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ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT
OF WATER AND SANITATION FOR ALL

A novel wastewater treatment ecotechnology to improve environmental sanitation in urban slums

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Rapid urbanisation has exerted severe pressure on urban housing and public services in the metropolitan city of Khulna, Bangladesh with which basic urban services could not cope. Situation coupled with the destitute economic condition of migrants has instigated the formation of large number of slums where service inadequacies on sanitation have been compounded and multiplied on a massive scale, resulting in hazardous environmental condition. Decentralized Wastewater Treatment System (DWTS) has recently gained much attention due to its build-as-you-go principle. This paper aims to examine and discuss the potential of a novel DWTS for urban development. The pilot DWTS was established in Panchtola colony located at Khalishpur, Khulna, Bangladesh. The paper first depicted how environmental sanitation of slum was improved with inclusion of ecotechnology. It was found that, overall removal efficiency of pollutants is more than 80% (COD, BOD_5, PO_4 and faecal bio-indicators) from influent.

Introduction

Khulna is the third largest city in Bangladesh which is known to all as an industrial area. Most of its industries such as Jute mills, News print mill, and Hardboard mill are situated in Khalishpur, Khulna. In the past, Khalishpur was very busy and crowdied area when mills were active. To meet up the accommodation of factory workers a total of eight building were constructed at Peoples Jute Mill area in 1982 (Saha and Alamgir, 2013). Every building has five floors, and for this reason it is called Peoples Panchtala (five floors) Colony. In order to address the pollution from the Peoples Panchtola Colony at Khalishpur in Khulna, the wastewater that is being discharged directly into the nearby open areas, would require proper treatment with regards to environmental conservation.

Prior to the start of Nabolok Enhancing Environmental Health by Community Organization (EEHCO) project, funded by WaterAid Bangladesh, mostly the residential wastewaters including sewage were being disposed directly either into storm water drains or open areas without any treatment. Due to unaffordable cost of construction, most of the drains in the towns and cities are open, as a result of which they are misused, sometimes serving as defecation sites for homes without adequate toilet facilities. In consequence, self-purification capacity of receiving water bodies is overloaded and it causes surface and ground water pollution, impacting directly to the health of the community. To improve this situation, wastewater treatment plant was therefore needed. But the municipality could not afford a centralised system for its entire area. For the circumstances, decentralised wastewater treatment system (DWTS) would be the most suitable to reduce the pollutant to an acceptably low level.

Decentralised wastewater management may be defined as the collection, treatment, and disposal or reuse of wastewater from individual homes, clusters of homes, isolated communities, industries or industrial facilities, as well as from portions of existing communities at or near the point of waste generation (Battilani et al., 2010). DWTS applications are based on the principle of low-maintenance since most important parts of the system work without electrical energy inputs and cannot be switched off intentionally (Butler and MacCormick, 1996). Targeting a sustainable communal wastewater treatment solution for urban areas where no wastewater management system is available, DWTS was established at the Panchtola colony premise.

Sanitation situation improvement

The Panchtola colony residences were originally built as bachelors' quarters for factory workers. However, following severe flooding in 1988, many families took shelter in the colony and eventually came to occupy all the residences. Following this, the factory disowned any responsibility of these residences that no longer housed their workers, and state agencies including the Khulna City Corporation (KCC), Khulna Water Supply and Sewerage Authority (KWASA) and Khulna Development Authority (KDA) also refused to provide any services to the residences. Consequently, Panchtola Colony could not legally access any public services, including electricity, and was known as *ondhokar* Panchtola (dark Panchtola).

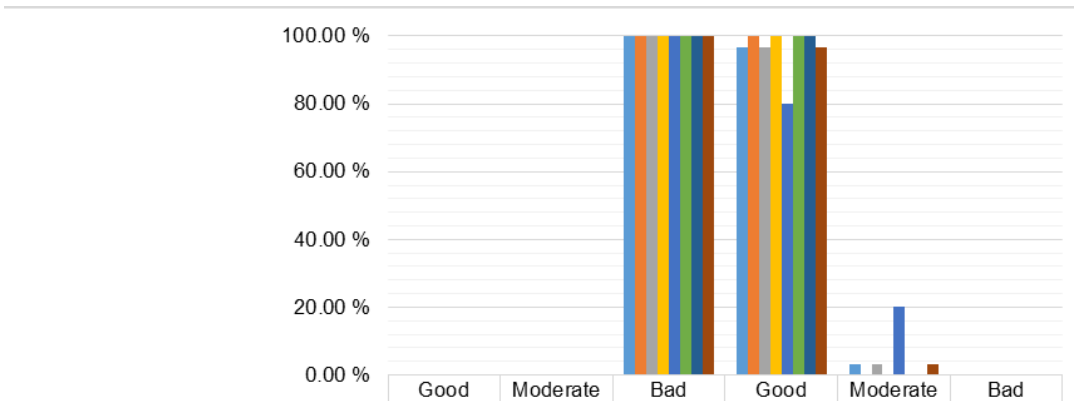
When WaterAid and Nabolok began its Promoting Environmental Health in Urban Project (PEHUP) in Khulna, a reconnaissance survey across all the wards revealed the dire state of Panchtola colony. With no functional sanitation system in place, residential wastewater even sewage and wastes were dumped directly next to residences, where sludge heaps 10 to 15 feet high had formed over the years. Thus, foul odour was emitted, and blockage of drainage systems occurred for wastewater overflow during rainy season. For that reason, surface water bodies as well as groundwater was polluted. Moreover, wastes was spread of by scavenging birds and animals were a common sight.

Realising the urgency improved sanitation systems for the colony, WaterAid and partner Nabolok initiated discussions with the colony residents. WAB and Nabolok explained that united action would have to be taken by the residents themselves while the organisations could provide technical support; and the residents, living in unacceptable questions, responded positively. Taking the advice of the project, the residents jointly approached the Ward Commissioner to advocate for his support. The Ward Commissioner, realising the extent of the problem, formally requested WAB and Nabolok for their support.

To identify improvement of sanitation situation, a questionnaire survey was conducted among the inhabitant households of Panchtola Colony, Khalishpur, Khulna. The survey was conducted among 15% of households on sample basis. In this survey, 08 parameters was considered including pre and post-DWTS intervention situation. The respondents expressed their statement on each condition as good, moderate and bad. As a matter of fact, the level of environmental pollution due to wastewater discharge was severe. The graphs presented in the Figure 1 show the level of pollutant found in wastewater from stack of faecal matter accumulated in nearby premises before DWTSs were implemented. It also shows the comparison of found pollutants with Bangladesh Standard for the effluent discharge to inland surface water.

Based on the nature and extent of the contamination problem, DWTS was selected as a feasible technology for Panchtola. The concentration of a large number of people in a small space, and the improbability of the colony becoming connected to the central sewerage system any time in the near future meant that decentralised technologies had to be considered. Although DWTS was a very new technology in Bangladesh at the time, WAB and Nabolok realised that if successful, DWTS could provide long-term relief to the Panchtola colony residents.

Figure 1 portrays that, with the implementation of DWTS, all the conditions that represent the overall situation of the community rapidly turns from 'Bad' to 'Good' or 'Moderate' scenarios. Presence of faecal matter in open space was removed by 100%, leading towards the improvement of surrounding environmental condition up to 96.67% (Figure 1). During the pre-intervention circumstances, water-borne diseases seemed as an obvious phenomena of the respective community, which reflects with significant changes as per post-intervention condition. Drainage condition has also been improved as of post-implementation situation. Moreover, as DWTS treats a substantial health hazardous contaminant with its praiseworthy efficiency, sanitation situation of community people has also enhanced. With the value addition of sanitation situation improvement, it depicts that both of economic and social status improvements for most of the community people.



	Pre Intervene Situation			Post Intervene Situation		
	Good	Moderate	Bad	Good	Moderate	Bad
Surrounding Environmental Condition	0.00 %	0.00 %	100.00 %	96.67 %	3.33 %	0 %
Presence of Foul Odor	0.00 %	0.00 %	100.00 %	100 %	0.00 %	0.00 %
Water-borne Disease Contamination	0.00 %	0.00 %	100.00 %	96.67 %	3.33 %	0.00 %
Spreaded Faecal Matter	0.00 %	0.00 %	100.00 %	100.00 %	0.00 %	0.00 %
Filthy Drainage Condition	0.00 %	0.00 %	100.00 %	80.00 %	20.00 %	0.00 %
Sanitation Situation Improvement	0.00 %	0.00 %	100.00 %	100.00 %	0.00 %	0.00 %
Social Status Improvement	0.00 %	0.00 %	100.00 %	100.00 %	0.00 %	0.00 %
Economic Status Development	0.00 %	0.00 %	100.00 %	96.67 %	3.33 %	0.00 %

Figure 1. Comparative analysis between pre & post intervene situation of DWTS

Components of DWTS

Decentralised system is the combinations of aerobic and anaerobic treatment process (Feng et al., 2013). The anaerobic treatment process comprise of settlers, baffle reactors and anaerobic filters. The aerobic treatment process has Horizontal/Vertical/ Flow Constructed Wetland. Combination of both horizontal and vertical flow of water in a wetland can be achieved with baffle wall wich is designated as Combined/Baffled Flow Constructed Wetland. And finally a Polishing Pond/ Surface Flow Wetland (Figure 2) (Saeed, 2012, 2014).

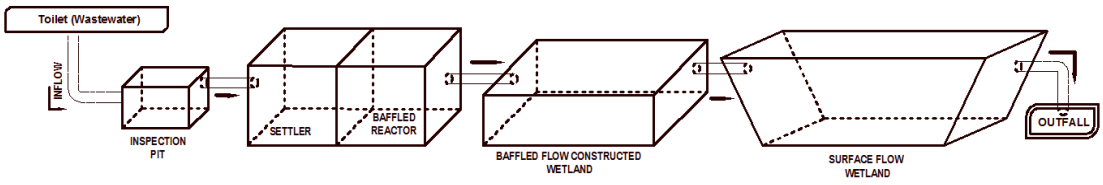


Figure 2. Components of DWTS

The basic idea of that is to treat the wastewater on-site by means of low-cost treatment systems, and make environmental friendly discharge of effluent according to standard.

Pollutant removal efficiency of DWTS

DWTS at Panchtola colony, Khulna is designed to treat 22,800 liter/day of wastewater produced by 285 inhabitants. Wastewater/Effluent test result of pre-intervene scenario shows that parameters such as Biological Oxygen Demand in 5 days (BOD_5), Chemical Oxygen Demand (COD), Faecal Coliform (FC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Nitrate (NO_3),

Phosphate (PO_4) have crossed the permissible limit by 3 to 4 times more (According to Bangladesh Standard 1997). To evaluate the effluent quality, the wastewater samples were collected from four different points such as middle of settler, outlet of Anaerobic Baffled Reactor (ABR), outlet of combined flow constructed wetland and outlet of surface flow constructed wetland of DWTS of the Panchtola Colony after 3 months of operation. Different parameters such as BOD_5, COD, NO_3, PO_4, TDS, FC, DO and TSS were determined of collected wastewater samples.

Table 1 indicates pollutant removal profiles and removal efficacy (expressed as percentages) of each component of DWTS established in Khulna city. As observed in Table 1, the first stage of treatment facilitated by number of settler and baffled reactors provided higher removal efficacy especially for BOD_5, TSS and NO_3 despite of higher concentrated influent pollutants. Anaerobic decomposition expedited through ABRs commenced reduction of TDS with furthermore removal of TSS. Also, in this stage FC concentration reduced by 52.94% of respective influent. A small amount of DO reduction depicts the anaerobic condition as well. Table 1 shows the combined flow constructed wetland facilitates COD abstraction steadily upward with 52.66% of effectiveness. Significant percentage of PO_4 removal take in place, compared with the first and second stages of treatment because of presence of cupola slag. In the last stage of the system shows significant reduced amount of FC. Furthermore, with the process of oxidation & sedimentation in this phase most of the pollutants (COD, TSS, TDS, FC, PO_4 and NO3) have shown detrimental phenomena towards meeting the limit for effluent in surface water-bodies according to Bangladesh Standard.

Figure 3 shows graphical comparative status among influent wastewater quality, Bangladesh Standard and system efficiency. For example, influent wastewater of the system contain 1830 mg/lit of TSS. In such case, DWTS with its 97.81% of removal evviciency release effluent with only 40 mg/lit. As like, Table 1 and Figure 3 also depict that the highest removal percentages of 89.47%, 89.13% and 96.25% respectively for the parameter of BOD_5, FC and COD and therefore DWTS meeting wastewater effluent Bangladesh Standard. In case of other major chemical parameters such as PO_4 and NO_3 eliminated up to the desired level with the efficacy of 82.43% and 34.48% correspondingly.

Again, the increase of DO from the influent indicates that it can be mixed together with surface water for further utilization like agriculture that attributes to environmental sanitation.

Table 1. Pollutant removal performances across DWTS

Parameter	Unit	Bangladesh Standard	Influent Concentration	Settler and Baffled Reactor		Anaerobic Baffled Reactor		Combined Flow Constructed Wetland		Surface Flow Wetland		Overall treatment efficiency of the system
				Effluent Concentration	Removal %	Effluent Concentration	Removal %	Effluent Concentration	Removal %	Effluent Concentration	Removal %	Removal %
pH	-	6~9	6.85	7.02	-	6.99	-	7.16	-	7.16	-	-
BOD_5	mgL^{-1}	50	381	141	62.99	69	51.06	48	30.43	40	16.67	89.50
COD	mgL^{-1}	200	4800	3072	36.00	2180	29.04	1032	52.66	180	82.56	96.25
TSS	mgL^{-1}	150	1830	600	67.21	110	81.67	60	45.45	40	33.33	97.81
TDS	mgL^{-1}	2100	1900	1860	2.11	1228	33.98	1130	7.98	770	31.86	59.47
FC	N/100ml	1000	4600	3400	26.09	1600	52.94	1100	31.25	500	54.55	89.13
DO	mgL^{-1}	6.25	0.96	1.15	-19.79	0.9	21.74	1.32	-46.67	2.2	-66.67	-129.17
PO_4	mgL^{-1}	35	148	131	11.49	123	6.11	73	40.65	26	64.38	82.43
NO_3	mgL^{-1}	250	87	69	20.69	67	2.90	63	5.97	57	9.52	34.48

* Negative percentage indicates incremental phenomena

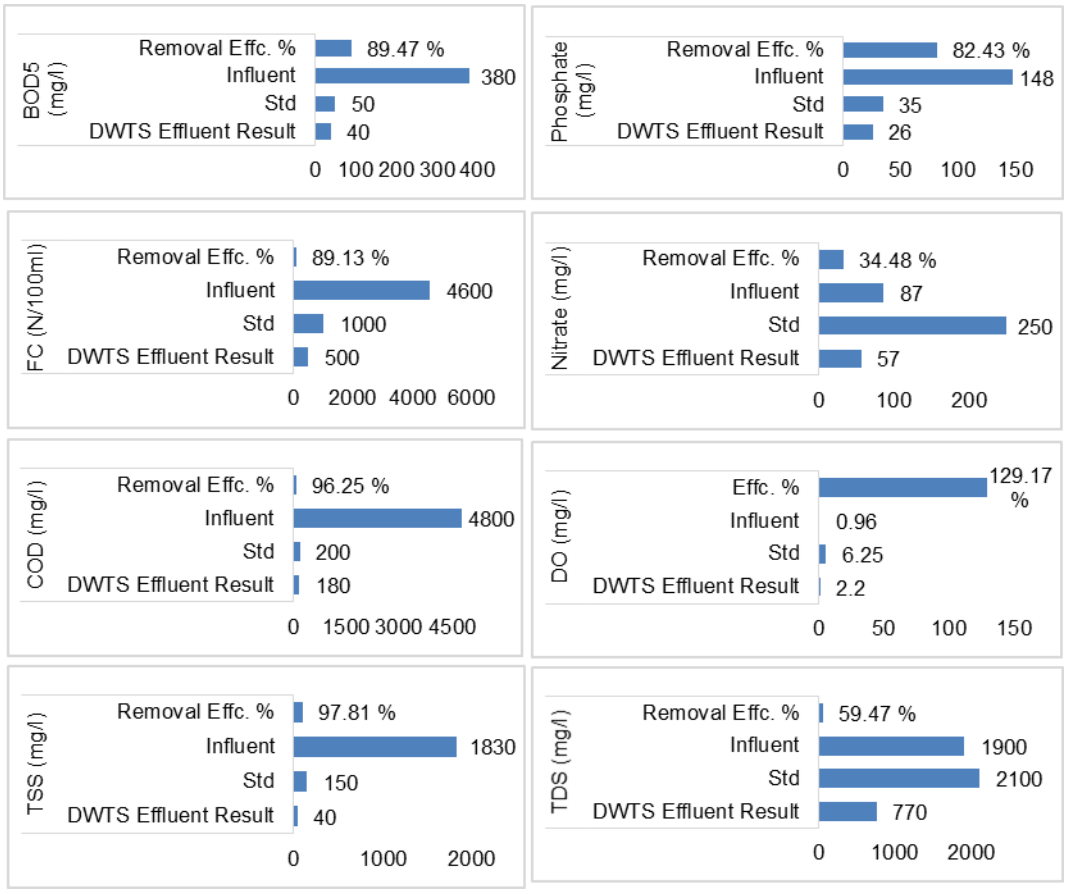


Figure 3. Overall removal efficiency against pre-intervene wastewater quality and Bangladesh Standard for different parameters

Going forward

As described above, the DWTS has seen much success in resolving the sanitation and environmental health issues plaguing Panchtola colony. The colony residents play a central role in the operations and maintenance of the system, contributing towards and managing waste collection and disposal. Additionally, a number of positive developments have taken place across perceptions of the colony. As a result of residents being motivated to advocate with the Ward Commissioner, the then mayor of Khulna city visited the colony, and took the decision to provide electricity in the residences.

The system has also generated interest amongst public services staff, researchers and other organisations, and has been visited a number of times. Currently, a sewerage master plan is being drafted for Khulna, where DWTS is recommended as a feasible technology for isolated, cluster communities beyond the reach of central systems. Once this is approved, it can be expected that many other areas deprived of services like Panchtola can also be benefited by this useful technology.

Conclusion

Considering the small isolated cluster having substantial numbers of people, DWTS seems to the perfect choice for wastewater treatment in Panchtola Colony, Khalishpur. Also the effluent quality of DWTS conforms Bangladesh Standard and therefore this option has been scientifically tested for further replication to the diverse contexts of Bangladesh. The beneficiaries along with the respective ward councillor have been very active and sincere in terms of participation in the process, significant contributions in terms of money, labour and land; playing very sincere roles on operation and maintenance; which indicates that option inspite

of being a new piloting has been owned by the community. Effective community mobilization is the most significant and potential background promoter for the successful establishment as well as ongoing operation and maintenances. Also in times of climate change, Khulna is one of the climate threatened divisions where DWTS should be perfect solution for wastewater management considering its proven climate change adaptation capacity. Apart from all positive findings with experience of DWTS in Khulna, there should be some challenges in future as of injecting the facilities within the City Corporation for future operation and replication. Construction cost as well as space would be another challenge as both the communities and government are still not yet prepared to spend such amount for improved sanitation where they have still been fighting with low cost latrines. But overall as second generation sanitation problem is already knocking the door, therefore based on this successful experience in Khulna, DWTS has to be considered as one of the ideal solutions where motivation, implementation, dissemination, advocacy and influencing should go in parallel.

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