses and marigold with wastewater. In Hyderabad, the farmers cultivating Jasmine through wastewater.
- Avenue trees and parks: In Hyderabad, secondary treated wastewater is used to irrigate public parks and avenue trees.
- Fodder crops: In Hyderabad, along the Musi River about 10,000 ha of land is irrigated with wastewater to cultivate paragrass, a kind of fodder grass.
- Aquaculture: The East Kolkata sewage fisheries are the largest single wastewater use system in aquaculture in the world.
- Agroforestry: In the villages near Hubli-Dharwad in Karnataka, plantation trees viz., sapota, guava, coconut, mango, arecanut, teak, neem, banana, ramphal, curry leaf, pomegranate, lemon, galimara, mulberry, etc. are irrigated with waste water.

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).

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

(Management and Handling) Rules, 1989; Municipalities Act; District Municipalities Act etc..

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).

In addition to setting up treatment plants, Central Government, State Government and the Board have given fiscal incentives to industries/investors to encourage them to invest in pollution control. Incentives/ concessions available to them are:

- Depreciation allowance at a higher rate is allowed on devices and systems installed for minimising pollution or for conservation of natural resources.
- Investment allowance at a higher rate is allowed for systems and devices listed under depreciation allowance.
- To reduce pollution and to decongest cities, industries are encouraged to shift from urban areas. Capital gains arising from transfer of buildings or lands used for the business are exempted from tax if these are used for acquiring lands or constructing building for the purpose of shifting business to a new place.
- Reduction in central excise duty for procuring the pollution control equipments.
- Subsidies to industries subject for installation pollution control devices.
- Rebate on cess due on water consumed by industries, if the industry successfully commissions an effluent treatment plant and so long as it functions effectively.
- Distribution of awards to industries based on their pollution control activities.
- Amount paid by a tax payer, to any association or institution implementing programmes for conservation of natural resources, is allowed to be deducted while computing income tax.
- Customs duty exemption is granted by the Central Government for items imported to improve safety and pollution control in chemical industries

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 CO_2 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).

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.

Types of crops that farmers can raise are affected by the wastewater quality and the prevailing climatic conditions. In arid and semiarid regions, high evaporation rates cause wastewater to be more saline and thus calls for the cultivation of salt tolerant crops and varieties. As many fodder crops are salt tolerant therefore use of wastewater for fodder production in urban and peri-urban areas, particularly having urban demand for dairy products, may be encouraged. However, the health of the livestock fed on the wastewater irrigated fodder may be seriously impaired (as currently in Hyderabad) and the quality of milk may be affected with the consequent transference of the danger to the humans.

Wastewater is also a rich source of plant nutrients, therefore soils irrigated with wastewater are enriched in nutrients. Hence, doses of fertilizers to be applied should be adjusted according to the nutrient contents in wastewater, amount of wastewater to be applied and crop nutrient requirement. Soil testing should also be carried on regular basis to check imbalanced nutrition or soil sickness.

Stopping irrigation 1–2 weeks before harvest can effectively reduce crop contamination. However, this is difficult to implement because many vegetables (especially leafy

vegetables) need watering up to the point of harvest to increase their market value. This technique may be possible for some fodder crops that do not have to be harvested at the peak of their freshness.

Under the situations where land has already been contaminated and food crops are not permitted; alternate land uses like establishment of manmade forests with high economic value and having high rate transpiring trees like sisal, mahogany, Eucalyptus, poplar, bamboo, neem (*Azadirachta indica*), shisham (*Dalbergia sissoo*) etc. for non-edible products like fuel and timber and developing green belts around the cities can be another approach to overcome health hazards. Under such systems, the quality of groundwater has been observed to be not affected by effluent applications and the heavy metals in soil have also been observed to be low. Biochemical oxygen demand removal efficiency of tree plantations has also been observed to be 80.0 to 94.3% (Thawale *et al*., 2006). Hence, based on varying water demand in different seasons, area to be brought under high rate transpiration systems may be evolved.

Crops vary in terms of tolerance to heavy metal concentration in soil. They also differ in terms of metal affinities and accumulation of assimilated heavy metals in different plant parts. Thus crops should be selected in such a way that they can tolerate the given toxic constituents of wastewater and accumulate in plant part which is of least importance or not consumed.

Depending upon the quantity and quality of the wastewater available for use, appropriate combination of wood trees, fruit trees, fodder, industrial crops and cereals should be formulated. Wastewater use in public park, golf course, green belts and tree plantation should be promoted.

Farmers should be encouraged to adopt modern methods of irrigation like drip. Combinations of emitter size, placements and filtration units need to be found for wastewater of different qualities for its better management.

Efficient strains of microbes for wastewater remediation should be searched out and applied at field scale.

Increased funding may be provided for research to design efficient, cost-effective, and sustainable natural wastewater treatment systems that conserve nutrients while effectively removing pathogens and other pollutants.

Similarly more research needs to be conducted to find remunerative crops with non-edible economic part to avoid food chain contamination and better phyto-remediation of polluted sites.

Socio-economic characteristics as caste, class, ethnicity, gender and land tenure influence the type of wastewater-dependent livelihood activities. Thus research needs to be participatory, and account for farmers' concerns, perceptions, and practices, if the research results are to be implemented in a sustainable fashion. Both socio-economic and bio-chemo-physical data must be collected through field surveys, water, soil and

plant sampling and analysis, group discussions, in-depth interviews with users, researchers and policy makers for the formulation of the practical policies.

Farmers should be made aware to use fresh water for washing the produce before taking to the market. Consumers should also resort to sufficient washing and cooking to reduce pathogen load.

Regular health checks and administration of antihelmintic drugs and awareness campaign should be carried to educate the farmers, consumers and policy makers about wastewater issues and impacts.

Indigenous technical knowledge (ITK), local knowledge'' and "Traditional Knowledge should also be properly documented for safe and sustainable wastewater use.

In this context, a consortium of research institutes and industries will help in identifying efficient wastewater utilizing and treatment methodologies. This co-creation process will boost the business development in the field of bio-treatment, wastewater re-use, and agricultural innovations to reduce the water footprint. It would also integrate the role of co-learning, links between traditional and industrial agri-production systems, better utilization from market opportunities and would further facilitate researchers and project partners to conduct science based research on wastewater treatment and its management thereby leading to the opening-up of the various avenues for low cost and long term sustainable up-scaling processes.

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.

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