

Strategies For Wastewater Treatment in Kathmandu Valley.

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Introduction

Wastewater is a big problem in Kathmandu valley. The control of pollution due to sewage is prime concern of the city. It is essential to control pollution due to sewage in the view of social responsibility and other indirect advantages of pollution control e.g. control of diseases, aquatic life in the water bodies, aesthetic values of water bodies etc.

The Bagmati River, which runs through Kathmandu, has been poorly managed for decades. The pollution of water leads to poor environmental situation which risks of water borne diseases. The pollution of rivers and other water bodies deteriorates the aesthetic and recreational values of the city. River is the showpiece of the city. It should be preserved. The pollution problem due to the organic load in the natural water bodies of the valley is alarming. The water downstream of the river water cannot be used for any beneficial purposes.

Only about 25 percent of people in Kathmandu have access to a proper sewerage system. There is no operating wastewater treatment facility in Kathmandu other than small wastewater treatment facilities operated by Municipality, private sectors and the industries. Very few numbers of industries treat their wastewater. This is also one of the major problems in the wastewater treatment of Kathmandu valley. Untreated water from individual latrines, factories and municipal sewers is commonly discharged into natural water bodies. Most of the newly built houses use septic tanks since there is no easy access to municipal sewage. The municipal pollution characteristics are pathogenic bacteria, suspended solids and oxygen consuming organic matter. In the city, these are disposed collectively, thus over burdening the receiving water bodies thereby lost self-purification capacity.

The industries discharge their effluents either in the domestic sewers or directly into the rivers. Sewerage networks, domestic wastewater are also discharged into the river. The river water of Kathmandu valley is unfit for any beneficial use. Studies show that its ecosystem has been destroyed in such an extent that the aquatic life is now non-existent. The rivers of Kathmandu valley seem to be open sewage. No organized projects have been conducted to abate water pollution in the valley.

In the view of the deteriorating situation and significant contribution of organic load through sewage, it is considered essential to suitably treat sewage before introduction into the river. To cope of these facts, integrated approach to wastewater collection, transportation, disposal and treatment has been important to improve environmental quality of the city. There are currently no sewage treatment plants in operation in

Kathmandu. A sewage treatment plant (Oxidation Pond) was constructed in Dobighat by funding of World Bank in 1970s. The treatment plant is not in operation nowadays. A Reed Based Treatment System (RBTS) is in experimental phase in Teku middle of city. A wastewater treatment plant is operational in Pashupati area, northeast part of the city. This plant intended to treat wastewater from Jorpati area before it discharges into Bagmati River near Pashupatinath, the biggest Hindu Temple in Nepal. But this treatment plant is not in good operational condition due to heavy influent load.

Strategies for wastewater treatment in Kathmandu valley

Construction of Conventional Treatment Plants with Combination with Anaerobic Digester

In **short term strategy**, the low cost technology has been proposed. The health of the people cannot be put into risk due to the water pollution. Hence, the quick and economic option has been chosen for the short-term strategy.

Apart from the operation of rehabilitated treatment facilities conventional plants, (activated sludge process or oxidation ditch) in combination with anaerobic digester after primary sedimentation is proposed in **long-term strategy**. The combination of anaerobic digester is capable for the production of biogas. The biogas energy is used for various purposes. It will help to generate income. This is one of the ways to make treatment plant economically viable and sustainable. The technology using only conventional technology e.g. activated sludge process and treatment plant with extended aeration will cost lots of money. The plant thus will not be sustainable in the context with the countries with poor economy. The operational as well as maintenance cost is very high in these processes. Likewise, the effluent quality would be better in terms of removal of Nitrogen unlike only using activated sludge process.

The conventional treatments plants are the ultimate alternative for urban areas, since land resources are usually expensive and conventional takes up less space and produce effluent quality. Due to excessive land cost in Kathmandu valley, the existed lagoons are about 500% more expensive on per person basis than conventional one.

For the convenience of operation and maintenance, one treatment plant would have been a best alternative. But the geographical structure of Kathmandu valley is barrier for this alternative. Likewise, long interceptor is required to sole purpose of reaching the site. Several pumping stations may be required to lift the sewage. Therefore, to serve different catchments, number of plants should be built.

i) Rehabilitation of Dobighat Oxidation Pond and Construction of other Oxidation ponds

The rehabilitation of the pond is very important. This is the only one sewage treatment plant, which have connections of the downtown of the Kathmandu City. The pond can be rehabilitated in different ways.

Option I: Anaerobic Digestion of sludge and Duckweed Pond

The effluent in the pond is fed into the sedimentation tank. The sludge of the pump is pumped into the anaerobic digestion. The effluent of the pond is fed into the duckweed pond.

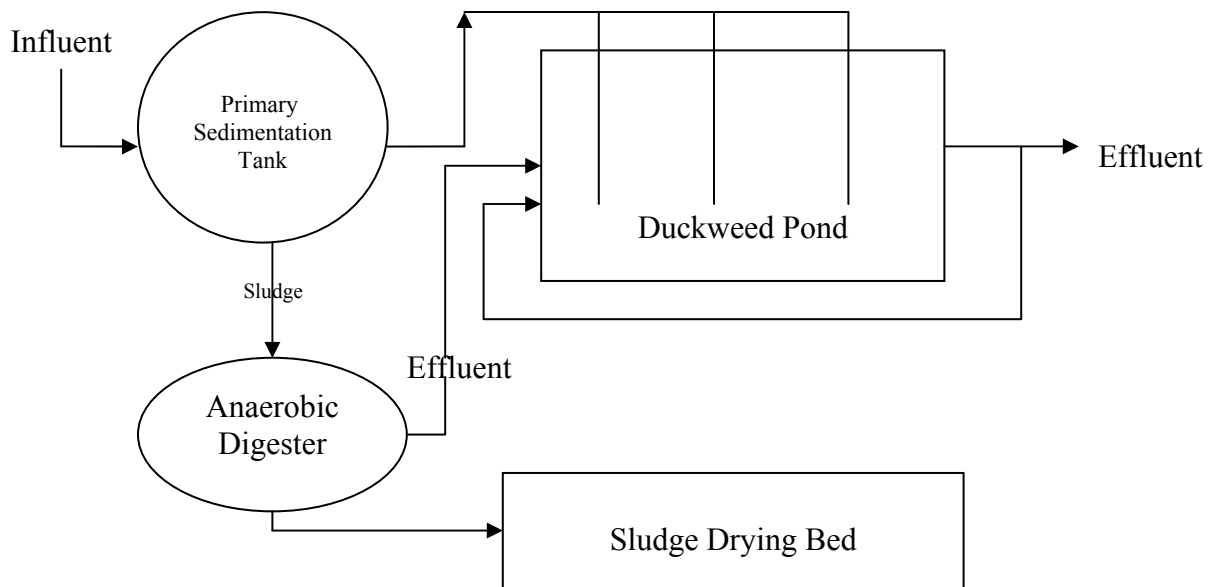


Fig. Proposed Flow Diagram of Rehabilitation of Oxidation Pond

Primary sedimentation

The pond receives the wastewater from 96,000 P.E. The per capita consumption of water in this area is about 70 l/day. The BOD concentration is about 375 mg/l and COD concentration is about 850 mg/l.

$$\text{Flow} = 6720 \text{ m}^3/\text{d}$$

Overflow rate (surface loading rate) at average design flow = $40 \text{ m}^3/\text{m}^2 \cdot \text{d}$, assuming BOD removal 35% and TSS removal 60%.

$$\begin{aligned} \text{surface area of sedimentation tank} &= \frac{6720 \text{ m}^3/\text{d}}{40 \text{ m}^3/\text{m}^2 \cdot \text{d}} \\ &= 168 \text{ m}^2 \end{aligned}$$

Assuming length-wide ratio = 4:1

$$4W:W = 168 \text{ m}^2$$

$$W = 6.5 \text{ m}$$

$$L = 26 \text{ m}$$

The depth of the tank = 3m

$$\begin{aligned} \text{BOD concentration of primary effluent} &= 0.65 \times 375 \text{ mg/l} \\ &= 243 \text{ mg/l} \end{aligned}$$

$$\begin{aligned} \text{BOD load} &= 243 \text{ mg/l} \times 6720 \text{ m}^3/\text{d} \\ &= 1632.97 \text{ kg/d} \end{aligned}$$

flow of primary effluent,

= Avg. flow in sed. tank – sludge withdrawal

$$= 6729 \text{ m}^3/\text{d} - \frac{1632 \text{ kg/d} \times 1000 \text{ g/kg}}{0.045 \text{ g/g} \times 1.03 \times 1 \text{ g/cm}^3 \times 10^6 \text{ cm}^3/\text{m}^3}$$

Assuming, 1g sludge = 0.045 g BOD

Sp. density of sludge = 1.03

$$= 6720 \text{ m}^3/\text{d} - 35.21 \text{ m}^3/\text{d}$$

$$= 6685 \text{ m}^3/\text{d}$$

After sed. tank, the sludge is pumped into anaerobic digester and effluent is fed in duckweed pond.

Anaerobic sludge digester

Assuming, sludge residence time = 15 d

$$\begin{aligned}\text{volume of digester} &= 35.21 \text{ m}^3/\text{d} \times 15 \text{ d} \\ &= 528.15 \text{ m}^3\end{aligned}$$

Biogas production

Digestion 1 kg COD gives 0.35 m³ of CH₄ at NTP
1 kg of COD gives 0.5 m³ of biogas (70% methane)

$$\begin{aligned}\text{Total COD load} &= 6720 \text{ m}^3/\text{d} \times 850 \text{ mg/l} \\ &= 5712 \text{ kg/d}\end{aligned}$$

$$\begin{aligned}\text{COD in effluent} &= 6685 \text{ m}^3/\text{d} \times (850 \times 0.65) \text{ mg/l} \\ &= 3693.46 \text{ kg/d}\end{aligned}$$

$$\begin{aligned}\text{COD load in sludge} &= \text{Total COD load} - \text{COD in effluent} \\ &= 5712 \text{ kg/d} - 3693 \text{ kg/d} \\ &= 2018 \text{ kg/d}\end{aligned}$$

Assuming, anaerobic digestion is about 80%, the COD digested

$$\begin{aligned}0.8 \times 2018 \text{ kg/d} \\ = 1614 \text{ kg/d}\end{aligned}$$

At NTP 1 kg of COD give 0.35 m³ of CH₄
1614 kg of COD gives 564.9 m³ of CH₄

$$\text{i.e. } \frac{564.9 \times 16}{22.4} = 403.57 \text{ kg of CH}_4$$

$$= 20340 \text{ MJ}$$

(1kg of CH₄ gives 50,400 kJ)

Hence, calorific value = $403 \times 50,400 \text{ kJ} = 20340 \text{ MJ}$

$$= 5650 \text{ kwh/d}$$

(1 Kwh is equivalent to $3.6 \times 10^6 \text{ J}$)

Duckweed Pond

The effluent of sedimentation tank is fed into the duckweed pond. Considering the equation (Reed et. al, 1988),

$$\frac{C_e}{C_0} = e^{-K_T \times \text{HRT}}$$

where,

C_e = effluent of BOD concentration (mg/l)

C_0 = influent of COD concentration (mg/l)

K_T = first order rate constant

HRT = hydraulic retention time

$$K_T = K_{24} \times (1.06)^{T-24} \quad (\text{Assuming, } K_{24} = 0.2078 \text{ for duckweed pond})$$

$$= 0.2078 \times (1.06)^{15-24}$$

$$= 0.12 \text{ d}^{-1}$$

$$\frac{C_e}{C_0} = e^{-K_T \times \text{HRT}}$$

Assuming, effluent BOD 25 mg/l

$$\frac{25}{240} = e^{-0.12 \times \text{HRT}}$$

$$\text{HRT} = 18.8 \text{ d.}$$

depth of pond = 1m

flow = 6685 m³/d

$$\begin{aligned} \text{area of pond} &= \frac{6685 \text{ m}^3/\text{d}}{1 \text{ m}} \times 18.8 \text{ d} \\ &= 125678 \text{ m}^2 \\ &= 12.5 \text{ ha.} \end{aligned}$$

Removal of nitrogen also can be calculated by the equation (Reed et.al. 1995),

$$N_t = N_0 e^{-kt}$$

N_t = Total effluent of nitrogen mg/l

N_0 = Total influent of nitrogen mg/l

k = Reaction rate, day⁻¹

t = Detention time in days

Assuming temperature in summer, 27⁰C and plant density 73 kg/ha (Readdy et.al 1987)

$k = 0.074$

$$N_t = 100 \times e^{-0.074 \times 19}$$

$$N_t = 24.51$$

removal of nitrogen = 75%

For winter temperature 14⁰C and plant density 40 kg/ha

$k = 0.028$

$$N_t = 100 \times e^{-0.028 \times 19}$$

$$N_t = 58.75$$

nitrogen removal = 41.25%

Sludge drying bed

Assuming 0.15 m² per capita,

area required for sludge drying bed = 0.15 m² X 90000

$$= 14400 \text{ m}^2$$

$$= 1.5 \text{ ha.}$$

Option II: anaerobic sewage treatment

In this option, the sewage is fed into the anaerobic digester. This type of treatment is also used in many cases. The average sewage temperature is moderate in Kathmandu.

Assuming HRT = 12 h

(sewage temperature is 10-15 °C)

$$\begin{aligned} \text{volume of reactor} &= 0.5 \times 6720 \text{ m}^3/\text{d} \\ &= 3360 \text{ m}^3 \end{aligned}$$

For reactor volume exceeding approximately 1000 m³, it is beneficial to build system consisting of more than one unit (Haandel et.al, 1994). Hence, it need more than 4 reactors.

Biogas production

To generate 1 mmole l⁻¹ CH₄, 4 mmole l⁻¹ of COD is required

To generate 1 mg l⁻¹ of CH₄ 64 mg l⁻¹ of COD is required

Knowing, 1 mole of CH₄ (16g) has volume 22.4 l at NTP
At , (15+273) K = 288 K

$$\text{volume of gas} = \frac{250 \times 22.4 \times 288}{273 \times 16} = 369.23 \text{ l CH}_4 / \text{kg of COD}$$

$$\begin{aligned} \text{Volume of gas produced} &= \frac{f_m \times 369.23}{p_m} = \frac{2/3 \times 369}{0.75} \\ &= 328 \text{ l/ kg COD} \end{aligned}$$

where,

p_m = partial pressure of methane

f_m = the fraction of collected methane

$$\text{COD load} = 6720 \text{ m}^3/\text{d} \times 850 \text{ mg/l}$$

$$= 5712 \text{ kg/d}$$

Assuming Digestion efficiency 80% and the digested amount of COD ;

$$0.8 \times 5712 \text{ kg/d} = 4569.6 \text{ kg/d}$$

COD per litre of sewage = 0.68 g/l

4569.6 kg of COD give $4569.6 \text{ kg} \times 0.35 \text{ m}^3 = 1599.36 \text{ m}^3$ of methane

$$\text{wt. of methane} = \frac{16 \times 1599.3 \text{ m}^3}{22.4} = 1142.4 \text{ kg CH}_4$$

The amount of methane dissolved in water is 15mg/l

i.e. $15 \times 96000 \times 70 = 100.8 \text{ kg}$ of COD

As the partial pressure of methane is 0.75 atm., the solubility of methane in water is given by,

$$0.75 \times 20 = 15 \text{ mg/l (the solubility of CH}_4 \text{ is 20 mg/l)}$$

$15 \times 4 = 60 \text{ mg/l}$ of COD is required to form 15 mg/l of methane

i.e. 60 mg/l of COD is lost by dissolving 15 mg/l of methane in water phase.

4569.6 kg of COD give $4569.6 \text{ kg} \times 0.35 \text{ m}^3 = 1599.36 \text{ m}^3$ of methane

$$\begin{aligned} \text{volume of gas at 288 K} &= \frac{288 \times 1599.36}{273} \text{ m}^3 \\ &= 1683.23 \text{ m}^3 \end{aligned}$$

The amount of methane dissolved in water is 15mg/l

i.e. $15 \times 10^{-3} \times 96000 \times 70 = 100.8 \text{ kg}$ of CH₄

At NTP 22.4 l of CH₄ weigh 16 gm

$$\text{volume of gas} = \frac{22.4 \times 100.8}{16} = 141.12 \text{ m}^3$$

At 288 K,

$$\text{volume of gas} = \frac{288 \times 141.12}{273} = 148.87 \text{ m}^3$$

$$\text{loss of methane} = \frac{149}{1683} \times 100\% = 8.8 \%$$

Likewise, there will be other losses as well. In practice, the losses may be between 20 and 50 per cent of produced gas (Haandel et.al. 1994).
Assuming 35% losses,

$$\begin{aligned} \text{available methane gas} &= 1142.4 \times 0.65 \\ &= 742.56 \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{calorific value} &= 742.56 \times 50,4000 \\ &= 37425 \text{ MJ} \\ &= 10395 \text{ kwh/d} \end{aligned}$$

In the anaerobic sewage treatment method, a big digester or series of digester is required. About digester volume 3360 m³ is required. But in digester volume of 528 m³ only is required in anaerobic sludge digestion method. The calorific value by the anaerobic sludge digester and anaerobic sewage digester is 5250 kwh/d and 10395 kwh/d respectively. Even the volume of anaerobic sewage digester is 6 times greater than anaerobic sludge digester; it hardly produces double calorific value. Hence, anaerobic sewage digester is not efficient and not feasible. In many cases, it is uneconomical to use produced gas a fuel.

Rehabilitation of Dobighat Oxidation pond by using anaerobic sludge digester and duckweed pond, it can treat wastewater more than 96000 P.E. giving rise to good effluent quality. According to Department of Waster Supply and Sewerage (DWSS), if the pond is rehabilitated without modification of current situation, it can serve on year around 42% of present connections.

The area of pond is about 20.4 hectare. When anaerobic sludge digester and duckweed pond is used with BOD effluent of 25 mg/l, it can serve fully or more than 96000 P.E. Thus, this combination of treatment is very efficient. Likewise, the produced gas can be used as fuel for heating of the digester and other purposes. The harvested duckweed also can be used as fish and cattle food.

Rehabilitation and construction of other oxidation ponds also should be carried out as soon as possible according to the combination suggested before to serve on the more connections added to the plant in the future.

ii) Expansion of Treatment Facilities with Constructed Wetlands

Kathmandu Municipal Corporation presently on way of construction of constructed wetlands in different parts of the city. Since, there are no sewage treatment plants in operation, these types of facilities are indispensable. The big and costly treatment facilities can't be built immediately due to the unavailability of money, manpower and management. The need of sewage treatment facilities is very urgent. Therefore, by finding out proper public lands in different parts of the valley, wastewater should be treated. This technology is very simple, efficient in terms of energy and investments.

Conclusion

There are no wastewater treatment facilities available virtually in Kathmandu valley. The facilities, which are existed also, need immediate rehabilitation.

The numbers of oxidation ponds were dug in past three decades. Due to the lack of money and management, the ponds are not in operation.

The oxidation ponds on rehabilitation also cannot serve the increasing population of the valley. The rehabilitation of ponds with combination of sedimentation tank, anaerobic sludge digester and duckweed pond increases the efficiency of the plant substantially. It not only reduces the area of the treatment plant, but also increases the effluent quality. Similarly, the biogas produced by the plant can be used as fuel for various purposes. The harvested duckweed can be used as fish food and cattle food.

Oxidation pond, constructed wetlands can be used for wastewater treatment since these need skilled manpower. There is dearth of skilled manpower in the country. Likewise these technologies are low cost and low energy consuming technologies.

Legislative measure is one of the important means to control pollution due to wastewater. The public must be levied for wastewater treatment apart from drinking water supply.

The conventional wastewater treatment methods e.g. activated sludge process; oxidation ditch can be used in combination with anaerobic sludge digester after sedimentation tank for long term planning. The price of land is very high in the city, so the conventional technologies are the ultimate alternative. In these combinations of methods, the biogas is produced. The produced biogas energy from anaerobic sludge digester can be used as fuel for various purposes.

By the use of appropriate and sustainable technologies in wastewater treatment, the treatment plants can be sustainable, efficient and economically viable.

In the city area, most of the people are using septic tanks without proper lining and soak pit. Proper management of septic tanks is very important to control probable ground water pollution. For long term planning, sewerage networks are necessary to connect with these septic tanks.

The constructed treatment plants, which are, now not in operation should be operated with necessary arrangements. Besides construction of big treatment plants, small treatment plants such as RBTS should be constructed in various places to abate present water pollution. In the city area, most of the people are using septic tanks without proper lining and soak pit, therefore for the time being the government and municipality must be able to aware people about the possible ground water pollution the city. The municipality must be able to transmit message of maintaining proper lining and constructing soak pit in the septic tanks to control the ground water pollution.

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