Constructed Wetland as a Leachate Treatment Option in Nepal

Bibhuti Ojha
Department of Civil Engineering
Nepal Engineering College, Nepal
bibhutio@nec.edu.np

Bibhuti Ojha *has received her Master's degree in Water Engineering Management from Asian Institute of Technology, Bangkok, Thailand. She is faculty of Nepal Engineering College, Civil Engineering Department, since 2013. Her ongoing research and project works are related to wastewater treatment technology, sustainable wastewater management and sustainable irrigation technology. She has experience and skill in designing sewer network, waste water treatment plant, water supply network and water treatment plant.*

Abstract–

Leachate is a complex and toxic liquid generated in a landfill site that is detrimental to the environment if not managed properly. Constructed wetland is considered as an environmentally friendly and low maintenance cost option for treating leachate. The performance of constructed wetland in the treatment of leachate depends on climatic condition, type of wetland and type of vegetation. Generally, it is observed that high content of organic waste generates leachate of high BOD concentration. Constructed wetland without pre-treatment and ***Phragmites australis*** *as vegetation can be a possible option for treating leachate.*

Keywords –Constructed wetlands, solid waste, leachate

I. Introduction

Leachate is a liquid generated in the landfill site during the course of percolation of moisture through the waste, accumulating dissolvable and suspended impurities. The composition of impurities of leachate is diverse and toxic therefore it poses a potential threat to the environment. The prime environmental problem of the leachate is often long term and is evident in contaminated groundwater, surface water and the expulsion of obnoxious gases to the environment [1]. The conventional concept of solid waste management where disposal of solid waste to the landfill site is characterized as the final step is actually the point of generation of harmful leachate, the negative impact of which is even more detrimental to the environment and hence needs to be addressed. The diverse characteristics of the leachate pose a challenge in its treatment process. The treatment plant is designed considering the characteristics of the leachate. The common practices of leachate treatment include gravel filtration, constructed wetland and the waste stabilization pond [2].

Literature indicates, of all the treatments available as a solution, constructed wetland is a low maintenance and environmentally viable option for leachate treatment. However, the governing factors of plant efficiency are the composition of the leachate, climatic condition where the treatment plant is installed and the condition of the treatment plant itself.

This paper aims to gather literatures on leachate treatment using wetlands and tries to examine the distinctions in terms of the treatment plant configuration and the removal efficiency. The findings can be used as a guideline in recommending wetland as a municipal solid waste (MSW) leachate treatment in Nepal.

II. Literature review

A. Lagoons as a pre-treatment unit

An integrated treatment system containing four stages of treatment units for treating leachate of MSW was developed and operated in June 1993 in a cool temperate continental climate. The first treatment unit is the anaerobic pond where sedimentation and anaerobic decomposition of organic matter takes place. The mean hydraulic retention time (HRT) of the anaerobic pond is 3 days. High volume aerated lagoon with a high HRT of about 30 days is the second unit of treatment in which atmospheric air is continuously forced into the aerobic pond and mixed by a rotating propeller. The objective of this aerated lagoon is to achieve about 50% of nitrification. Owing to the fact that nitrifying bacteria are relatively sensitive to the low temperature and toxicity, a low loading rate is necessary. The treatment units in stage 3 are two horizontal subsurface flow wetland systems with the filter units consisting of (i) washed gravel and (ii) Light Expanded Clay Aggregates (LECA) in the size range of 10-20 mm. Proper drainage system of about 2% gradient and mulching is provided. It is designed for HRT of at least 5 days or more. It is important that raw leachate with high concentration of pollutants does not enter the wetland as it may affect rhizome growth and reduce the permeability of the medium. Finally, the stage 4 is free surface flow constructed wetlands with a depth of 1 to 1.2m. planted with Scirpus and Typha. sp.

Samples at six different points were collected during the study period of one year and observations were made for different parameters like Chemical oxygen demand (COD), Biological oxygen demand (BOD)7 (The test was carried out for 7-day BOD) total organic carbon (TOC), N-total, P-Total and E Coli. The removal efficiency of these parameters appears to be most significant from the aerated lagoons (60-95%) [3] in comparison to the effects of anaerobic pre-treatment pond (Stage 1) and the horizontal flow wetlands.

This finding was further verified with the fact that in the course of operation during winter when the aerator froze, there was an increase in the concentration of COD and N-total.

TABLE 1 OVERALL REMOVAL EFFICIENCY [3]

Parameter	Removal rates (%)
Chemical Oxygen Demand (COD)	88
Biological Oxygen Demand $(BOD)_7$	91
Total Organic Carbon (TOC)	71
N-tot	83
P-tot	88
E-coli	95

The findings of the study carried out by Maehlum [3] showed that the aerated lagoon is by far the most effective treatment unit.

B. Constructed Wetland with cyerus haspan

Akinbile et. al. [4] conducted a study for leachate generated in Pulau Burung Sanitary Landfill (PBSL) in Penang, Malaysia. The leachate was treated by constructed wetland consisting of sand and gravels as its substrate material and *cyperus haspan* as the plant. There is no pre-treatment unit in this plant. Based on the result of an experiment performed for 3 weeks, the characteristics of the sample pH, turbidity, color, total suspended solid, Chemical Oxygen Demand, Biochemical Oxygen Demand, ammonia nitrogen, iron (Fe), Magnesium (Mg) and Manganese (Mn) concentration were examined. The removal efficiencies are as shown in TABLE 2.

TABLE 2 OVERALL REMOVAL EFFICIENCY [4]

Parameter	Removal rate, %
pH	7.2-12.4
Turbidity	39.3-86.6
Color	63.5-86.6
Total suspended solid	59.7-98.8
COD	39.2-91.8
BOD_5	60.8-78.7
NH_3-N	29.8-53.8
TP	59.8-99.7
TN	33.8-67
Fe	34.9-59
Mg	29-75
Mn	51.2-70.5
Zn	75.9-89.2

In reference to the overall removal efficiency of the system, it can be concluded that wetland without any pre-treatment unit results in an appreciable removal of impurities.[4]

C. Constructed Wetland with phragmites australis

The treatment was introduced for landfill leachate treatment generated at the Oragonja landfill site located on the Adriatic coast, Slovenia. The system consists of two interconnected beds as a subsurface flow constructed wetlands and the plant used in the wetland was phragmites australis at a density of 4-5 per sq.m. This treatment plant does not have any primary treatment units.[5]

TABLE 3 PERFORMANCE PARAMETERS

Parameter	Average Removal rate, %
COD	68
BOD_5	46
NH3-N	81
Fe	80
Bacteria	85

The removal efficiency of the treatment plant was fluctuating which is attributed to the fact that there was weather variation-heavy rainfall flashing high amount of organic impurities, poor plant establishment due to toxicity and the fluctuating dissolved oxygen.

D. Factors affecting performance of constructed wetland

Bulc [6] performed a study on a combination of two subsurface flow wetlands- 2 units of Vertical flow (VF) and 1 unit of horizontal flow (HF)- as interconnected beds used to treat leachate from one of the old landfill sites in Slovenia. Test on parameters - COD, BOD5, ammonia nitrogen, nitrate, total phosphorus, sulfates, sulfides, chlorides, and iron in connection with the amount of precipitations was performed. The study evaluated performance of the wetland for 7 years (1997-2003) and showed that overall performance of the system of wetland is well dependent on the variable condition of the system itself, variation in the inflow parameter of the pollution and the environmental factors - primarily temperature and rainfall. The removal efficiency of the system (TABLE 4) showed that this CW can serve as a good treatment for leachate as a tertiary system (after treatment by screening and reactors) or as an independent system.[6].

TABLE 4 AVERAGE REMOVAL EFFICIENCY

Parameter	Average Removal Efficiency, %
COD	50
BOD5	59
NH_3-N	51
TN	Negative
TP	53
Sulphate	Negative
Sulphide	49
Chloride	35
Fe	84

E. Examination of Green House Gas Emission in Constructed Wetland

A study was conducted to evaluate the removal of organic carbon and nitrogen of young and partially stabilized Municipal Solid Waste (MSW) leachate along with the emission of greenhouse gases (CH4, CO2 and N2O). In terms of organic removal efficiency of young leachate, the value was upto 90%, with significant COD removal within the inlet part. The removal of Total Kjeldahl Nitrogen (TKN) was moderate (36–43%). In case of the stabilized leachate, BOD5 removal efficiency was less and moderate whereas TKN removal was about 40%. The wide difference in removal efficiency of BOD5 is attributed to the fact that the young leachate consisted of high degradable carbonaceous organic matter in comparison to that of partially stabilized leachate. The emission of greenhouse gases was maximum at the inlet zone for the young leachate following the removal rate as that of carbonaceous organic removal while for the stabilized leachate higher emission was observed in the middle zone [7].

F. Treatment by series combination of constructed wetland.

The performance of surface flow wetland to treat leachate was studied for a period of 4 months. The parameters analyzed were TPO, NH3, NO3, NO2, TKN, TPO4, BOD5, chlorides, and alkalinity. The average removal efficiency was as shown in TABLE 5.

TABLE 5 AVERAGE REMOVAL EFFICIENCY

Parameter	Average Removal rate, %
BOD_5	97.7
TOC	94.6
TPO_4	69.5
TKN	79
NH_3	98.3

These studies show that constructed wetlands can be a cost-effective and efficient approach to the treatment of landfill leachate with high TOC, BOD, nitrogen, and phosphorus.[8]

G. Treatment using an aerated, horizontal subsurface-flow constructed wetland

A subsurface-flow constructed wetland operated in Jones County Municipal Landfill near Anamosa, Iowa in August 1999 was studied to find the removal of the high concentrations of organic matter and NH4–N present in the landfill leachate. In order to maintain DO content of the treatment process, the plant was equipped with aeration process facilitating nitrification and aerobic removal of organic matter. Since the study was carried out in a cold climate, algal photosynthesis method alone could not meet the oxygen demand. So, air was delivered for 12 hrs a day to enhance the microbial process; however, at night when the supply of air was cut off the decomposition process could switch to anaerobic condition. The major challenge observed in the plant was clogging of the aeration tubing due to precipitation of ferric hydroxide. For some time period of about 6 months, aeration was taken off and the plant operated without supplemental air. It was observed that BOD5 removal efficiency was up to 90% until the time when there was supply of air. As clogging started and the plant operated without supply of air, the BOD removal was sporadic ranging from 0 to 100%. The variation in the removal of BOD is related to the air supply. Similarly, the removal of ammonia nitrogen was about 90% in the startup time and the performance was poor and inconsistent as clogging started and the plant operated without supply of air. The system was then renovated by installing a pretreatment system to oxidize the iron present in the leachate, and to settle the precipitate out of solution before pumping the leachate into the wetland system. The pretreatment unit was also supplied with air by an air blower. Following the renovation work, improved oxygen supply and pretreatment system for iron removal, treatment efficiency of BOD5 and ammonia nitrogen was greatly improved.[9]

H. Comparison of Horizontal and Vertical Constructed Wetland Systems for Landfill Leachate Treatment

The study was conducted to observe the removal efficiency of subsurface flow wetland of both vertical and horizontal type, focusing on removal efficiency of the impurities NH4-N, COD, PO4.

The effect of different bedding material for the vertical flow CW (gravel and zeolite surface) was investigated. A pilot-scale study was conducted on the subsurface flow constructed wetland systems operated in vertical and horizontal mode. Two vertical systems differed from each other with their bedding material. The systems were planted with (cattail typhalatifolia). The findings showed better NH4–N removal in the vertical system with zeolite layer than that of the vertical 2 and horizontal system, while COD was better removed by horizontal flow wetland [10].

III. Summary of Different Cases

From the comparative study of the wetlands performing leachate treatment, following are the key information drawn

1. Performance of wetland can be enhanced by use of pre-treatment units such as anaerobic lagoons and aerated lagoons. This combination is significant in cold climatic zone where required dissolved oxygen content cannot be fully met by algal photosynthesis process.
2. Constructed wetland with *cyerus haspan* as the plant is suitable for tropical zone which does not require any pretreatment units.
3. Condition of wetland, variation in the inflow parameter of the pollution and the environmental factors primarily temperature and rainfall affect the removal efficiency of the plant.
4. There is a concern of green house gas emission like CH_4, CO_2 and NO_2 while treating leachate from wetland.
5. In the cold climate zone, supplemental air to the wetland will maintain DO content thereby helping in nitrification process. The problem observed with this system is precipitation of ironoxide which will cause clogging of aeration pipe, this problem can be taken care by installing pretreatment unit for iron removal.

6. The common findings from all the study showed that vertical flow wetland is more effective in removing nitrogen, phosphorous, BOD_5 while COD is better removed by horizontal flow wetland.

IV. Leachate composition, prevailing treatment condition in Nepal

Analysis made on the composition of leachate carried out in different landfill sites of Nepal-Kathmandu (Sisdole), Pokhara and Dang (Karaute Dada) showed very high organic impurities in waste composition (>60%), consequently, the leachate collected from these sites have high organic content [11]. A study conducted in Gokarna landfill site showed that there is no collection of leachates, generated causing a direct threat to public health and the environment. Similar condition was observed in Bishnumati dumping site where the leachate generated through MSW is directly discharged into the Bishnumati river [12].

V. Final remarks

Landfill site, a final destination of MSW, is the point of generation of leachate. Growing economy and population is a driving factor of increasing solid waste. While there are ample efforts made in handling solid waste, the concern towards leachate treatment and its disposal seems to get little or no interest. The immediate consequence is pollution of land and water bodies paving a path to a series of negative environmental and public health impacts. Various studies conducted across the globe have verified the effectiveness of treating leachate through wetland system. From the point of economic viability - land footprint and other resources, vertical flow wetland with phragmites australis with no pre-treatment units can be the best option in specific context of Nepal.

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