Centralised Vs. Decentralised Wastewater Systems

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ABSTRACT

Urban waste management systems are being increasingly transformed from a disposal-based linear system to a recovery-based closed-loop system that promotes the conservation of water and nutrient resources thereby contributing to sustainable development. The current manuscript compares the decentralized and centralized approaches to wastewater systems by citing several studies that have listed various well defined criteria to choose decentralized systems over centralized systems. The manuscript also lists recommendations for decentralised systems as mandated by CPCB.

INTRODUCTION

Urban waste management systems are being increasingly transformed from a disposal-based linear system to a recovery-based closed-loop system that promotes the conservation of water and nutrient resources thereby contributing to sustainable development. According to Qasim (1999), 'a cost-effective [waste-water treatment] solution is one that will minimize total costs of the resources over the life of the treatment facility. Resources are not only the capital, operation and maintenance costs, but also social and environmental costs. Benefits from sludge and effluent reuse must also be included in the feasibility study.

The main component of domestic wastewater management of any city consists of collection, treatment and disposal. In conventional centralized sewage treatment system (Wilderer 2001), about 80% of the cost is accounted for the collection alone (CPCB newsletter).

The other major component namely treatment, can involve a number of processing stages, depending on the quantity and quality of the wastewater source. The current challenge is the financially realistic implementation of new and highly effective, but cost and energy intensive, treatment technologies (Sægrov et al., 1999).

Centralised Vs Decentralised Approach to Wastewater Systems

The origins of municipal wastewater treatment dictated a centralized treatment approach. The drivers for centralized water treatment included centralized municipal governance, economies of scale, knowledge of water treatment methods and limited ability for remote monitoring and control.

To maximize the use of reclaimed water in a centralized system, water transfer and distribution pipelines have to be constructed for reclaimed water supply, if the benefit of reclaimed water is to reach the customers which are generally dispersed in the city area. As was the case with wastewater collection system, the construction as well as the operation cost for the transfer and distribution pipelines for reclaimed water often becomes more expensive than the construction cost for the treatment facility itself.

Such a shortcoming of the centralized system has restricted the utilization of available reclaimed water in many cases, because both the government which is promoting wastewater reuse and the users who are willing to use the reclaimed water, look forward to a price for the reclaimed water to be much cheaper than the tap/ fresh water. In fact, in order to promote wastewater reuse, a number of cities have set the selling price of the reclaimed water at a very low level, no matter how much is spent for its production, and the government is providing subsidies for the business. However, this may not be a sustainable way for wastewater reuse. Moreover, the cost of collection of sewage and its conveyance to one terminal point in the larger cities is very high. Further, the depth of

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sewer goes on increasing with the increase in length of sewer line and pumping of the sewage is usually required at intermediate and terminal points which are energy intensive propositions.

Owing to the above stated limitations, "decentralized" systems for wastewater treatment and reuse are drawing attention widely (Fane et al. 2002; Wang 2007). Such a system stresses onsite wastewater treatment and onsite reuse. Therefore, construction of a long distance transfer pipeline and a large scale distribution network for the reclaimed water may no longer be necessary. Promoting the development of decentralized wastewater treatment and recovery technologies would result in small-scale facilities equally dispersed through environment. This approach would allow for independent, self maintained, and self sustained facilities that are capable of recovering wastewater resources.

As per the concept of "polluter pays", every polluter should accept the burden of wastewater treatment. In the decentralized treatment system, a balance between the advantages of large scale treatment in terms of economics of scale and individual responsibility for domestic wastewater treatment can be obtained by providing colony wise/sector wise treatment system.

Most recently the term ecological engineering has been used in describing the treatment of waste water in ecologically based "green machines" or "living machines". The development of solar technologies and an increased understanding of the role of organisms in wastewater purification process is providing both economic (owing to their significantly less energy/ maintenance requirements) and environmental benefits. Such Natural treatment technologies are considered viable because of their low capital costs, their cost of maintenance, their potentially long life cycle compared to electro- mechanical solution and their ability to recover a variety of resources.

Although the cost observed for wastewater treatment for a resident of a smaller population serviced by a treatment plant capacity of less than 9.8 MGD (less than 37 x 103 m3) is much higher ($0.10–$1.24) than a resident of a larger population serviced by a larger plant capacity (greater than 187 MGD or 708 x 103 m3) using similar treatment systems (Raftelis Financial Consulting, 2004), even when normalized on a per capita basis; Cost-effective treatment technologies such as lagoon and land treatment systems have the potential to reduce these costs by at least one-half (reduced costs to the order of US$100 per household) (Helmer and Hespanbol, 1997).

However, these technologies have significantly more spatial footprint. Proposing these in a centralized manner for urban growth centers spread over vast geographical zones would require immense spatial footprint.

Mechanised or conventional treatment systems are efficient, in terms of their spatial requirements (0.5-1 m^2 / Person Equivalent, PE - compared to natural treatment systems at 5-10 m2/ PE as reported in CPCB newsletter), but depend on economies of scale to make them economically feasible. Electro-mechanical wastewater treatment technologies designed to remove high levels of biological oxygen demand (BOD) are not only huge capital investments, but also pose certain dilemmas if reuse of treated effluents is to be an option. Conventional, aerobic, treatment results in maximum reductions in BOD and nutrients while it is desirable to retain biomass BOD and nutrients for agricultural production. Often, the removal of pathogens requires chemical inputs to meet disinfection guidelines, which increases the operation cost and complexity of the system. Dependence on chemical disinfection also complicates effluent reuse in non-restricted irrigation schemes when compared to low-cost solutions such as wastewater stabilization ponds (WSP), which are economical, produce similar reductions in BOD, nutrients, and greater pathogen reduction, but at a fraction of the cost.

According to the World Bank, "The greatest challenge in the water and sanitation sector over the next two decades will be the implementation of low cost sewage treatment that will at the same time permit selective reuse of treated effluents for agricultural and industrial purposes" (Looker, 1998). Decentralized, organic waste recovery systems that integrate the best available low-technology in the recovery of urban domestic wastewater flows are essential and appropriate components in the promotion of a comprehensive urban ecosystem health strategy.

Decentralized systems can effectively deploy distributed technologies which can be used to provide redundancy in case of component failure (e.g., Nieuwenhuis et al., 1993; Verma and Tamhankar, 1997). Centralization causes the concentration of large flows in one pipe, lifting station or treatment plant, so that any mishap would have far-reaching consequences. In a decentralized concept system, the flows remain comparably small at any point, therefore causing only comparatively small environmental damage in case of failure (GTZ, 2001). With the hardware systems decentralized, there would be no reason to impose a "one size fits all" management approach. Moreover, the collection system planned in decentralized way consist of shorter runs of smaller pipes containing fewer openings, implying far less potential for infiltration to and losses from the piping system as well as overflows.

The ideal scenario is when returns to scale approach unity (unit processing or treatment cost is equivalent across all systems sizes) and financial efficiency exists due to the ability to provide selective treatment, such as in energy cogeneration (Strachan and Dowlatabadi, 2002). Such systems can be further used to enhance delivery efficiency by providing temporary storage locations (Burns et al., 2002) or as dampers to the peak/ lean fluctuations. The demand for system extension can be met by integrating new treatment centers rather than by routing a continually increasing flow to existing facilities (GTZ, 2001).

Decentralized systems can effectively provide distributed technologies to highly customizable products or processes desired by the end consumer (Sull, 1998; Bagajewicz, 2000; Schoop et al., 2001). Treatment and reuse can be "tailored" to the waste stream. The industry can be asked to implement treatment methods specific to their wastewater characteristics and reuse opportunities (GTZ, 2001). Non-centralized systems are more flexible and can adapt easily to the local conditions of the urban area as well as grow with the community as its population increases (Schertenlieb, 2000). This approach leads to treatment and reuse of water, nutrients, and byproducts of the technology (i.e. energy, sludge, and mineralized nutrients) in the direct location of the settlement.

Centralized Wastewater Treatment has been documented to pose a higher risk of contamination of water downstream, causing public health hazards if treatment has a low efficiency and contaminated sludge due to challenges in separating out the contaminated industrial wastewaters (Rose, 1999)

Finally, decentralized systems can work more efficiently when the delivery process is not efficient enough to maintain a quality standard, such as in electrical power distribution (El-Khattam et al., 2003).

As documented in a report by GTZ (2001), the decentralized concept is easier to plan and finance. Each project is small compared to the typical "regional" concept. The management needs of each area or new development are considered separately and can be implemented independently. Many of the costs can be privatized or assigned directly to the activity generating new financial demands on a much fairer basis. Capacity expansion and therefore capital requirements can track demand much more closely, thus minimizing the amount of money spent to construct facilities which will not be used to capacity for years to come, as it frequently occurs in conventional, centralized systems. Different strategies can be employed in various zones, responding in the most fiscally efficient and environmentally responsible manner to each set of circumstances.

Moreover, decentralized systems can aptly fulfill the following criteria as defined for sustainability in the treatment of wastewater (van Lier, 1998)

- Maximum of recovery and re-use of treated water and by-products obtained from the pollution substances. (i.e. irrigation, fertilization)

- Acceptable for the local population.

Several studies have listed various well defined criteria to choose decentralized systems over centralized systems. For example, Wang et al., 2008, introduced the concept of System selection by introduction of a "critical distance". If we consider the distance from the housing development/ industrial complex requiring reclaimed water to the access point of the centralized reclaimed water supply system and denote it as L. It is considered that the cost for the construction of a pipeline to the access point will depend on both L and the design flow rate Q which corresponds to the demand for reclaimed water. On the other hand, if a decentralized wastewater treatment and reuse (DESAR) system is installed, the cost for its construction will only depend on Q. Therefore, under a given Q, there should be a distance L0 at which the cost for pipeline construction equals to that for DESAR system installation. L0 can be called the "critical distance". If L is less than L0 then using reclaimed water from the centralized system is economically more feasible, and if L is more than L0 then DESAR system is economically more feasible. This simple comparison is under an assumption that the tariff of the reclaimed water is about the same as the cost for water reclamation from the DESAR system. The housing development project sites within the circled areas belong to the category of L is less than L0 and using reclaimed water from the centralized system is considered to be more feasible, while those outside the circled areas belong to the category of L is more than L0 and DESAR system installation is considered to be more feasible.

Recommendations for Decentralised systems as Mandated by CPCB

To propagate the concept of Decentralized Sewage Treatment System in the country a national workshop was organized by CPCB on 24th January 2003. The recommendations of the workshop are as follows:

Policy and Rules for Promoting Decentralized Sewage Treatment System (DTS)

1. In view of the critical problem of increasing contamination of surface and groundwater and of the solid-mantle due to untreated or inadequately treated wastewaters and the unsatisfactory performance of the Municipalities in handling the problems of existing dwellings, all new housing constructions should provide for appropriate treatment, recycling, reuse or disposal of the wastewater generated by them. This could be on the basis of a colony, co-operative group of houses or individual houses. The proposals should be cleared by the Municipal and Pollution Control Authorities who would also be responsible for monitoring after commissioning of the system.

2. Consent to establish to be made mandatory for new townships or residential colonies, on the line of industry.

3. Use of EIA/EMP tool for township and residential colonies also to be encouraged.

4. For new piped water supply project, corresponding capacity of sewage treatment in terms of Decentralized Treatment System (DTS) or augmentation of STP capacity should be associated as part of the project.

5. Special standards for DTS under the Environment (Protection) Act, 1986/ the Water (Prevention & Control of Pollution) Act, 1974 may be considered.

6. Provision for DTS by developers may find place in Municipal bylaws and Municipal Act.

7. Town planning in respect of sewerage and drainage network should be planned in such a way that it has scope for DTS.

8. Decentralized treatment should form part of development plan for all new settlement programme.

9. The designers and builders for sewerage/drainage systems should be made responsible for the treatment & utilization of wastewaters on long-term basis.

10. AICTE may consider including courses on DTS, Diffused Pollution Control, Environmental Protection and Pollution Control Rules & regulations in Degree & Diploma curricula.

Economic Incentives for DTS

1. Price for water supply may have two components

   a. For fresh water supply; and

   b. For sewage treatment.

   And the community which has DTS may be supplied water at lower cost.

2. The Resident Welfare Associations (RWAs) should be made responsible for operation and maintenance (O & M) of DTS and should be given rebate in House Tax.

3. In the absence of clear policy framework from the

government for DTS and since the recycling of treated wastewater only partially meets the O & M costs, the onus of meeting the O & M costs rests with public/people who set up DTS in colonies. The government in such a situation should provide immediate rebate in property/house tax for those participating in DTS in order to promote DTS.

4. Land development charges levied has a component for sewerage network, which should be kept separate and be spent on DTS or centralized STP.

Demonstration Projects, Documentation and Dissemination

1. Demonstration plants using onsite DTS should be promoted/funded throughout the country for which progressive builders and Resident Welfare Associations may show the way.

2. Pilot and nodal schemes should be promoted by MoEF/CPCB.

3. The development authority like DDA may install DTS at two colonies. Based on the experience, policy may be made for implementation in other colonies in future.

4. Mass awareness and public participation needs to be promoted.

5. Documentation and dissemination of case studies/ practical experiences need to be taken up on a wider scale.

6. Advertisement in Press and on Television, Radio for Environment friendly sewage treatment for all housing colonies should be planned in such a way that it has scope for DTS.

Technology and Operation & Maintenance

1. Sewage fed lakes/ponds in urban centers may be converted to DTS so that water quality of lakes and ponds are improved.

2. Proper operation and maintenance of DTS to increase the social acceptance.

3. 'Polluters Pay Principle' should be adopted for O & M of the treatment plants.

4. Segregation & reuse of wastewater at household level be encouraged.

5. Resource recovery like energy should be part of technology to make the system sustainable.

6. Technology selection should be on case-to-case basis.

7. The decentralized treatment plant construction and O & M responsibility should be given to specialist agencies that can take the responsibility for technology risk.

8. People who contribute wastewater should be a party right from planning, construction to operation & maintenance.

SUMMARY AND CONCLUSIONS

Considerable work has been done to optimize the location of decentralized systems (Galan and Grossmann, 1998; Bagajewicz, 2000; Wang et al., 2008). However, most of these efforts were driven by the inherent efficiency of treating specific waste streams with specific treatment methods. No work has been performed on finding a balance between centralized and decentralized systems.

Decentralized concepts cannot be the solution to all wastewater management problems, there will always be specific cases where centralized treatment plants are more appropriate. Still, the many potential benefits of the decentralized strategy indicate that it is a method which deserves greater attention, especially in smaller communities and the developing urban fringe. Most of the barriers to broader implementation of the decentralized concept are clearly institutional rather than technical. These matters command the attention of policymakers, regulators, operating authorities, engineers, developers and interested members of the public. Given the water resource challenges encountered in many parts of the world, it is time to engage in a rational analysis of all possible management strategies, not merely those accepted as "conventional wisdom".

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