Tropical Agricultural Research Vol. 22 (2): 154 - 164 (2011)

Performance Evaluation of Selected Sewerage Treatment Plants in Sri Lanka

M.I. Sudasinghe, L.W. Galagedara[1] and E.R.N. Gunawardena[1*]

Postgraduate Institute of Agriculture
University of Peradeniya
Sri Lanka

ABSTRACT. *Sri Lanka faces a number of water and wastewater issues and water related health hazards. These problems arise primarily due to the increasing level of qualitative and quantitative depletion of water resources owing to over- utilization and continuous discharge of wastewater. Sewerage treatment plants (STP) have been constructed in most places to reduce the degradation of water quality and to ensure a healthy environment. However, the effectiveness in treating sewerage has been a major concern. Therefore, this study was carried out to evaluate the performances of eight STPs representing different locations and management organizations such as government, private sector and community and to investigate the reasons for their performance. The methodology included a checklist survey with 109 performance criteria under five categories such as general, technical, physical, personnel and operational and maintenance, complemented by focus group discussion, formal and informal discussion and stakeholder interviews. The results showed that only 2 out of 8 STPs studied performed well. In general the physical and technical aspects were found to be satisfactory whilst personal and operational and maintenance aspects were poor. This indicates that the construction of technically sound STPs does not necessarily guarantee its success. Recruitment of trained personnel and providing them with responsibilities are required for better performance of STPs. The private sector appears to be performing well in managing the STP compared to government and NGO sectors.*

Key words: *Institutions, Performance, Sanitation, Sewerage treatment plant, Wastewater,*

INTRODUCTION

Many health hazards in developing countries and transition-economic countries are related to poor water quality and limited water quantity (Vandeweerd *et al*., 1997). According to Vandeweerd *et al.* (1997), more than 90% of sewerage in the developing world is discharged directly into rivers, lakes, and coastal waters without any treatment. Sri Lanka also faces a number of water and wastewater issues and water related health hazards (WHO, 2000). These problems arise primarily due to the depletion of water resources and degradation of its quality, part of which can be attributed to sewerage and silage disposal (Bandara, 2003; Sally *et al*., 2006). The large cities such as Colombo, Galle, Jaffna and Kandy have serious problems disposal of sewerage, industrial effluents and industrial and of domestic solid waste, as they generate large quantities but have no facilities for their treatment and/or proper disposal (Bandara, 2003). As reported by Nawas *et al*. (2005), access to clean water and adequate sanitation facilities is a great challenge in highly populated areas. A report by

* To whom correspondence should be addressed: nimalgun@pdn.ac.lk
1 Department of Agricultural Engineering, University of Peradeniya, Peradeniya, Sri Lanka

UNEP (2001) estimated that each day in the Colombo Metropolitan Region, 428 MT of sewerage is released into the ground through septic tanks and pit latrines and 138 MT of sewerage is released into waterways. Moreover, Kandy suffers from a serious problem of wastewater disposal which contributes to the pollution of Mahaweli river. There is no proper system of wastewater disposal, and about 80% of used water is released as wastewater (Thrikawala *et al.*, 2008). In addition, highly polluted water is carried by tributaries like Meda-ela, Pussellawa Oya, and Pinga Oya, which connect to Mahaweli River (Dayawansa, 2006). Pussalla Oya catchment was the main source area for the "*Hepatitis A*" outbreak recorded in Gampola in May 2007 (Abeysinghe, 2007). A recent study conducted by Rajapaksha *et al.* (2008) showed that comparatively higher pollution levels are found at the outflow points in Pussallawa town due to unavailability of onsite wastewater treatment facilities and mismanagement of wastewater.

Due to lack of the knowledge of health hazards by wastewater or scarcity of resources, sewerage treatment and/or improved sanitation were not given due attention by most communities. According to Gijzen (2001) there have been substantial developments in wastewater management and treatment technology. As a solution to the discharge of untreated wastewater, sewerage treatment plants (STPs) have been constructed especially in rapidly urbanizing cities. The typical domestic wastewater treatment system is a centralized municipal-sized facility that treats wastewater to specified discharge limits, to protect human health and the environment (Bradley *et al*., 2001). The onsite wastewater treatments are not possible in all places especially with respect to limited land availability (Rajapaksha *et al.,* 2008). There have been complaints of the effectiveness of STP, though it is the commonly available wastewater treatment technology currently being practiced in Sri Lanka. Performance of a STP depends on number of technical, social, economical and institutional aspects. Therefore, this study was carried out to investigate the present situation and performance of selected STPs in Sri Lanka and to identify the criteria to be considered in their construction and management.

METHODOLOGY

Selection of performance criteria

A total of 8 STPs representing different locations and management organizations such as government, private sector and community were selected for the study as shown in Table 1. Past studies and guidelines from reports of Central Pollution Control Board, Ministry of Environment and Forestry Board In India (2007) and China (Boller, 1997 & Mins, 1996), along with preliminary investigation and informal discussion with the officers who manage the selected STP was used to develop 109 performance criteria under five categories *viz.* general, technical, physical, personnel, and operation and maintenance (O&M). The descriptions of five categories are described below.

General criteria

The general criteria show whether the management is keen to maintain records of general information of STP including funding agency, cost, number of connection, water supply, wastewater generation and produce annual report at regular intervals. The index provides an indication of the availability of above information with the management of the STP.

Technical criteria

These criteria show whether the design and functional characteristics of a STP is adequate to treat the sewerage. A higher index value indicates that the STP has the capacity to treat the sewerage effectively from the respective community or organization.

Physical criteria

This criterion shows the current physical status of the STP to carry out its technical functions to treat the sewerage effectively and efficiently. A higher value implies that the physical condition of the STP is good and do not require repairs.

Table 1. Description of the selected STPs for the study

Name of the STP	Location	Treatment technology	Year of Construction	Capacity (m^3 / day)	Wastewater treated (m3) per day	Number of connections	Population served	Operation and maintenance agency
Raladinugama	Kalutara	Aerobic/ana-erobic + Reed bed	2006	50	20	39	169	Community Based Organization
Zoysapura	Colombo	Trickling filter	1983	2750	2700	2000	13000	National Water Supply and Drainage Board
Suwasewana Hospital (PVT) Ltd	Kandy	Aerobic/ana-erobic Digestion	2008	580	140	100	1500	Suwasewana hospital
Hantana Housing Scheme	Kandy	Trickling filter	1978	1200	6280	404	2700	National Water Supply and Drainage Board
Digana Village	Kandy	Stabilization pond	1979	-	2383	282	2000	Mahaweli Authority of Sri Lanka
Raddolugama	Nittambuwa	Activated sludge	1982	3000	3264	2128	10000	National Water Supply and Drainage Board
Earl's Regency hotel STP	Kandy	Aerated lagoon + Rotating biological reactor	1999	150	130	104	100	Hotel Management
Dental faculty STP	Kandy	Aerated lagoon	1999	2750	50	20	-	Staff of Dental Faculty

Personal responsibility criteria

Personal responsibility criteria provide an indication of whether personnel have been recruited trained and provided responsibilities to carry out various functions of the STP. A higher value shows that there are adequate, trained personnel who are given responsibilities to look after various activities in operating and maintaining the STP.

Operation and maintenance criteria

This shows as to how the STP is operated and maintained in order to provide the services which are expected from it. It is possible to have a lower value for O&M irrespective of having a higher value for all the above indices. This may be due to many reasons, such as a) structural and functional defects of the STP, b) lack of funds, and c) not willing to carry out the assigned tasks by the maintenance staff.

Performance index

Each of these STP was visited during the study and the checklist was completed from the observation made, discussions with the officials who operate the STP and the responses of the community which is served by the STP. The observed status of the criteria was compared with the ideal status and combined score was used to decide whether the performance was good, satisfactory or poor. If a STP satisfies more than 70% of the criteria (or the index has > 70), the performance is considered as good. Index values of less than 50% and between 50%-70% are considered as poor and satisfactory, respectively. These index values were calculated for each of the five performance criteria described above. The overall performance was determined by dividing the number of better performing criteria observed by the total number of criteria tested.

RESULTS AND DISCUSSION

Figures 1(a) through 1(h) show the values of five major performance criteria and the overall performance of selected STPs. Raladinugama, a settlement of displaced people by tsunami, scored poorly in all five aspects with an overall performance of 33% (Fig. 1a). The STP is in very bad condition due to lack of facilities such as funds, man power and poor operational and management activities. This STP was constructed by funds provided by an NGO and was managed by the community. Only one person, the chairman of the Community Based Organization (CBO) was trained and is responsible for O&M. He is more interested in his main livelihood, i.e. fishing, compared to his responsibility to operate and maintain the STP. This is revealed in results shown in Fig. 1(a) where O&M received only 22% while physical condition received 42%. The community people in the Raladinugama housing scheme are living under very difficult condition due to malfunctioning of the STP.

The STP at Zoysapura housing scheme at Moratuwa scored an average of 45% based on five broader categories with a poor overall grade Fig. 1(b). The scores in the assessed criteria vary from 18% for personal to 73% for technical. The lower performance is mainly due to shortage of labour, under training of personnel, lack of officers for O&M and technical defects such as design of plant equipment and aging structures. The National Water Supply and Drainage Board (NWSDB) is planning to replace the present STP by a new one. The STP at Suwasewana in Kandy is a newly constructed privately maintained system and has not a single criterion with bad performance Fig. 1(c). Four criteria, i.e. general, physical, O&M and overall performance were good implying that the system is being looked after very well. The STP is designed and managed by a private firm. General details are maintained by the construction firm which bears all personal responsibilities of O&M of the STP.

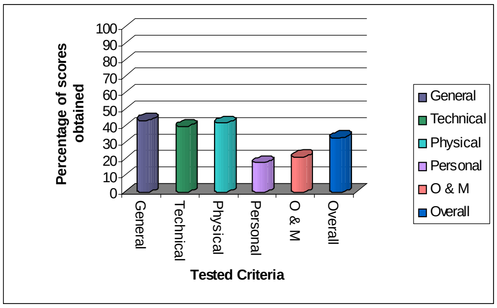
Hantana housing scheme shows an overall value of 48% with a poor grade. Field observation and information gathered from the residents in the area reveal that the bad odour is the major problem that the community is facing due to the STP. According to the survey conducted, the physical defects and personal responsibilities with scores of 23% and 36%, respectively are mainly responsible for the overall poor performance, though the STP has comparatively higher values for general (63%) and technical (73%) criteria Fig. 1(d).

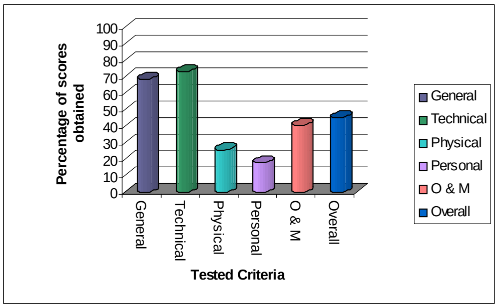
Out of the 8 STP studied, the one at Digana Village was the worst performing one. Fig.1 (e). All other criteria, including the overall performance criteria with a score of 26% were in the poor range. The STP at Digana was installed during the construction of the Victoria reservoir and is vested with the Mahaweli Authority of Sri Lanka (MASL) for O&M. It is found that there are no adequate personnel responsible with hardly any O&M activities. It is also revealed that the expansion of number of connections over the years has led to problems associated with inadequate capacity of the STP. Residents in the area are concerned about the STP only when they face difficulties due to blocking or some other problems in system.

The STP at Raddolugama housing scheme in Nittabuwa also has a poor grade with an overall score of 39% Fig. 1(f). As in Digana village, this STP also appears to have problems with available personnel with a score of 9%. To make matters worse, several outside gully suckers discharge their waste to the STP without screening leading to the reduced performance. In addition, outsiders bring industrial wastewater for which the plant is not designed for. This is becoming a major problem in Sri Lanka and needs to be addressed giving special consideration in future. Earl's Regency has an overall good performance with a score of 72% as shown in Fig. 1(g). As a five stars hotel in Sri Lanka, Earl's Regency complies with standards recommended by the Central Environmental Authority (CEA) of Sri Lanka. This STP shows the best performance among the 8 STPs studied. The STP at the Dental Faculty of University of Peradeniya was constructed with Japanese International Cooperation Agency (JICA) grant and is in good physical condition as shown in Fig. 1(h). However, the overall performance is poor (47%) mainly due to the unavailability of personnel (index value of 0%).

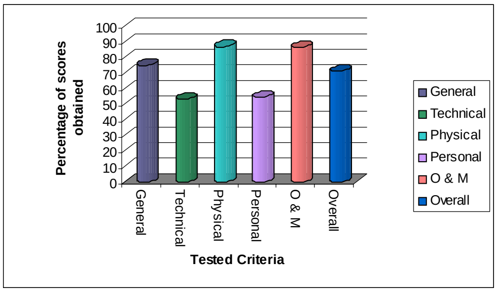
Overall performance of sewerage treatments plants

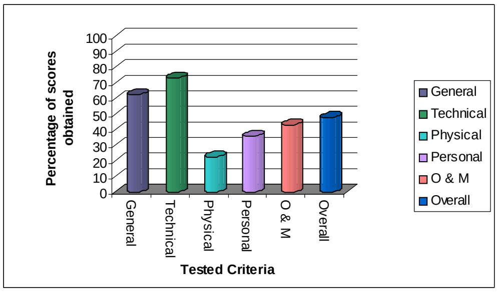
Figure 2 shows the overall performance of each of the five criteria tested for the 8 STPs. The general, technical and physical criteria have values more than 50% indicating that the STPs are conceived, designed and the current physical status in general are satisfactory. The problem appears to be in the area of recruiting competent, trained personnel with responsibilities to look after the day to day operation of the STPs. In some STPs, the chlorination plant had been removed without chemical disinfection due to lack of sound knowledge on the treatment process. It was found that most officers responsible for managing the treatment plant do not possess the required knowledge on chemical treatment. They are not aware of the importance of chemical treatment to eliminate health hazards and prevent environmental problems. Therefore, substantial investments in construction of STP does not help to treat sewerage unless there is a strategic approach to develop the required man power development in Sri Lanka in the area of sewerage treatment.



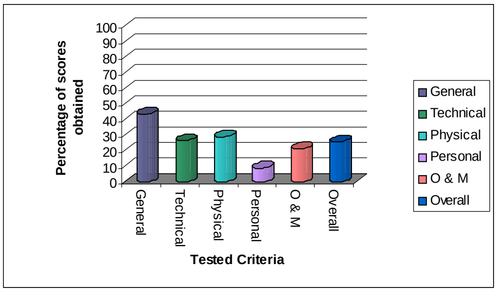


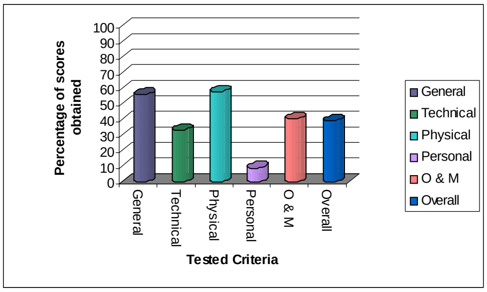
a. Raladinugama STP **b. Zoysapura STP**



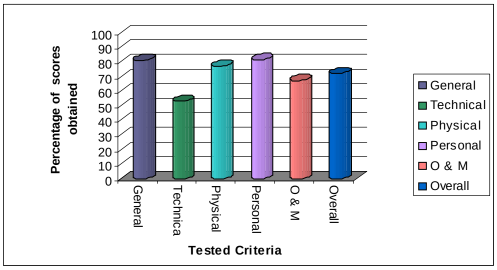


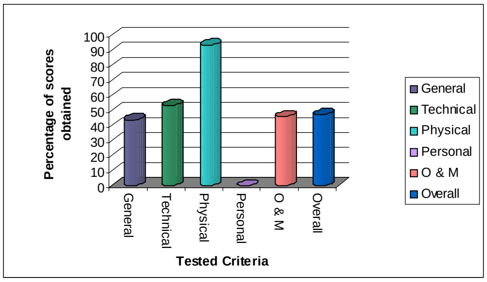
c. Suwasewana (PVT) Ltd STP **d. Hantana housing scheme STP**





e. Digana village STP **f. Raddolugama STP**





g. Earl's Regency Hotel STP **h. Dental Faculty STP**

Fig. 1. Performance of selected STPs based on five major criteria studied

As shown in Table 2, only Earl's Regency Hotel and Suwasewana Hospitals have STPs with good performance. This indicates that the institutional aspect is more important than the technical designs and physical status. For example, the STP at the Faculty of Dental Sciences was built under a JICA grant with the supervision of experts. The current physical status of the STP is good with an index value of more than 90% Fig. 1(h). However, non-availability of trained, responsible personnel for its management has led to the overall poor performance. The STPs of Earl's Regency Hotel and Suwasewana are being managed by the private sector and the accountability of the service provider to the client has guaranteed its success.

However, the above inference should not imply that only private sector has capable personnel and the competence to manage STP. There are number of constraints that the government institutions experience in managing STPs. In adequate allocation of funds for O&M, lack of required trained personnel, difficulty of getting the required work done from them due to many institutional and political reasons, lack of accountability to the client are some of the major reasons. They also should have a proper plan for O&M, rehabilitation and replacement. Most of STPs managed by government organizations are now over 20 years of age and reaching the end of its useful life such as Zoysapura STP and Digana stabilization pond system. In general, STP life time is 30 years (Tchobanoglous *et al.*, 2003).

Another problem that the government managed STPs are facing is due to the pressure of providing additional connections exceeding the capacity of STPs. Some of the connections are given illegally to new householders who are out of the housing scheme. These extra connections cause overcrowding of the designed capacity of the STPs leading to malfunctioning of the treatment process. As a result, STP releases partially treated or raw sewerage to the environment. As observed during the study, partially treated STP effluent has polluted water resources due to high concentration of organic matter. Overflowing of STPs due to malfunctioning of the treatment process has, in some instances, created conflicts within the community.

Handing over responsibilities to CBO has to be carefully considered since they neither have trained personnel nor required institutional capacity. The health hazards, conflicts within the community due to overflowing of untreated sewerage and resulting bad odour are some of the examples from Raladinugama housing scheme managed by a CBO which is especially established to manage the STP.

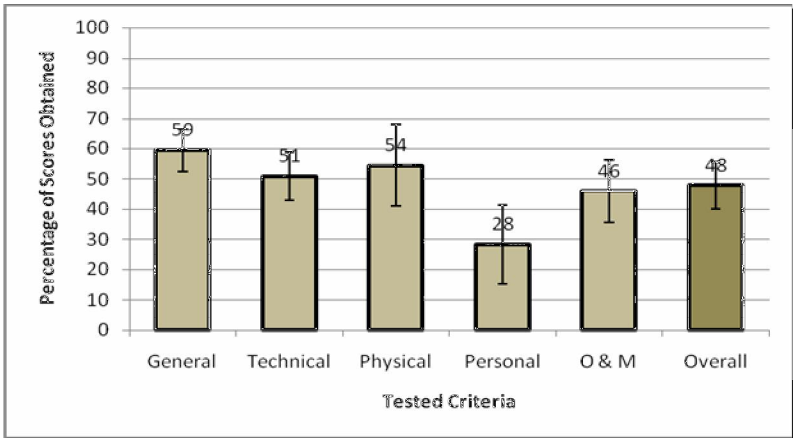


Fig. 2. Overall results of the tested criteria based on eight STPs. Error bars show the standard deviation (n=8).

Table 2. Summary of overall grades of STPs

Name of STP	Good	Satisfactory	Poor
Raladinugama Tsunami Housing Scheme			√
Zoysapura Housing Scheme			√
Suwasewana (Pvt) Ltd Hospital	√		
Hantana Housing Scheme			√
Digana Village			√
Raddolugama Housing Scheme			√
Earl's Regency Hotel	√		
Dental Faculty			√

Important aspects in establishing STP

This section briefly describes some of the essential criteria to be considered in establishing a STP based on the observations made during the study. These aspects are discussed under technical, socio-economical and institutional aspects.

Technical aspects

Foul odours and resulting negative impacts from wastewater collection and treatment plants are a primary concern for many communities served by the STPs. Raladinugama and Hantana STPs produce high concentrated bad odour due to anaerobic condition in the collection tank. Strict rules and regulations from the Ministry of Environment are required to control odours and nuisance conditions in STP. It is reported that bad odour from STPs could cause health issues, environmental degradation, property devaluation, and their overall quality of life (Witherspoon *et al*., 2002). Each O&M agency of STPs should prepare odour management plan to (a) Identify sources of odour, (b) finds failure of treatment process leading to problems associated with it, (c) action taken to reduce odor and implement them, and (d) keep records and settle complains from the community.

Sewerage overflow from STPs enhance the contamination of soil and water resources. Frequency and volume of sewerage overflow of STP should be assessed to address this problem. In this regard, it is necessary to design and upgrade the collection system with increasing number of connection tanks to avoid overflow. Sewerage overflow is found to be a common experience in Zoysapura STP due to flooding in the surrounding areas.

Treatment nature of the STP will be changed time to time due to new connections with industrial wastewater and changes in type of industries which affect STP performance. Raddolugama plant has been designed only for treating domestic wastewater. At present number of gully suckers which collect wastewater from factories dispose into the plant altering wastewater characteristics from domestic to domestic and industries. Therefore, it is necessary to redesign to replace the plant structures to accommodate changing wastewater characteristics. Furthermore, Zoysapura STP has been designed only for domestic wastewater. Number of factories has since immerged and operating in the surrounding area. To address this problem, the NWSDB is going to replace the old STP with a newly designed one capable of treating both domestic and industrial wastewater.

It is important to select the design and treatment process to meet the required effluent quality which will be discharged to the environment. Wastewater treatment effluent quality is variable because of varying organic loads, changing environmental condition and new industrial discharges. Earlier Earl's Regency hotel used rotating biological contractor technology and it had failed with time due to the death of microorganism by detergent and other chemicals used for cleaning purposes. It is reported that sodium dichloroiso cyanurate, quaternary ammonium salts and biquaternary ammonium salts had better killing effect on sulfate reducing bacteria (SRB) while the bactericidal effect of formaldehyde was worse (Xiaojuan *et al.*, 2008). The hotel management had replaced rotating biological treatment with an aerated lagoon. Therefore, it is necessary to select the best suitable technologies at the implementation stage by considering all the factors mentioned before.

It is also important to use energy efficient technologies to reduce the O&M cost. Large amount of energy is used for aerated lagoon and activated sludge process. About one half of the entire plant electricity usage is for aeration (Tchobanoglous *et al.*, 2003). The energy requirement can be reduced by correct site selection, using energy efficient equipment and designing the plant to conserve energy.

Most operating agencies in Sri Lanka do not use chlorination plant for disinfection. As a result, water sources get contaminated with effluent discharges from STPs. Therefore, it is a must to use chlorination plant in the treatment process to disinfect the treated effluent.

Treatment of the return flow is another major concern on STP. Almost all the evaluated plants in this research do not use treatment of return flow. The management at Hanthana STP is planning to introduce a return flow treatment (RFT) on its STP. The RFT reduces the nitrogen level in the treated effluent. It addition, RFT enhances the removal of ammonia, fine settlers and soluble heavy metals (Tchobanoglous *et al.*, 2003).

Socioeconomic aspects

Technically perfect STP alone does not guarantee its successful operation and sustainability over time. Funds are required to pay personnel and cover other operational expenses. In addition, regular repairs need to be carried out to guarantee the best possible performance. It is apparent from the results that two STPs in the private sector institutions are performing well since they have the required funds and trained personnel for smooth operation. The community managed STP at Raladinugama finds it difficult to collect required payments from the community and hence has affected the proper functioning of the STP. The rest of 5 STPs managed by NWSDB, MASL and Dental Faculty has serious problems with fund allocation for personnel, repairs and O&M. Therefore, the aspect of cost recovery needs to be looked into more detail before installing STPs with very high capital costs in Sri Lanka.

Institutional aspects

It is important to identify the institutional roles in operating and managing the STP to provide a better and sustainable service to the people whilst protecting the environment. Local authorities along with the support of Environmental Ministry should be entrusted with the monitoring of performance of STP under their jurisdiction. Air and water quality parameters along with disposal of sludge need to be regulated in this regard. The permission to operate an STP should be granted only after assessing the capability of the relevant organization. Submission of annual reports to local authorities should be made mandatory. In addition, it is necessary to maintain records of all special events such as physical defects, pump repairing, overflowing of STP and complaints made by beneficiaries and outsiders. At present implementing agencies do not practice record keeping due to lack of awareness on O&M and the paucity of regulation.

CONCLUSIONS AND RECOMMENDATIONS

The results from the study show that only 2 out of 8 STPs studied are performing well. In general the physical and technical (hardware) aspects are found to be satisfactory whilst personnel and operation and maintenance aspects (software) are poor. This indicates that the construction of technically sound STPs does not necessarily guarantee its success. Recruitment of trained personnel and providing them with responsibilities are required for better performance of STPs. The private sector appears to be performing well in managing the STP compared to government and NGO sectors. The study has provided insights into many aspects which require further research. Among them institutional arrangements, regulation for proper sewerage management and cost recovery from the beneficiary communities are found as priority areas.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Crossing Boundaries Project of the PGIA, University of Peradeniya Sri Lanka; SaciWATERs, Hyderabad, India and the Government of Netherlands for proving funds and facilities to undertake this research.

REFERENCES

Abeysinghe, M.R.N. (2007). Weekly Epidemiological Report, Ministry of Healthcare and Nutrition, Government of Sri Lanka. 15-21.

Bandara, N.J.G.J. (2003). Water and wastewater issues in Sri Lanka, Water Sci. and Technol. 47(12), 305-312.

Boller, M. (1997). Small wastewater treatment plants – A challenge to wastewater engineers, Wat. Sci. Technol. 35: 1-12.

Bradley, B.R., Daigger, G.T., Rubin, R. and Tchobanoglous, G. (2001). Evaluation of onsite wastewater treatment technologies using sustainable development criteria. J. of Clean Technol. and Envt. 4, 87-99.

Dayawansa, N.D.K. (2006). Water pollution status in Sri Lanka. *In:* Dayawansa N.D.K. (ed), Water pollution in Sri Lanka, Geo-informatics society of Sri Lanka, Department of Agric. Engineering, University of Peradeniya. pp. 13–21.

Gijzen, H.J. (2001). Aerobes, anaerobes and phototrophs: a winning team for wastewater management. Water Sci. and Technol. 44(8), 123-132.

Mins, K. (2007). Wastewater pollution in China, [online]. [Accessed on 23.09.2009]. Available at http://darwin.bio.uci.edu/~sustain/suscoasts/krismin.html

Nawas, M.F., Mowjood, M.I.M. and Galageedara, L.W. (2005). Contamination of shallow dug wells in highly populated coastal sand aquifer: A case study in Saithamarudu, Sri Lanka, Tropical Agric. Res. 17, 114-124.

Rajapaksha, I.H., Galagedara, L.W. and Najim, M.M.M. (2008). Microbial water quality variation in different water sources in the Pussallawa Oya catchment and pollution Contribution by Communities, Tropical Agric. Res. 20, 313-325.

Sally, L.R., van der Hoek, W. and Ranawaka, M. (2001). Wastewater reuse in agriculture in Vietnam: Water management, environment and human health aspects. Working paper 30, International Water Management Institute, Colombo, Sri Lanka. 10-57.

Sinha, A.K. and Nazimuddin, M. (2008), Evaluation of operation and maintenance of sewage treatment plants in India-2007, Central pollution control board, Ministry of Environment and Forestry, [on line], [Accessed on 20.05.2009], Available at: http://www.cpcb.nic.in.

Tchobanoglous, G., Burton, F.L. and Stensel, H.D. (2003). Wastewater Engineering Treatment and Reuse, McGraw-Hill Companies Inc, U.S., 4^{th} edition, pp 60-63.

Thrikawala, S., Gunaratne, L.H.P. and Gunawardane, E.R.N. (2008). Impact of different tariff structures on residential water demand: A case study from Kandy, Sri Lanka, Tropical Agric. Res. 20, 60-72.

UNEP. (2001). Annual report, Regional Resource Centre for Asia and the Pacific 2001, Sri Lanka: State of the environment 2001. Pathumthani, Thailand: UNEP.

Vandeweerd, V., Cheatle, M., Henricksen, B., Schomaker, M., Seki, M. and Zahedi, K. (1997). Global Environment Outlook (GEO), UNEP Global State of Environment Report 1997. pp, 121-132.

WHO. (2000). Global water supply and sanitation assessment, 2000 report. World Health Organization. (114-126).

Witherspoon, J.R., Torres, E.D., Dao, C., Kogan, V., Groskreuts, R., Desing, B., Peter, B., Cris, Q., Glen, T.G. and Card, T. (2002). Do you have an odour problem? We have a plan that will work for you *In*: proceedings of the water environment federation, odor sand toxic air emissions, 26,194-219.

Xiaojuan, Y., (2008). Exploration on Germicidal Regularity and Action Mechanism of Several Bactericides. J. of Anhui Agric. Sci. 36, 7425-426.