Wastewater Treatment Technologies in Nepal

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Abstract: Though the need for appropriate wastewater management technologies is undoubtedly a realized issue, so far there has been very little action taken towards wastewater treatment in Nepal. The centralized approaches of wastewater management have been unsuccessful as the existing traditional lagoons or activated sludge type wastewater treatment plants are not functioning or partially operating at far below capacity. The major causes of failure are high capital investment, high operational and maintenance costs, complexity of the systems, be short of spare parts and lack of skilled resource persons. It creates opportunities to employ decentralized systems for wastewater reuse as well as resource recovery. This review emphasizes on the state of wastewater treatment units and prospects of sustainable decentralized wastewater systems including constructed wetlands in Nepal.

Keywords: Wastewater treatment; Decentralized system; Constructed wetlands; Nepal

1. Introduction

A major portion of the population of the world is suffering water stress due to unavailability of sufficient amount of fresh water (Kivaisi, 2001). The situation is getting worse as the population of the world is increasing and consequently the availability of fresh water per capita is decreasing significantly. However, Nepal is one of the richest country having abundant water resources with 6,000 rivers of an anticipated span of greater than 45000 km, and 660 lakes and ponds, Nepal is experiencing water scarcity at the urban centers and water sources are deteriorating due to inadequate sanitation facilities (Green *et al*., 2003; Shrestha *et al*., 2001). There are many visible water stresses, especially in the urban areas including dry season water uncertainty, groundwater depletion and climatic variability.

Though the growth of urban areas is particularly rapid, the centers have inadequate infrastructures such as water supply and sanitation facilities in low-income countries. The urban centers are usually in a state of transition with social, political, economical, ecological and environmental tensions. Moreover, the waste regulatory bodies are unsystematic and weak. As the haphazard discharge of untreated domestic and industrial wastewater and agricultural runoff are common practices in Nepal, water sources are converting into open sewers with contaminations and water-borne diseases (WaterAid, 2008). The conception of treatment or recycling of wastewater before discharging into water bodies is normally considered as unaffordable and consequently adopting rate of treatment technology is very slow.

In term of sanitation, situation of Nepal is worse and lags behind other developing nations (Green *et al*., 2003). Only 12% households of the urban centers are having access of sewer networks. As most of the pipelines are directly connected to a water body or river, only 5% of generated wastewater is appropriately being treated (WaterAid, 2008). In addition, Nepal's 52% population practices open defecation (WHO and UNICEF, 2010). Due to unplanned urbanization and lack of basic sanitation facilities, water stream and rivers contains harmful materials including biodegradable organic matter, toxic substances, pathogens and chemicals. In addition, disposal of wastewater on and inside ground is resulting in large-scale contamination of soil, water, and air. It is necessary, therefore, to have treatment of wastewater before it is released into the environment. Appropriate treatment and disposal is a prerequisite to avoiding the development of conditions that may endanger public health and welfare.

However reutilization of wastewater is an imperative approach for safeguarding water possessions, wastewater management is not a main concern of governments, municipal authorities or industrialists because it is not treated as one of the profit-making processes. In the absence of waste treatment technologies and transmission of water-borne diseases, as is normally the case in Nepal, the environmental damage costs to the society works out to be more than the financial costs. Due to the national and international legislation and standards, some of the waste streams were being started to treat since past some years. There are a few number of wastewater treatment plants, mainly located in Kathmandu valley (Shrestha *et al*., 2001) but most of the plants based on central wastewater treatment strategy are not operating well. Decentralized wastewater treatment such as constructed wetlands are amongst the proficient technologies to treat wastewater in Nepal (WaterAid, 2008). The paper summarizes the state of wastewater production and treatment technologies in Nepal. It also discusses the feasibility, sustainability and commercially attractiveness of the decentralized wastewater management system.

2. Methodology

This study was conducted by visiting various waste water treatment plants in Nepal. For the survey and investigation, relevant data was collected from several different sources including different organizations, research papers, internet surfing and various literatures. Data collected was processed, reviewed and edited. The data was tabulated and analyzed as well. Because of the lack of uniform data, several generalizations had to be made during the data analysis process.

3. Results and Discussion

3.1 Wastewater management practices

Wastewater, critically exaggerated as a result of anthropogenic influence was noted to have increased significantly in Nepal since 1970, especially in the urban areas because of high growth rate of urban population, disorganized expansion of infrastructure and services for water supply, sanitation and wastewater management (Shukla *et al.*, 2012). Common waste management practice in Nepal involves discharging of untreated sewage, domestic waste, industrial waste and municipal waste into aquatic environments without proper treatment (Jha *et al.*, 2011). The wastewater is being discharged in water resources such as streams, lakes, rivers that are close to the society or urban center. The discharge of wastewater depends essentially on rate of water supply and consume by residential households, restaurants, hotels, markets, institutions, hospitals, industries and commercial complexes. Wastewater produced from the domestic routes includes grey water and black water produced in washing, cleaning, bathing and sanitary uses. Only small numbers of houses are connected to sanitary wastewater system and therefore most houses end up disposing the wastewater directly into the rivers and other water bodies (Ellingsen, 2010). Due to insufficiency in water supply, the contamination in wastewater has been increasing along with the generation. In the urban centers, sewers are often present but sewage treatment is lacking (Shrestha *et al.*, 2001). Sewage is correctly subset of wastewater that is contaminated with feces or urine. Discharging the polluted wastewater in water resources turns them into open sewers. As a result, pollution of the rivers is more severe and critical near urban stretches. Major rivers flowing via Kathmandu Valley are deeply polluted and consequently infected by a variety of pathogens (Haramoto *et al.*, 2011). Unplanned urbanization and industrialization are making the situation worst day by day. Most of the municipals are using on-site sanitation services including pit latrines, septic tanks and pour flush toilets. Almost all Nepalese urban centers have inadequate facilities to collect and treat wastewater. It seems that there is no chance of considering to provide investment for adequate sanitation facilities in near future. It is anticipated that only about 12% of urban households, mainly in Kathmandu valley, are connected to the sewer system (WaterAid, 2008). The wastewater of all kinds including grey water, landfill-leachate and septage of septic tanks is released straightforwardly in Bagmati, Bishnumati and Dhobikhola with no proper treatment through sewer system in Kathmandu valley (Ellingsen, 2010). In other cities also, the wastewater even containing very high pollutants and pathogens is discharged into the nearby rivers or water streams.

Wastewater generated from the industries has been another source of wastewater. The industries producing significant amount of wastewater in the country include brewery, distillery, cigarette, tobacco, cement, iron, steel, rosin, turpentine, soap, oil, ghee, jute, paper, sugar and leather industries. Total of 4500 industrial units of different sizes are estimated to be operating in different parts of the country and the concentration of industries are large in Kathmandu Valley and some urban centers (Birgunj, Biratnagar, Bharatpur, Butwal and Bhairahawa) in Terai-Madhesh (Shukla *et al.*, 2012). The wastewater generated in most industries is mixed with the municipal sewerage system while the solid industrial waste is collected and dumped into pits or in open spaces (Jha *et al.*, 2011). Since the wastewater generated in the industries contain high loads of oxygen demanding wastes, synthetic organic compounds, inorganic chemicals and minerals, these lead to significant degradation in the water quality at the local level.

Table 1: Wastewater treatment plants in Nepal

Plant	Type	Capacity MLD	Status	Remarks
Dhobighat	Non-aerated lagoons	15.4	Not Operational	Needs Rehabilitation
Kodku	Non-aerated lagoons	1.1	Partial Operational	Needs Rehabilitation
Sallaghari	Aerated lagoons	2.0	Partial Operational	Needs Rehabilitation
Hanumanghat	Aerated lagoons	0.5	Under Construction	Needs Rehabilitation
Guheshwori	Activated sludge	17.3	In partial operation	

In addition to wastewater and sewage from domestic and industrial sources, the rivers also receive inputs of storm water directly from the roads and streets in the urban areas and the runoff originating from the agricultural lands. The streets in the urban areas contain different kinds of solid wastes in different volumes which get emptied directly into the river after every rain storm and become important part of wastewater and contributor of river pollution. Though the present level of use of inorganic fertilizers and other agricultural chemicals in Nepal is much lower than other countries in the region, the use of agricultural chemicals and fertilizers has increased in some areas, especially in Kathmandu valley and agriculturally prosperous districts in Terai-Madhesh (Basnyat, 1999).

3.2 *Existing wastewater treatment plants*

The pace of development of infrastructure and services for wastewater treatment has been basically inadequate and incomplete to meet the needs. Only few units for treating wastewater exist throughout the state (Table 1) and even these are not functioning well (Green *et al*., 2003). However, 370 million liters per day (MLD) wastewater is produced, the existing wastewater treatment systems can treat only 37 MLD. It is estimated that only 5% wastewater is presently being treated (Nyachhyon, 2006). The initiative for wastewater treatment has been commenced after Binnie and Partners, U.S.A. suggested to use stabilization pond system for the treatment of wastewater in Nepal three decades ago. A treatment plant of 17x106 L/day capacity was constructed on the basis of that recommendation however it was discontinued to operate after few years of operation.

The wastewater-managing hitch is rigorous in major cities of Nepal including Kathmandu Valley. In the year of 1980, four wastewater treatment units were constructed in Kathmandu Valley. One of them was built in Sundarighat in order to treat wastewater of the central parts whereas another plant was put up in Balkumari in order to treat wastewater of Lalitpur. The other two locate in Sallaghari and Hanumanghat areas of Bhaktapur (Green *et al*., 2003). These lagoon-in-series-type units are treating wastewater using sedimentation as well as biological degradation processes. Even though they are simple without mechanized parts, these units are still not working sound due to poor operation and maintenance as well as mismanagement. The two anaerobic ponds and one facultative pond at Sundarighat for treating sewage and having design capacity 15.4 MLD is not in operation due to non-functioning of pumping station and breakage of pumping main laid across the bed of Bagmati River. The treatment plant at Balkumari with two anaerobic ponds, one facultative and one maturation pond, of 1.1 MLD capacities is partial in operation. The sewage treatment at Bhaktapur, 2 MLD capacities is not in operation due to failure in pumping station and farmers tapped the wastewater to irrigate their cropland. The Department of Water Supply and Sewerage (DWSS) has started to construct a sewage system of about 6 km of sewer line and a treatment plant (lagoon type) on 20.54 hectors to serve design population of 53000 in Thimi, Bhaktapur.

In 2001, the first activated sludge wastewater treatment plant of 17.3 MLD capacity is constructed and partially in operation at Guheshwori, Kathmandu to clean up the Bagmati River. It consists mainly of mechanical bar rack and grit compartment for screening, aeration tank by means of activated sludge as well as a settling reservoir. Unlike oxidation ditches used smaller plants, it lacks primary clarification tanks (Green *et al*., 2003).

Table 2: Constructed wetlands treatment plants in Nepal

Plant	Location	Capacity (m3/day)	Treating
Dhulikhel Hospital	Dhulikhel	40	Hospital wastewater
Private house at Dallu	Kathmandu	0.5	Grey water
Kathmandu Metropolitan City	Kathmandu	40	Septage
Malpi International School	Kathmandu	25	Wastewater
Sushma Koirala Memorial Hospital	Kathmandu	15	Wastewater
Kathmandu University	Dhulikhel	40	Wastewater
Staff Quarter of Middle Marshyangdi Hydro Electric Power Station		26	Wastewater
ENPHO Laboratory	Kathmandu	1	Wastewater
Kapan Monastery	Kathmandu	17	
KMC Septage and Leachate Treatment Plan	Kathmandu	Septage:75 Leachate:40	Septage and leachate
Sunga Municipal	Lalitpur	25	Wastewater
Septage and Leachate Treatment system for Pokhara Submetroploitan City	Pokhara		Septage and leachate
Tansen Municipality Sewerage Treatment Plant	Tansen		Sewerage

The plant has been treating wastewater produced from houses, institutions and industries in the areas of Bouddha, Jorpati, Gokarna and Chabainhil in Kathmandu. Green *et al*. (2003) reported that the performance of the plant in 2001 was not so satisfactory as it could only remove 54% TSS, 78% COD and 91% BOD5. In addition, it has high both installation and operating costs as well as large energy needs.

These wastewater treatment units are not performing sound because of complex operation and maintenance, expensive spare parts, high prices of chemical additives, electricity expenses and be short of skilled human resources. In this context, wastewater treatment technologies should be quantified from technical, environmental, economic and socio-cultural perspectives. It can be noted that Nepal as like other low-income countries can not afford capital investment as well as having no expertise for complex central wastewater treatment approach. Another central issue for the sustainability of the wastewater treatment technologies is how the systems can be operated and maintained effectively in a simple manner. In the context of Nepal, this treatment technology should be of simple construction, should work efficiently, be preferably of low in cost and easy to maintain.

3.3 Decentralized wastewater management systems

Unlike energy intensive and expensive central approaches, decentralized wastewater treatment systems (DEWATS) can be operated nearby the source of wastewater. Though it treats comparatively small mass of wastewater, the beauties of DEWATS are simplicity, low investment, easy operation, high efficiency and low maintenance (WaterAid, 2008).

Anaerobic digestion process is regarded as a suitable tool in order to treat organic matters including grey-water, black-water and faecal sludge. Unlike aerobic process that is energy consumer, it produces biogas along with organic fertilizer. The anaerobic options incorporate simple septic tanks and anaerobic waste stabilization ponds to high efficient bioreactors such as anaerobic filters, upward-flow anaerobic sludge blanket reactors and anaerobic baffled reactor. It has potential for widespread applications. The major drawback of this system is the effluents are required to treat aerobically to meet effluent discharges standards. Waste stabilization ponds mean anaerobic or facultative ponds, which connect both anaerobic and aerobic processes. Simplicity, low cost and reduction of a large variety of pathogens due to its lengthy digestion period are the conspicuous benefits of this system whereas requirement of large area and long retention time are major drawbacks.

Constructed wetland (CW) is considered as one of the suitable biological technology based on natural processes for decentralized wastewater treatment, especially for rural communities, small towns, institutions, individual households and villages. It is actually deigned alike natural wetlands but has controlled conditions. Wastewater is evenly poured over superficial basin that is filled with stone, gravel, sand and reeds for filtering contaminants. In this system, Phragmites karka is commonly utilized as vegetation. The CW degrades organic materials and pollutants due to plant-bacterial symbiotic reactions among wastewater, media, plants and microorganisms (Bista and Khatiwada, 2004).

Table 2 discloses some of major constructed wetland plants in Nepal to treat hospital, domestic and grey wastewater, septage and leachate. The first constructed wetland system of 10 m^3/day capacity at Dulikhel Hospital was built in 1997 by Environment and Public Health Organization (ENPHO) to treat hospital wastewater. Shrestha *et al*. (2001) observed that more than 95% of the major pollutants including TSS, organic materials, and NH_3-N had been removed during the interval of time 1997-2000. The elimination rate (approximately 99.99%) of *E. coli* was even superior. Green *et al*. (2003) reported as per data of July 2002 to Jan 2003 that the removal efficiencies were significantly reduced. Due to its successful operation, thirty more constructed wetland systems have been installed at various locations in last 15 years, including hospitals, schools, university, and individual households. The two-staged sub-surface flow technique (Reed Bed Treatment System) sort of constructed wetland with 0.3-0.6 m depth of the media is mainly in use in Nepal. In 1998, Kathmandu Metropolitan City installed constructed wetlands wastewater treatment plant of approximately 50 m^3/day by means of 200 m^3 settlement tank, 3x 75 m^3 of gravel-sand filter beds and 362 m^3 vertical reed-bed in order to treat septic-wastes (Bista and Khatiwada, 2004). The Malpi International School has implemented an identical technique to treat residential wastewater prior to releasing the water in DeRosie River in Panauti. Similarly, the Sushma Koirala Hospital, Sankhu and Kathmandu University, Banepa also constructed wastewater treatment plants based on constructed wetland method. Lamichane *et al*. (2011) evaluated wastewater treatment plants sited at different parts in Nepal and observed that the treatment plant of Kathmandu University has sound performance in term of removal efficiency of organic matter. One household constructed wetland technology at Dallu, Kathmandu is running successfully to treat and recycle the domestic grey wastewater. The treated water is being used for washing, gardening and flushing. The foremost community-based constructed wetland plant of 375 m^2 area was constructed at Sunga, Bhaktapur to treat domestic wastewater in Nepal. The treatment plant consists of a coarse screen as well as a grit compartment for preliminary treatment, an anaerobic baffle reactor of 42 m^3 for primary treatment, horizontal flow followed by vertical flow reed-beds for secondary treatment and two sludge-drying beds in order to treat sludge. It is presently serving to 80 households by treating wastewater of 10 m^3/day in average. The biggest constructed wetland (1645 m^2 area) of Nepal with seven sludge-drying beds was constructed in Pokhara in order to treat faecal sludge as well as landfill-leachate. Green *et al*. (2003) reported that the performance of the plant is satisfactory in terms of reduction of TSS, NH_3-N, COD, BOD and pathogens. The treated wastewater can be reused for non-drinking water whereas the sludge is beneficial as soil conditioner. A biogas plant, recently affixed to the treatment plant is recovering renewable energy and organic fertilizer.

As constructed wetlands are comparatively cheap, simple and easy to operate, it has an enormous potential to be successful in low-income nations like Nepal (Shrestha *et al*., 2001). Due to having warm tropical and subtropical climates in Nepal, there is a chance of better biological activity and consequently better performance of constructed wetlands. Although the prospective for the usage of constructed wetlands in Nepal is huge, the dissemination of the CW is unsatisfactory. The reason for this could be lack of awareness, information and familiarity. Hence, advocacy, training and policies might play vital roles for its development. However, its construction, design, operation and maintenance is simple, requirement of a large land area may limit its usage. Green *et al*. (2003) suggested that chemically enhanced primary treatment is an alternate and viable wastewater technology for Nepal. The construction and operational costs of chemically enhanced primary treatment plant are generally lower than those of traditional biological wastewater treatment plant. Not only this, the chemical costs are comparable to the high energy cost for biological treatment in Nepal. Advanced integrated pond system containing an anaerobic pit underneath an oxygenated together with aerobic bioreactor might be viable and cost effective wastewater technology in Nepal as well (Green *et al*., 2003). This wastewater technology is apt in state of common wastewater stream as well as extremely inconsistent flow rates and organic loading rates, particularly in cases of inadequate industrial pretreatment and in the existence of toxic materials and heavy metals (Swanson, 2002).

4. Conclusions

It is needed to consider wastewater as a resource and broaden its uses. The existing problems of wastewater treatment in Nepal can be solved using appropriate and viable technologies. The centralized and complex technology based solution to wastewater management was noted to have failed in addressing the wastewater problem in Nepal. Decentralized wastewater treatment systems including constructed wetlands are supposed as effective, economic and environmentally friendly and sustainable systems in context of Nepal. The effective policies at local and national levels can accelerate decentralized wastewater systems in Nepal.

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