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A Study on Environmental Improvement of the River Bagmati of Kathmandu Valley, Nepal

Reena Shrestha
Kathmandu University, Kathmandu, Nepal

Peter Krebs, Isolde Roeske
Dresden University of Technology, Dresden, Germany

1. Introduction

The Kathmandu valley, which has been listed in the world heritage list in 1979 comprises the city of Kathmandu, the capital of Nepal, the city of Lalitpur, the third largest city in Nepal and Bhaktapur city. The area is 899 km^2, with 1.5 million population [1]. Tourism is one of the major sources of revenue in the valley. The river Bagmati runs somewhat in the middle of it. The valley is facing a challenge from it. It is the well-known polluted river in Nepal. It is mainly polluted by the domestic and industrial wastewater [2].

Waste stabilization ponds are large shallow basins enclosed by earthen embankments in which wastewater is treated naturally. They indicate that the easily degradable organic materials from the inflowing sewage are processed by bacteria in the same way as in activated sludge system. This technology is cheaper than the activated sludge system because there is no aeration, no desludging, easy operation, etc. The use of oxidation ponds or stabilization ponds in the treatment of wastewater is old technology. The studies on stabilization ponds for domestic sewage and other wastewater in India and other tropical and sub-tropical countries show highly successful results [3]. These results are prompted the study presented in this paper.

2. Climatological conditions and description of ponds

2.1. Climatological conditions

The Kathmandu valley is the largest valley in Nepal with the average monthly air temperature ranging from 2°C in December (only a few days) to 34°C in May. Most of time, the temperature of the Kathmandu Valley is above 15°C. Total pH of surface water ranges 5.3 to 7.7 [4].

2.2. Description of present oxidation ponds

There are three oxidation ponds, Balkumari (for Lalitpur) having inflow rate of 15000 m^3/day, Dhobighat (for Kathmandu) and one in nearly leaving point of the river Bagmati from the valley, Sundarighat having 15800 m^3/day in the Kathmandu Valley. Out of these the first one is not working due to difficulty in collection of wastewater and high cost to pump the wastewater. Other two have not been operated properly and have fallen into disrepair [5].

2.3. Location of collection ponds

The wastewater of the major industries discharging into rivers in Kathmandu are Banswari Tannery, the Balaju Industrial District, a number of carpet factories, the Jawalakhel Distillery and the Patan Industrial District were found to be high BOD and chemically polluted to high degree [6].

The location of primary ponds; collection ponds should be determined before the main anaerobic and aerobic ponds. Points are proposed on the basis of NWSC, 1999, A. Hoffmann, 1994, water quality classes and the final report of Soil Test, Nepal, 1999 [4,5,7]. In the case of the Kathmandu Valley, following arrangement can be made for collection as shown in Table 1.

Table 1. Location of collection ponds
Tabela 1. Położenie basenów zbiorczych

Location	Selection Criteria
Between Gujeswori & Gaurighat	Storm water from airport area, religious area, effluents from carpet factories and untreated sewage discharge from heavily populated area of Boudha and Chabahil
Before Tinkune	Sewage discharge from heavily populated area and new settlements
At Shankhmul	Discharge of untreated sewage from second largest city of the valley, Patan
After Shobha Bhagawati	Industrial and agricultural zone and heavily populated zone

All collection ponds are connected to main collection ponds in Sundarighat, which have oxidation ponds. These oxidation ponds can be used as pre-ponds. The design of the anaerobic and aerobic ponds can be made according to the sewage and effluent load. So, the collection ponds and WWTP are in the same sewer network as in Fig. 1.

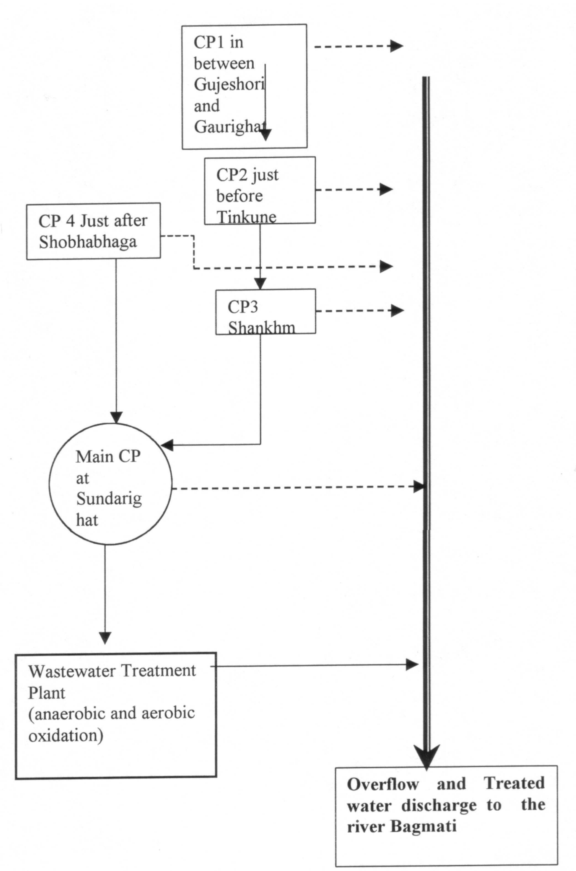

Fig. 1. Sewer network
Rys. 1. Sieć ściekowa

2.4. Design of anaerobic and aerobic ponds

There are mainly four types stabilization ponds; facultative, maturation, anaerobic and high rate ponds. Out of them, anaerobic pre-ponds are popular for a high organic loading like mixed sewage system that is domestic and industrial wastewater that they are completely devoid of dissolved oxygen. They are most advantageous used to pre-treat strong wastes which have a high BOD value. The successful operation of anaerobic ponds depends upon the delicate balance between the acid-forming bacteria and methanogenic bacteria: thus temperature >15°C is necessary and the pond pH must be >6.0. Actually, these are appropriate conditions for the Kathmandu valley. Under these circumstances sludge accumulation is minimal: desludging which is required when the pond is half of sludge, is necessary only every 3÷5 years. The ponds are useful for Kathmandu valley due their capacity, anaerobic ponds can cope with flows more than 10000 m^3/d.

Provided that the pH is >6, BOD reduction in anaerobic ponds is a function of temperature and BOD loading. That means that with increase in temperature and BOD loading, the BOD is reduced. BOD reduction depends upon highly on retention time.

Higher the retention time is higher in BOD reduction. If the retention time is about 5 days, the reduction is 70 percent. The retention time must be more than 5 days for:

- the less risk of odor,
- longer the interval between successive desludging operations,
- the good bacteriological quality of final effluent and
- larger BOD removal.

The retention time, t* can be theoretically calculated from pond volume, V and the flow rate, Q of the inlet wastewater as:

$$t^* = \frac{V[m^3]}{Q[m^3 \cdot d^{-1}]} .$$

The embankment slope for the anaerobic ponds should be 1 in 3 in which the average depth, D should be usually 3 m and the retention time is 5 days, d. In case of the Kathmandu Valley with 150000 m^3/d water demand must have 100000 m^3/d wastewater. So, area, A of the pre-pond must be 0.134 km^2.

An average domestic sewage exhibits a BOD of 250 mg/L. It was also reported that maximum BOD of sewage at main part of city was 250 mg/L (CEDA, 1990). If an outflow BOD of 25 mg/L is acceptable, (which normally is this case) this corresponds to a performance – BOD removal of 90%.

The outflow BOD, S can be calculated by using following formula:

$$S = \frac{S_O}{\left(1 + K^1 t^* / n\right)^n}$$

where:

So – inflow BOD,
K^1 – rate coefficient of BOD removal
n – no. of ponds (n > 1 is better)

Pond I and pond II are aerobic lagoons (Fig.2). The lagoons are activated sludge unit operated without sludge return. They achieve BOD removals >90% at comparatively retention times (2÷6 d). In case of the Kathmandu valley, after the aerobic ponds, the negligible amount of BOD is left. Size of two pond I and pond II is almost same volume and depth as pre-ponds i.e. 0.134 km^2 for the Kathmandu valley. If ponds are arranged in series, so that there is a series of two, three or more cells, the organic loading will relate to total volumes of all ponds. This also means, that the loading to the last cell is much lower than this average loading. According to the successive decrease in L, the biotic structure is different in successive cells as shown in Fig. 2 and Fig. 3.

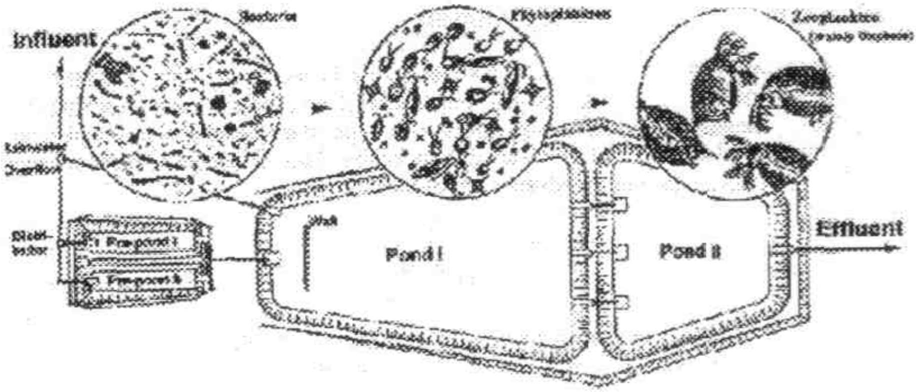

Fig. 2. A series of wastewater lagoons (an oxidation pond systems) including the dominant organism involved
Prepond I: anaerobic pond in operation
Prepond II: anaerobic pond after draining serving as sludge drying bed
Ponds I and II: aerobic ponds

Rys. 2. Seria lagun ściekowych (systemy stawów utleniających) zawierające dominujące zaangażowane organizmy
Staw wstępny I: działający staw beztlenowy
Staw wstępny II: staw beztlenowy po zdrenowaniu służący do odwadniania osadu
Stawy I i II: stawy tlenowe

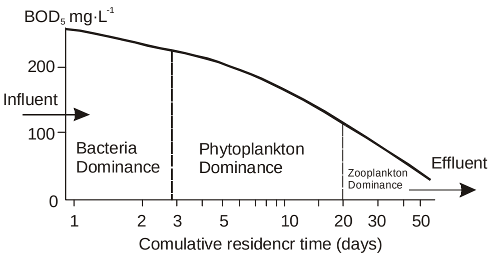

Fig. 3. Relationship between BOD load, dominating organisms and cumulative residence time of water in stabilization ponds

Rys. 3. Zależność między ładunkiem BZT, dominującymi organizmami i łączny czasem przebywania wody w stawach stabilizacyjnych

An abundant phytoplankton growth occurs and the fecal bacteria is nearly inactivate in the pond I. These phytoplantons generate oxygen for oxidation in aerobic ponds by photosynthesis. In pond II, zooplankton such as Daphnia can grow very well and remove surplus phytoplankton biomass and fecal bacteria. It is better if there is no fish in the pond to get non-return pond system.

2.5. Operation and maintenance

This treatment of wastewater by oxidation ponds system is very simple as compared to other systems with biological wastewater treatment. Ponds can effectively treat a wide variety of domestic, industrial and agriculture wastewater. They are able to withstand organic and hydraulic shock loads or at least have a much higher buffering capacity (also with concern to the inflow of stormwater) than other wastewater treatment systems. The minimum maintenance requirements are the following: regular cutting of grass embankments to remove all emergent vegetation. This can also be done by sheep or goats

Desludging of sub-tropical ponds is rarely required. The intervals normally are not shorter than 10÷15 years in many cases they are still longer. This is valid only for ponds which are situated in plains. In hilly areas, stormwater with a high content of slit will be introduced into the ponds. Thus, their desludging may become necessary at shorter intervals.

3. Conclusion

This study is concerned with the fact that the river Bagmati of the Kathmandu valley are polluted and degraded, in a broad sense which includes the loss of cultural and religious values as well as reduced environmental quality and physical dimensions. The main and most important cause of the river Bagmati pollution is inadequate wastewater disposal. Briefly, we can say due to discharge of untreated sewage and industrial effluents into biological oxidation method can be used to treat these wastewaters.

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Badania nad środowiskowej poprawą rzeki Bagmati w Dolinie Kathmandu, Nepal

Streszczenie

Dolina Kathmandu w Nepalu została wpisana na listę dziedzictwa światowego w 1979 roku. Turystyka jest jednym z głównych źródeł dochodu w dolinie. Rzeka Bagmati biegnie przez jej środek. Dolina Kathmandu staje wobec wyzwania spowodowanego przez tą rzekę.

Zrzut przemysłowych i komunalnych ścieków do rzeki Bagmati przez dwie dekady spowodował stopniowe pogorszenie jakości jej wód. Obecnie, można powiedzieć, że rzeka Bagmati, która jest symbolem czystości i świętości dla ludzi w Nepal, jest „rzeką ścieków", która może nawet zanieczyszczać wody gruntowe. Celem badań jest zasugerowanie możliwej do wykonania oczyszczalni ścieków z beztlenowymi stawami wstępnymi i tlenowymi lagunami, które są popularne w krajach z gorącym klimatem. Ten system oczyszczania ścieków w stawach utleniających jest bardzo prosty w porównaniu do innych systemów z biologicznym oczyszczaniem ścieków. Stawy mogą skutecznie oczyszczać szeroki zakres ścieków komunalnych, przemysłowych i rolniczych. Są w stanie stawiać czoła szokowym ładunkom organicznym i hydraulicznym albo co najmniej mają dużo większą pojemność buforową (również w stosunku do napływu wód burzowych) niż inne systemy oczyszczania ścieków. Poza tym, podano sugestie, by polepszyć jakość wód rzeki Bagmati.