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Significance of natural treatment systems to enhance reuse of treated effluent: A critical assessment

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ABSTRACT

This paper summarizes the results of the recently completed India-wide survey of 108 wastewater treatment facilities based on natural treatment systems (NTSs) engaged in wastewater treatment and reuse. During assessment of NTSs, a questionnaire survey was administered for collection of vital data on the shortlisted 41 treatment facilities – especially to obtain insights about the technical, economical and social issues influencing the success and failure of the given facility. Further, five case studies based on the most commonly practiced NTSs were selected for in-depth evaluation and the critical issues including effectiveness of technology and the socioeconomic aspects were studied. The treatment performance of these systems was assessed for one year by collecting primary data during January, June and August corresponding to the three seasons *viz.* winter, summer and monsoon. The effectiveness of the facilities was assessed in terms of percentage removals as well as the mass removal rate for commonly used parameters.

As of today, the total load of sewges including sullages serviced by NTSs in India adds up to be around 1838 million liters a day. The most commonly practiced NTS in India has been the waste stabilization ponds (74 facilities) when compared with the phyto-remediation based systems (19 facilities) followed by the polishing ponds (15 facilities). Among the 41 facilities, nearly 75% facilities were compliant and managed to produce treated sewages suitable for irrigation, discharged into wastewater canals or percolated in the riparian zone of the river. All the five systems that were selected for in-depth evaluation were found compliant during assessment. Also, two facilities (Sewage-fed Aquaculture Karnal and Duckweed Pond Ludhiana) were found to be operating on the public private partnership model and generating revenue for operation and maintenance along with ample benefits to the operating agencies. The study also reveals the associated socioeconomic benefits of various practiced NTSs. Finally, strategies for achieving improved performance of NTSs were articulated – especially focusing the potential for recycling and reusing of treated wastewaters.

1. Introduction

The *Water (Prevention and Control of Pollution) Act* was promulgated in the year 1974 in India to address wastewater treatment and disposal-related challenges faced by the then India. One of the challenges in those days was associated with regulating disposal of the sewages and industrial trade effluents in the nearby receiving bodies including lakes, rivers, estuaries, creak as well as in the ocean (Asolekar et al., 2013). Several landlocked areas did not have opportunities to dispose their treated effluents in surface waters and they demanded permits for disposal of on-land or for irrigation using treated effluents either in agriculture or in commercial agro-forestry (Arceivala and Asolekar, 2006). Clearly, two decisions were critical in that context. First, the regulatory agencies (Central Pollution Control Board governed by the Ministry of Environment and Forests, Government of India or by the State Pollution Control Boards in respective states in the Union of India) were expected to decide what would constitute "expectable receiving body of water" suitable for disposal of treated sewages and effluents (Arceivala and Asolekar, 2012). Second, it was equally important to articulate and legally notify the minimum quality standards for treated sewages and industrial effluents that shall be deemed fit for disposal in the legal receiving water bodies (Asolekar et al., 2015; Gopichandran et al., 2015).

Tables turned, in the today's context (after nearly 40 years) the number of challenges associated with disposal of treated sewages

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and effluents has gowned multi-fold. Today the third important consideration has entered the fray. Nearly every community is thirsty for potable as well as process waters. It has not been possible for communities living in the slums to get even 10 l of water per person per day. Both, quality and quantity of water available for drinking and sanitation, industrial applications, commercial purposes, including construction as well for irrigation are in short supply (Arceivala and Asolekar, 2012). On one hand, there is an escalating demand for water for domestic, agriculture, as well as industrial purposes. On the other hand, the available water is being deteriorated as a result of a disposal of domestic and industrial effluents.

The conventional mechanised systems turn out to be rather expensive in terms of, both, the installation as well as operation and maintenance (O&M) costs (Matamoros and Salvadó, 2012; Avila et al., 2013; Reddy et al., 2014). It has been estimated that the energy used in the conventional wastewater treatment systems is around one fifth of a municipality's total energy used by public utilities, and it may continue to rise by 20% in the next 15 years on account of increase in water consumption and implementation of further stringent regulations (Meneses et al., 2010; Mo and Zhang, 2012). For example, the energy footprint becomes nearly double if the outlet BOD value decreases from 30 mg/L to 15 mg/L (Singh et al., 2016). Further, it is now recognized that the conventional wastewater treatment systems, including activated sludge processes, up-flow anaerobic sludge blanket reactors, trickling filters are efficient in removing carbonaceous pollutants, but unable to reduce the nutrients effectively, particularly nitrogen and phosphorus (Arceivala and Asolekar, 2006; Wu et al., 2011). It is therefore argued here that the newer solutions should be such that the *peri*-urban and small communities should be able to own and operate their wastewater treatment systems. This strategy precisely has been reshaping the face of sewage treatment and management in India in the recent times.

A class of sewage treatment technologies that mimics natural processes such as interaction of soil-micro-organisms with pollutants as well as interaction of plants and other life in natural settings with pollutants in wastewaters are called as natural treatment systems (NTSs). It is well known that the engineered natural treatment systems render quite effective environmental services by treating biodegradable carbonaceous pollutants and by separating suspended loads of particulates (Reinhold et al., 2010). This class of treatment systems typically incorporate river banks, wet-zones and their modified versions such as constructed wetlands (CWs), waste stabilization ponds (WSPs), sewage-fed aquaculture ponds, hyacinth and duckweed ponds, oxidation ponds, algal-bacterial ponds, lemna ponds, polishing ponds, Karnal Technology (KT) for on-land disposal of wastewater *etc* (Chaturvedi et al., 2014).

In addition, NTSs have attracted attention of environmental engineers and scientists by the virtue of treating sewages and wastewaters at phenomenally low O&M costs and yet render higher degree of treatment as compared with conventional mechanised treatment systems (Brix, 1994; Zimmels et al., 2008; Rana et al., 2011; Symonds et al., 2014). Ideally, the use of natural treatment systems like constructed wetlands has potential in contributing to sustainability as they rely on non-energy processes that return nutrients to the surrounding environment (Chen et al., 2006; Muga and Mihelcic, 2008). More importantly, the provision of implementing appropriate the waste management system is not only an indicator of development, but also of a broader sustainability (Emongor et al., 2015).

In India, temperate climate conditions and land availability have proven as a boon in selection of NTSs as an appropriate technological solution for cost-effective management of wastewaters. In this framework, the Indian Government has implemented more than one hundred NTSs for wastewater treatment and reuse across the Nation. Interestingly, in the recent past, communities in India seem to accept the NTSs that are capable of giving adequate treatment to wastewaters (CPCB, 2009; Starkl et al., 2013) in conjunction with supplementing fish and nutrition to the food baskets of the fishing communities engaged in managing the systems (Kumar et al., 2015a) as well as by generating adequate water for irrigation of farms and agro-forests (Starkl et al., 2015a). However, the studies published in the Indian context lack in critical assessment of the prevailing treatment facilities in India – especially about the strengths, limitations, typologies of success as well as the factors influencing reuse of treated effluents (Starkl et al., 2015b).

This paper presents the results from the recently concluded India-wide survey of 108 wastewater treatment facilities based on NTSs engaged in wastewater treatment and reuse. Among the several facilities existing in India, based on CWs and other NTSs, the present study addresses only the engineered systems that are at least partially successful in treating and recycling the domestic wastewaters. Efforts have been made to identify gaps between sewage generation and installed treatment capacities, hydraulic loading, compliance status and overall performance for wastewater treatment, typologies of success and failure of the facilities and needs of post-treatment of the treated effluents.

Based on this compressive study, gaps in understanding of the current state-of-art as well as strategies for achieving improved performance of NTSs were articulated – especially focusing the potential for recycling and reusing of treated effluents in the Indian context. Finally, five case studies on NTSs have also been included to highlight the significance of the critical issues including effectiveness of technology and the socioeconomic aspects.

2. Methodology of survey and data collection

The field surveys were carried out in three phases to assess the potential of existing constructed wetlands (CWs) and other natural treatment systems (NTSs) which are currently operated for wastewater treatment and reuse in India. In the first phase, a list of engineered NTSs was prepared after discussing with the various water and wastewater practitioners as well as governing and regulatory bodies, including state pollution control boards, public health engineering departments of different states, and water and sewerage boards. This India-wide reconnaissance survey was aimed at identifying those wastewater treatment systems based on NTSs in general and CWs in particular that are at least partially successful in treating and recycling the domestic wastewaters.

During the second phase of assessment, 41 sites were shortlisted from the 108 sites analysed in the reconnaissance survey (phase 1). A questionnaire survey was administered at the outset of this phase and vital data were collected on the shortlisted 41 treatment facilities – especially to obtain insights about the technical, economic and social issues influencing the success and failure of the given facility. Each of these sites was visited three times over the period of 18 months and secondary data were collected by interviewing the operating staff as well as by accessing their log books and progress reports with the help of the respective personnel. The second phase of assessment was helpful in summarizing the overall performance as well as various issues associated with NTSs. In addition, interviews were conducted with farmers and community representatives to evaluate the adequacy of quality of treated effluents for designated recycling application, including any undesirable experiences during the course of handing of treated wastewaters. Also, the associated cost-benefit analyses were conducted in comparison with using bore-well water for irrigation.

In the third phase of the survey, five NTS-based sewage treatment facilities were selected for further in-depth assessment by collecting wastewater samples to assess the quality of raw and