World Applied Sciences Journal 15 (1): 142-150, 2011
ISSN 1818-4952

Assessment of Waste Stabilization Ponds for the Treatment of Hospital Wastewater: The Case of Hawassa University Referral Hospital

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Abstract: This paper is aimed to examine the suitability of a series of facultative and maturation ponds for the treatment of hospital wastewater. Sampling were done in different time periods from 2009-2010. The hospital produced 470 liters of wastewater per occupied bed per day. The percentage treatment efficiency of the pond was 94.11, 87.72, 87.1, 86.52, 68.58, 54.81, 54.59, 31.95, 18.12 and 10.58 for BOD_5, Sulfide, TSS, COD, Nitrate, Nitrite, Total Nitrogen, Total Dissolved Solids, Conductivity and Chloride respectively in decreasing order. However, there was a 204.85% increment for total Ammonia in the effluent of the pond. The organic loading rate was 678.7 kg/he/day and the BOD_5/COD ratio was 0.455. There were 204.2, 13.1, 8.1, 6.2, 4.5, 2.9 fold increments in concentrations of Zn, Cd, Fe, Pb, Co and Cr respectively in the final treated effluent in the recent year. The treatment efficiency for total and fecal coliform bacteria were 99.74% and 99.36% respectively. However, the effluent still contain large numbers of these bacteria, not suitable for irrigation and aquaculture. The treatment plant is not efficient to threat some selected physicochemical substances. Use of constructed wetlands in conjunction with the existing treatment system is recommended.

Key words: Hospital wastewater · *E. coli* · Trace elements · Physicochemical parameters · Stabilization ponds

INTRODUCTION

Hospital wastewaters contain antibiotics, X-ray contrast agents, heavy metals, disinfectants, pharmaceuticals and substances with genotoxic and cytotoxic activity and enteric pathogens [1, 2]. As much as 50 to 90 percent of an administered drug may be excreted by the body in a biologically active form [3]. These drugs are known to be resistant to most biological wastewater treatment plants [4]. Antibiotics, particularly some sulfonamides and fluoroquinolones, were found at relatively high concentrations in hospital wastewater and were not completely removed by wastewater treatment [5].

Hospital wastewater also contains several organic substances that are resistant to biological degradation with low biodegradability ratios Biochemical Oxygen Demand (BOD_5) to Chemical Oxygen Demand (COD) of 0.3, which show a resistance toward conventional activated sludge biological treatment process [6, 7]. Heavy metals such as Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Silver and Zinc are toxic to wastewater treatment systems [8]. They are toxic to humans and other organisms, may end up in surface water where they may influence the aquatic ecosystem and interfere with the food chain [9]. Some pharmaceuticals such as anti-tumor agents are carcinogenic, mutagenic, teratogenic and fetotoxic [10].

Studies have shown that the release of wastewater from hospitals was associated with an increase in the prevalence of antibiotic resistance [11]. Even, exposure to low concentrations level over long periods of time may results in selection and consequent spread of resistance to pharmaceuticals. Antimicrobial resistant gram negative bacterial species were identified in final hospital effluents [12, 13]. Residues of pharmaceutically active compounds have also been found as contaminants in sewage, surface and ground-and drinking water samples [14]. Diatrrzoate, iopromide and iopamidol (X-ray contrast media) have been detected in drinking water wells [15].

The general wastewater treatment methods depend on biological processes, principally bacteria feeding on organic material in the wastewater and most wastewater

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treatment plants are designed to remove biodegradable organic material, but not designed to remove low concentrations of synthetic pollutants [16]. Several conventional wastewater management practices are not effective in the complete removal of antibiotics. Most hospitals which use activated sludge and oxidation ditch, bacteria exceeded standard numbers; pathogenic bacteria and parasites were found in two-thirds of the hospitals and heavy metals, namely lead, chromium and cadmium, in the hospital effluent were in an acceptable range [17]. A study conducted in Iran on seven hospitals revealed that activated sludge process as the secondary treatment was not efficient in treating hospital wastewater [18].

Waste stabilization ponds have been successfully used for the treatment of domestic wastewater throughout the world. They are the most important method of wastewater treatment in developing countries where sufficient land is normally available and where the temperature is most favorable for their operation [19]. If properly designed and operated, waste stabilization ponds (WSPs) can attain a 99.9% faecal coliform reduction and are capable of attaining a l00% removal of helminths [20]. They are arranged in a series of anaerobic pond, facultative pond and finally one or more maturation ponds, where anaerobic and facultative ponds are designed for BOD_5 removal and maturation ponds are designed for faecal bacterial removal [19]. The principal mechanisms for faecal bacterial removal in facultative and maturation ponds are retention time, temperature, high pH (>9) and high light intensity together with high dissolved oxygen concentration [21]. BOD_5 and suspended solids are removed only very slowly and nutrient (nitrogen and phosphorus) removal is also quite slow, although in a well-designed and properly operated and maintained series of WSP (anaerobic, facultative and several maturation ponds), cumulative removals of BOD_5, suspended solids and nutrients are high [19]. The main chemical factors affecting pond performance are pH value, toxic materials and oxygen. Both anaerobic and facultative ponds operate most efficiently under slightly alkaline conditions.

Health Care Waste Management in Ethiopia has been a neglected activity by health service providers, managers both at local and national levels and lacked the attention it deserves. Some studies have been carried out on solid waste management of hospitals but little or no previous data is available on wastewater. Hence, no data and records are available and it is difficult to estimate the damages it has inflicted on human health and the environment. However, practices from daily observation indicate that, most health facilities had not put in place an organized management system to address Health Care Waste Management (HCWM) properly and if such a system was present, it did not meet the minimum requirements [22]. In countries where the management of healthcare wastes is often poor, they could pose a potential risk to public health through the circulation of agents in the environment, animals and people [18].

Waste stabilization ponds have been used successfully and widely to treat municipal wastewater. However, researches on the treatment of hospital wastewater by oxidation ponds and their performance to remove different pollutants and antibiotic resistant bacteria and other forms of pathogens especially from hospital origin are limited. Therefore this paper tries to examine the suitability of a series of Polyvinyl Chloride (PVC) geomembrane-lined facultative and maturation ponds for the treatment of hospital wastewater by determining the treatment efficiency of the system. In addition, drawing from the available literature, it suggests better treatment options for the wastewater from the hospital. The results obtained will serve to identify areas where control measures are necessary, enhance decision making tools for management to identify opportunities for reducing waste and would be applicable to other urban hospitals generating similar types of waste.

METHODS AND MATERIALS

Description of the Study Area: The study was conducted from August 2009 to August 2010, in Hawassa University Referral Hospital, southern Ethiopia. It is located at the eastern shore of Lake Hawassa, a fresh water lake (Figure 1). The hospital has been functioning since April 2005 as a teaching institute and as a referral center for the community of the region and other neighbor areas. At the time of data collection, the hospital had around 800 fulltime students, 658 permanent employees, 305 functioning beds in 6 wards. The number of patients who visited the hospital per day ranged 90 to 120 and 70 to135 in outpatient department and antiretroviral therapy clinic respectively. The total number of patients admitted in the inpatient department per day were in the range of 120-220 and at least one caregiver (patient relative) per patient equivalent to the number of admitted cases accompany patients. The number of births per day was 5-6 with an average of 3 attendants.

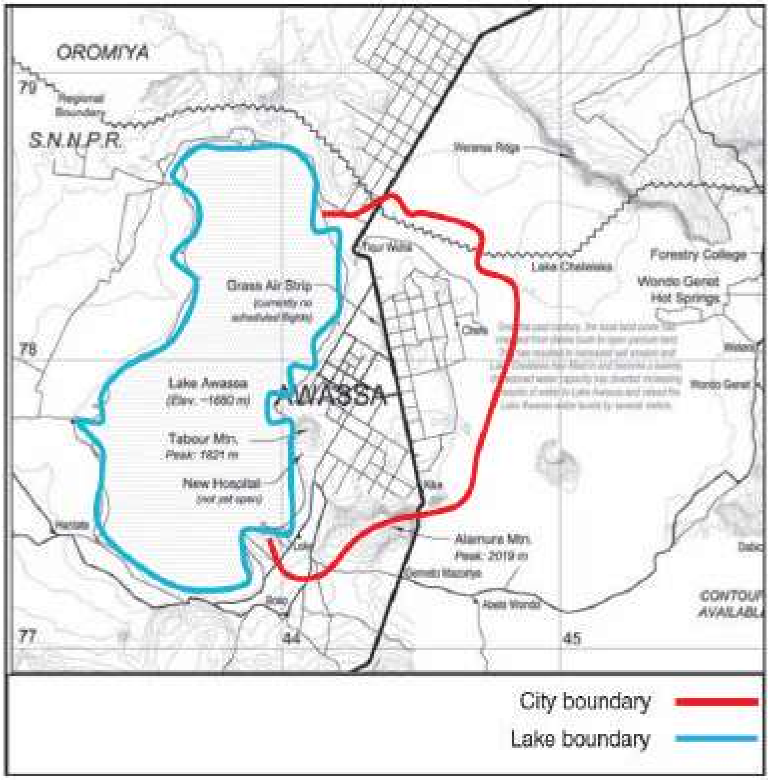

Fig. 1: Map of Hawassa City. (Source: SNNPRS Finance and Economic Development Bureau)

Fig. 2: Picture of the oxidation ponds of the Hawassa University Referral Hospital

The buildings of the compound comprises of wards, emergency and outpatient departments, delivery rooms, X-ray rooms, operation rooms, laundry, chemical and microbiological laboratories, offices, general and pharmaceutical stores, class rooms, staff and students lounge, students' cafeteria and dormitory, staff residence. A portion of the wastewater generated in the above activities have been intercepted by sewer lines and pass through a septic tank pretreatment before it inters to the ponds. There is no onsite separation or treatment of toxic and infectious wastes. No storm water containment and treatment system and it directly join the lake through ditches.

The wastewater treatment system employed in the hospital is an oxidation pond system which comprises of two facultative ponds and two maturation and a fish ponds for fish farming, all lined with PVC geomembrane (Figure 2). The purposes of the ponds were not only to treat the wastewater but also to rear fish in the treated water and finally to reuse the treated wastewater for

Table 1: Dimension of Waste Stabilization Ponds, Hawassa University, Referral Hospital

Pond type	Average surface area (M^2)	Depth (m)	Volume (M^3)	Retention time, (day)
Facultative pond I	667.17	1.5	1000.75	13.97*
Facultative pond II	667.17	1.5	1000.75	13.97*
Maturation pond I	401.1	1.1	441.21	3.08
Maturation pond II	396.15	1.1	435.77	3.04
Fish Pond	862.42	1.51	1302.25	9.09

*Assuming that the incoming quantity of wastewater to the facultative ponds has been divided equally to the two facultative ponds.

compound gardening. However, the latter two purposes have not been practical since the commencement of the treatment plant. Rather the wastewater is released in to an ecologically sensitive area (Lake Hawassa) which is located adjacent to it.

Assuming no net loss in the quantity of incoming wastewater in the treatment system, the total time the wastewater spent in the treatment system is 29.18 days (Table 1). This value indicates that the detention time of the facultative pond was found to be less than the typical detention time of a facultative pond (25 to180 days).

Sampling, Preservation and Analysis: Wastewater sampling and analysis was conducted twice. The first was conducted in August 2009 and sampling was conducted three times throughout the month, primarily to determine the concentration of selected trace elements in the pond effluent so as to compare with recommended discharge permits. The second and detailed investigation was conducted in August 2010 in which sampling were done twice throughout the month to determine the overall efficiency of the whole treatment system. The samples were taken at the influent (before the wastewater joins the first pond) and final effluent (after the wastewater left the final fish pond). Pretreated plastic bottles were used for the collection of wastewater samples. For the determination of metals wastewater samples were immediately preserved after sampling by acidifying with concentrated nitric acid (HNO_3) to pH < 2. After acidifying, the sample was stored in refrigerator at approximately 4 °C. Temperature, pH, DO and Conductivity were measured onsite immediately after sampling.

The analyses of all the trace elements were conducted at Addis Ababa City Environmental Protection Authority (EPA) laboratory. The other physicochemical parameters were also done at the laboratories of the Addis Ababa City EPA and School of Environmental Health, Jimma University. The total and fecal coliform analyses were conducted at of Department of Public and Environmental Health laboratory, Hawassa University.

Chemical oxygen demand (COD), Total nitrogen, Total ammonia, Phosphate (PO_4) and Sulphide were measured using spectrophotometer (DR/2010 HACH, Loveland, USA) according to HACH instructions. Total dissolved solids (TDS) and Suspended Solids (SS) were measured by 2540D and Biochemical Oxygen Demand (BOD_5) was measured based on 5210A procedure, the methods described in standard methods [23]. Nitrite ($NO2^-$ -N) was measured using Ferrous Sulfate method, program 8153, HACH DR/2004 portable spectrophotometer. Nitrite (NO_3^-N) was determined by Cadmium reduction method using powder pillow or accuVac ampules spectrophotometer. Total Phosphorous (TP) was measured by the persulfate digestion procedure. Dissolved Oxygen (DO), temperature, pH and conductivity were measured onsite by HACH mutliparameter probe. The heavy metals, Chromium (as Cr Total), Copper (Cu), Zinc (Zn), Lead (Pb), Nickel (Ni), Iron (Fe), Cadmium (Cd), Mercury (Hg) and Arsenic (As) were determined using Atomic Absorption Spectrophotometer (Buck Scientific Model 210 VGP, USA) according to standard methods [23]. Total coliform and Faecal Coliforms were determined using Membrane Filtration Plate Count method as explained in standard methods [23].

RESULTS AND DISCUSSION

Water Consumption and Wastewater Production: The main water source of the hospital was municipal treated water from Awassa City. The daily water consumption rate was 168.57 m^3 (553 liter per occupied bed per day). With 85% water to wastewater conversion factor, the quantity of wastewater generated has been calculated to be 143,285 liter (143.28 m^3), which is equivalent to 470 liters per occupied bed per day. Though little data exists on wastewater quality and no data on quantity at all, potential units of the hospital that can produce toxic and infectious wastes were identified to be the wards, operation rooms, delivery wards, pathology and other microbiological and chemical laboratories which use toxic reagents, X-ray, laundry and cleaning and disinfection unities.

Table 2: Comparison of the physicochemical characteristics of the inlet and outlet of the treatment system, 2010

	Inlet	Outlet	
Parameters Analyzed	mean±SD	mean±SD	Efficiency (%)
pH	7.41±0.25	7.85±0.91	-
Conductivity, μmh	1098.00±288.54	898.5±31.82	18.12
DO, mg/L	0.69±0.03	0.675±0.01	-
Temperature, °C	24.25±1.91	22.6±0.28	-
Total Ammonia (NH_3), mg/L	0.165±0.13	0.503±0.39	-204.85
Sulfide(S^2), mg/L	2.85±0.21	0.35±0.07	87.72
COD, mg/L	1388.75±206.83	187.25±3.18	86.52
BOD_5, mg/L	632±31.11	37.25±15.2	94.11
Total phosphorus T-P/asP/, mg/L	37.36±23.48	36.55±20.58	8.2
Phosphate (PO_4), mg/L	22.30±10.2	20.45±2.18	2.2
Chloride (Cl^-), mg/L	104.00±1.41	93.00±1.41	10.58
Total Nitrogen (T-N), mg/L	98.00±35.35	44.50±41.01	54.59
Nitrate NO_3 (as N), mg/L	25.25±6.72	7.933±0.61	68.58
Nitrite, mg/l	0.1018±0.01	0.046±0.003	54.81
Total Suspended solids(SS), mg/L	469.00±1.41	60.50±0.71	87.10
TDS, ppm	615.00±1.41	418.5±0.71	31.95
Total Coliform	$7.4 \times 10^7 \pm 9.18 \times 10^7$	$1.95 \times 10^5 \pm 1.5 \times 10^5$	99.74
Fecal coliform	$1.23 \times 10^6 \pm 1.9 \times 10^6$	$7.9 \times 10^3 \pm 8.9 \times 10^3$	99.36

Efficiency of the Treatment Plant: The results of the analysis for the various physicochemical parameters are presented in Table 2 below. The mean DO concentration (0.675±0.01 mg/L) of the treated wastewater was far less than the value recommended for fish to respire and perform metabolic activities. A DO saturation level lower than 5 mg/L can put undue stress on the fish and levels reaching less than 2 mg/L may result to death [24]. This is an indication of anaerobic condition prevailed in the treatment system where oxygen unable to enter into the system through direct diffusion or the rate oxygen diffusion and photosynthesis were lower than the rate of oxygen removal through respiration and decomposition.

The average pH value of the treatment plant was comparable to pH of domestic wastewater which is suitable from the viewpoint of wastewater treatment processes [25]. pH values increased from 7.4 in the influent to 7.85 in the effluent of the treatment plant. It might be associated with the increasing algal activity as CO_2 is consumed during photosynthesis of the algae. The increment in pH could also be due to high concentrations of ammonia in the effluent. The percentage treatment efficiency of the pond was 94.11, 87.72, 87.1, 86.52, 68.58, 54.81, 54.59, 31.95, 18.12, 10.58, 8.2 and 2.2 for BOD_5, Sulfide (S^{2-}), Total Suspended solids (SS), COD, Nitrate (NO_3-N), Nitrite, Total Nitrogen (T-N), TDS, Conductivity, Chloride (Cl^-), total phosphorus and Phosphate in decreasing order respectively.

The mean BOD_5 (632 mg/L) and COD (1388.75 mg/L) concentrations of the wastewater of the hospital were higher than values obtained in other areas [18, 25]. This might be due to the release of strong organic compounds in the hospital wastewater. With this BOD_5 value of the influent, the calculated organic loading rate on the facultative ponds was 678.7 kg per hectare per day, which is much higher than the typical organic loading rates of 22-67 kg BOD_5 per hectare per day. The effluent BOD_5 and TSS concentrations were higher than that set by the U.S. federal standards for secondary effluent and the European Community Commission for Environmental Protection minimum effluent standards. This higher value indicated that the total area of the facultative pond is not enough to handle the current BOD_5 concentration of the wastewater. This might also be because of pharmaceuticals such as antibiotics, cleaning agents and other pollutants, could potentially affect the ability of microorganisms to break down and detoxify waste in sewage-treatment plants particularly on the community of organisms in charge of the biological decomposition of the organic matter [10].

For better treatability, the BOD_5/COD ratio should be greater than 0.5 [25]. The BOD_5/COD ratio of the wastewater received at the facultative pond was 0.455. This indicated that organic substances with low biodegradability have been in use in the hospital. Such characteristics of hospital wastewater showed a resistance toward conventional activated sludge biological treatment process [6, 37]. The treatment efficiency of the pond for TDS and Conductivity were relatively low. This might be due to the low treatability of hospital wastes as it can be revealed by the low treatment efficiency of the ponds for trace elements.

The mean TSS concentration (469 mg/L) of the raw wastewater of the hospital was higher than the average TSS concentration of domestic wastewater [25]. This might be due to the short retention period of the ponds and the release of algae as a suspended solid from the fish ponds. There has been a 54.8% reduction of Nitrate in the effluent of the pond as compared to the amount that entered to the pond system. Though the concentration of Nitrite in the effluent of the fish pond was very low (0.046 mg/L), the occurrence of high pH value, low dissolved oxygen and high ammonia can increase its toxic effect [26].

For Phosphate (PO_4), Total phosphorus as P and Total Ammonia (NH_3), there were 66.76%, 110.48% and 204.85% increment in the final effluent of the pond respectively (Table 4.4). The concentration of total phosphorous in the final effluent was 36 fold higher than the recommended value by the European Community Commission for Environmental Protection, < 1 mg/L as the minimum effluent standards for wastewater treatment plants [40]. Though the effluent concentration of ammonia was little, there was a threefold increment of total ammonia in the effluent of the pond as compared to the influent. This might be due to the relatively higher pH value of the effluent which could result in conversion of a greater number of ammonium ions into ammonia gas thus causes an increase in ammonia to leave from the fish pond [27]. The concentration of ammonia in the effluent was 25 times greater than the recommended safe value of 0.02 ppm for aquaculture [24]. However, it is less than the Indian standard for total ammonia (= 50 mg N/L) and the European Union standard, = 15 mg N/L. The occurrence of sulphides might be due to the sulphate-reducing bacteria oxidized the organic compounds and reduce the sulphates to form sulphides [28].

The treatment efficiency of the pond for the trace elements were 93.54, 86.95, 81.02, 66.83, 66.57, 59.93, 54.37, 48.34, 42.77 and 22.22% for Fe, Cu, Pb, Cr, Cd, Zn, Hg, As, Co and Ni in decreasing order respectively.

The present study identified the mean concentration of zinc, Lead, Cadmium and chromium to be higher than these threshold values which could pose toxic effect for the biological treatment system of the hospital. Cadmium, Chromium, Nickel, Lead and Zinc have got inhibiting or toxic effect on the biological treatment system. Copper, Chromium, lead, nickel and zinc are toxic and can be a significant issue in wastewater treatment systems [8].

Table 3: Comparison of inlet and outlet of the pond based on 2010 analysis result

Parameters analyzed	influent mean± SD	effluent mean± SD	Efficiency (%)	FAO, (mg/l)*
Cadmium(Cd), µg/L	24.83±0.03	8.3±0.14	66.57	0.01
Chromium (Cr), µg/L	121.3±0.28	40.23±0.1	66.83	0.10
Cobalt (Co), µg/L	25.76±0.06	14.74±0.14	42.77	0.05
Copper(Cu), µg/L	113.1±0.23	14.76±0.23	86.95	0.20
Iron (Fe), mg/L	38.82±0.27	2.51±0.03	93.54	5.0
Nickel (Ni), mg/L	0.45±0.01	0.35±0.01	22.22	0.20
Lead (Pb), µg/L	119.95±0.1	22.77±0.17	81.02	5.0
Zinc (Zn), µg/L	14.015±0.01	5.62±0.12	59.93	2.0
Arsenic (As), µg/L	4.84±0.004	2.5±0.03	48.34	0.10
Mercury (Hg), µg/L	1.10±1.45	0.5±0.01	54.37	-

* Recommended Maximum Concentration of trace elements for Crop Production (FAO, 1992).

Table 4: Percentage increment of heavy metals comparison of 2009 and 2010 results of the pond effluent

Parameters analyzed	Mean±stdev 2009	Mean±stdev 2010	Increment (fold)	P value
Cadmium(Cd), mg/ L	0.63±0.33	8.3±0.14	13.1	0.000[a]
Chromium (Cr), mg/ L	13.88±8.10	40.23±0.1	2.9	0.022[a]
Cobalt (Co), mg/ L	3.25±0.42	14.74±0.14	4.5	0.000[a]
Copper(Cu), mg/L	25.57±16.87	14.76±0.23	0.6	0.383
Iron (Fe), mg/L	0.31±0.39	2.51±0.03	8.1	0.005[a]
Nickel (Ni), mg/L	ND	0.35±0.01	-	0.018[a]
Lead (Pb), mg/L	3.65±2.53	22.77±0.17	6.2	0.006[a]
Zinc (Zn), mg/L	0.03±0	5.62±0.12	204.2	0.000[a]

[a] significantly associated

Concentration of Cadmium exceeding 0.02 mg/l, will result in toxic effect for anaerobic processes in the digester effluent. If the concentration of Chromium exceeds 2 mg/l, it has toxic effect on aerobic process. The concentrations of Nickel, Lead and Zinc exceeding 1 mg/L, 0.1mg/L and 5 mg/l respectively will inhibit biological wastewater treatment processes [29]. The concentration of Nickel and Zinc in the treated wastewater of the hospital was higher than the valued recommended by FAO's for agriculture reuse [30]. Though the values of most of the trace elements in the treated wastewater was low, continuous release to an ecologically fragile environment, might result in bioaccumulation of this trace elements in the food chain [9]. Ducks and other birds were observed feeding on the pond algae and other insects which could result in persistence of heavy metals in successive trophic levels of hospital pond ecosystem [31].

There were 204.2, 13.1, 8.1, 6.2, 4.5, 2.9 fold increments in concentration of Zn, Cd, Fe, Pb, Co and Cr respectively in the recent year as compared with the previous year (Table 4). The one sample T test analysis showed that there has been significance difference among the two years in the values of the effluent of the pond (Table 4). This shows that the treatment efficiency of the pond for trace elements is decreasing from time to time. It might be due to the introduction of settleable solids that might reduce the retention time of the ponds.

Although the wastewater treatment processes reduced the numbers of total coliform and fecal coliform bacteria to 99.74% and 99.36% respectively, the effluent still contained large number of these bacteria which are higher than recommended by World Health Organization (WHO) for restricted and unrestricted irrigation [19]. This also doesn't fulfill the quality of water required for aquaculture as the WHO guideline for this is = 1000 *E. coli* per 100 ml of aquaculture pond water. There could be a risk that bacterial pathogens will be present in the lake water, not only on the skin of the fish, but also in their flesh and internal organs [32]. Thus, the chance of multi drug resistant bacteria to leave the treatment plant is also high.

Better Options for Wastewater of Health Care Origin: Various literatures were reviewed to identify the best treatment methods recommended for the treatment of hospital wastewater and wastewaters having similar characteristics. Accordingly, the following treatment methods have been suggested by various literatures:

Series of Treatment Procedures: primary treatment followed by secondary and tertiary treatment such as lagooning or rapid sand filtration, followed by disinfection with chlorine or ultraviolet light. The sludge should also be digested anaerobically or should be dried in natural drying beds and then incinerated to ensure thermal elimination of most pathogens [33]. This can be possible but it could be impractical in terms of cost of construction, operation and further maintenance.

Lagooning Followed by Infiltration: two successive lagoons to achieve an acceptable level of purification followed by infiltration of the effluent into the land [33]. This can be applicable; however, infiltration to the ground might end up in contamination of ground water since the infiltration will be possible only just at the Shore of Aawassa Lake.

Use of Constructed Wetlands: Application of CWs for the treatment of hospital wastewater is highly recommended for the present wastewater. It is effective in treatment of the wastewater and it is not expensive for construction, operation and maintenance. Land will not be a problem too.

Photo-Fenton process has been found to be a suitable pretreatment method in reducing toxicity of pollutants and enhancing biodegradability of hospital wastewaters treated in a coupled photochemical-biological system [34] and amoxicillin plant wastewater [38]. However, this will be difficult in terms cost, operation and maintenance. Therefore, its applicability for the treatment of our hospital will be unlikely.

Membrane Bio-Reactors has high removal efficiency of bacteria; reverse osmosis, activated carbon and ozonation have been shown to significantly reduce or eliminate antibiotics and pharmaceutical substances [35]. A submerged hollow fiber membrane bioreactor (MBR) was also proposed in treating the hospital wastewater [36]. High organic load and COD concentration of Antibiotic Plant effluent were efficiently treated by an up-flow anaerobic sludge blanket fixed film bioreactor [39]. However, their applicability in terms of cost, installation, operation and maintenance might be difficult.

In conclusion, the percentage treatment efficiency of the pond for BOD_5, Sulfide, Total Suspended solids, COD, Nitrate, Nitrite and Total Nitrogen were satisfactory. However, the effluent BOD_5, COD and TSS concentrations were higher than standard set by the U.S. federal standards for secondary effluents. The treatment efficiency of the pond for some of the trace elements was satisfactory. However, zinc, Lead, Cadmium and chromium were found to be higher than the threshold values. There were also increments in concentration of some trace elements in the recent year as compared to the previous year values. The treatment efficiency of the overall pond system for total and fecal coliform was good; however, the effluent still contain large numbers of these bacteria which are higher than recommended by WHO for restricted and unrestricted irrigation. In general there might be a release of toxic wastes and multidrug resistant microorganisms which put further pressure on the receiving surface water, Lake Awassa. Therefore, there need to be reliable pretreatment for the raw wastewater and onsite containment and treatment of toxic waste to reduce the toxicity of the wastewater, separate collection of excreta of patients and opportunities for using less laundry chlorine bleach should be sought. Continuous training for the employees is important. Further study is required to investigate the ecotoxicological risk of the hospital effluents.

The authors thank Hawassa University for funding this project.

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