Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.9, No.5, 2017

Evaluation of Hospital Wastewater Treatment and Disposal: The Case of Wolita Soddo Teaching Referral Hospital, Wolaita Zone, Southern Ethiopia

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Abstract
Untreated liquid hospital wastes are known sources of several chemicals, remnants of medicine, disinfectants and antineoplastic drugs regarded as perilous for humans and the environment and un-metabolized antibiotics in low concentration that contributes largely to the development of antibiotic resistance in our natural micro-flora or environmental micro-flora. Therefore, issues of improving the management of hospital wastes are receiving increasing attention throughout the world since hospitals generate tons of medical waste each year. Septic tank is a sanitization technology that exclusively treats domestic wastewater. Thus, this study was conducted to examine the adequacy of hospital wastewater treatment and disposal in Wolaita Sodo Teaching Referral Hospital. The physicochemical, heavy metals and bacteriological parameters were investigated by taking appropriate samples from March to July 2015 from 5 sampling points. Both the sampling and analysis of the samples were carried out employing standard methods. The results of nine (9) parameters such as Turbidity, conductivity, Temperature, pH, TDS, TSS, NO_3^-, SO_4^{-2} and PO_4^{-3} had significant difference between sampling points ($p<0.05$). On the other hand, the results of BOD_5, COD, DO, Mn, Fe, Cu, Cr, FC and TC were comparable among sampling points($p>0.05$). Amongst the physicochemical parameters, the average value of BOD_5 (46.17+20.21mg/l), COD (205±76.48mg/l), TSS (12,788.2±0.78mg/l),), NO_3^- (2492.67±0.1mg/l),TKN (11,422.5mg/l), Fe (0.795±0.01mg/l), Pb (0.042mg/l) were found to be higher than the maximum permissible limit set by Ethiopia Environmental Protection Authority (EEPA, 2003 : USEPA, 2002) while EC (198.08±2.275NScm-), Turbidity (53.25±3.68NTU , TDS (98.84±1.14mg/l) and SO_4^{-2} (4±2.18mg/l) were below the maximum permissible level. The mean concentration of all heavy metals except Pb and Fe were lower than the maximum permissible level (USEPA, 2002) for effluent discharged to the environment. Similarly, the mean value of TC (1158.335±515.32MPN/100ml)and FC (1041.67± 360.85MPN/100ml were higher than the standard set by (EPA, 2002) effluent discharged into the environment. In addition, the removal efficiency of septic tank was evaluated and presented as TSS (67.08%), BOD5 (54.61%), PO4-3 (33.68%), Cu (95.83%),Mn (66.44%), Cr (60.98%) and Fe (47.47%) %). However, septic tank had poor performance on removing turbidity (9.37%), COD (21%), TDS (27.45%), NO_3^- (-39.00%), SO_4^{-2} (-3.24%), TKN (-5.04), TC (14.58%) and FC (20.23). Evidently, the septic tank treatment plant of study area was not effective on removing contaminants from the hospital, due to the absence of maintenance, lack of desluding, lack of preliminary/primary treatment and absence of secondary/ tertiary wastewater treatment system, lack of sound waste management system i,e sorting and disposal of hospital waste, and lack of proper operation and maintenance program. Therefore, there should be optimal treatment technology for hospital wastewater treatment and a continuous monitoring and evaluation of the effluent quality of the septic tank before discharging in to the environment is of paramount importance.
Keywords: Physicochemical parameters, Heavy metal, Bacteriological parameters, Septic Tank, Treatment efficiency

1. INTRODUCTION

Hospital wastewater contains Antibiotics, X-Ray Contrast Agents, Heavy Metals, Disinfectants, Detergents, Solvents, Pharmaceuticals, and some Radionuclide [1]. Untreated liquid hospital wastes are known sources of several chemicals including remnants of medicine, disinfectants and antineoplastic drugs are regarded as risky for humans and the environment [2]. Several factors, such the exchange of antibiotic-resistant organism between people and exchange of resistance genes among bacteria thereby increase the prevalence of resistant strains [3]. Waste effluent from hospitals also contains high numbers of resistant bacteria and antibiotic residues at concentrations able to inhibit the growth of susceptible bacteria. Accordingly, hospital waste effluent could increase the numbers of resistant bacteria in the recipient sewers by both mechanisms of introduction and selection for resistant bacteria [4]. Issues of improving the management of hospital wastes are receiving increasing attention throughout the world since hospitals generate tons of medical waste each year [5]. Shaner [6] estimated that around 15% of hospital waste is contaminated with infectious agents potentially hazardous to human health such as Hepatitis and Human Immuno deficiency Virus (HIV). According to WHO [7] 80% of medical waste are caring and comparable to domestic waste while the remaining approximate of 20% is

considered hazardous, as it may be infectious, toxic and/or radioactive of which 15% where from infection wastes and Sharp objects, genotoxic waste, heavy metals (1% each), chemicals and pharmaceuticals (3%) constitute the rest of the hazardous waste.

In wastewater treatment system all wastes from any institute should be discharged or disposed in a form that will not cause any environmental damage or risk to human life [8. Hence the improper disposal of hospital waste in the developing countries poses a high health risk to humans as well as the environment. But in many developing countries the large percentage of hospital –generated waste but also other wastes such as wastewater and air pollution have become serious problems [9]. In minimizing risk to the environment and human health for many years, environmental protection activities by hospitals focus on treating and disposing waste through appropriate treatment methods. For instance, 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 [10]. Besides, Membrane Bio-Reactors (MBR), have high removal efficiency of bacteria whereas Reverse Osmosis, Activated Carbon and Ozonation have been shown to significantly reduce or eliminate antibiotics and pharmaceutical substances [11]. High organic load (BOD) and Chemical Oxygen Demand (COD) concentration of Antibiotic plant effluent were efficiently treated by an Up flow Anaerobic Sludge Blanket (UASB) fixed film bioreactor [12].

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 [13]. 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 [14]. 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 [15]

2. MATERIAL AND METHODS

2.1 Description of the Study Area

The study Hospital is located in Soddo Town, Soddo Zuriya Woreda, Wolaita Zone, Southern Nations, Nationalities and People's Regional State of Ethiopia and at 365km south of Addis Ababa, east ward of Soddo town and 5km east to Soddo town. Geographically, Soddo Town is located between longitude of 37º26'24'' E to 37º27'36''E and latitude of 6º28'48''N to 6º31'48''N. The annual rainfall is between 1200-1400mm and the mean annual temperature ranges between 15 ^{o}C -20^{o}C. The altitude above sea level is 1920 m.a.s.l. and mostly its climatic condition is Dega [16].

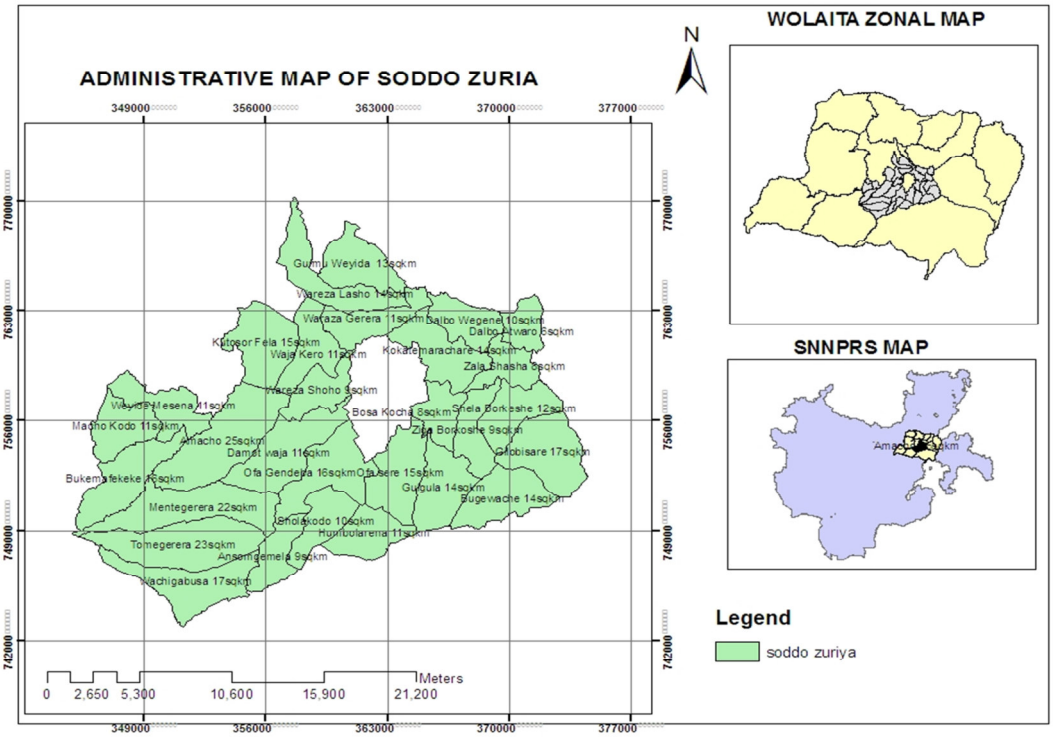

Figure 1: The map of study area

Soddo Zuria Woreda is one of the Woreda in Wolaita Zone which has teaching referral hospital that

generated wastewater from different sources of the hospital and treats it in a Septic Tank. Finally, the hospital disposed effluent in Fundunya manmade forest which is located in this Woreda. The Hospital was constructed in 1928 as a Clinic which rendered curative service for about 10 years. Subsequently, the then Clinic was upgraded to the Hospital level and the first school of health assistance was opened in 1946. Currently the hospital is run by few Ethiopian physicians. There are 7(seven) specialist and 40(forty) general practitioner doctors and 483 permanent employed and 58 contract employed are performing the hospital activities. The Hospital has six wards: Surgical, Pediatrics, Gynecology and obstetrics, Ophthalmology, Medical, and Labor wards, with 196 maximum bed capacities. It has 190 beds and the outpatient flow on average is 150-200 per day. The hospital, in addition to its curative activities, serves as an academic institute for training of Health Professionals. It is one of the largest institute which releases considerable amount of wastewater to the Fundunya manmade forest. The hospital consumes considerable amount of water. The Wolaita Sodo Referal Hospital Environmental Office Team estimates that the hospital consumes 109.6 m^3/day (190,600L/ day); 0.577 m^3/bed/day of water per day, which translates to 577 L bed–1day–1 when the currently functioning 190 beds of the hospital are considered. On the assumption that 50% of the entire water consumed in WSRH (Wolaita Sodo Referal Hospital) would be discharged as wastewater, the quantity of wastewater flowing into the septic tank is expected to be 54.8 m3 day–1. Conversely, following a hydraulic detention time of one year, the resultant effluent of around 51 m^3 day –1 is discharged from the septic tank and finally disposed into Fundunya manmade forest [17].

Figure 2: Wastewater disposed to Fundunya forest

2.2 Sample Collection and Analysis

Wastewater samples for Physico-chemical and Bacteriological analysis were taken from five sampling points A_1 raw wastewater, A_2 influent wastewater of septic tank, A_3 effluent of wastewater septic tank, and A_4 and A_5, from wastewater dumpsite (disposal site), Wolaita Soddo Teaching Referral Hospital, SNNP, Ethiopia

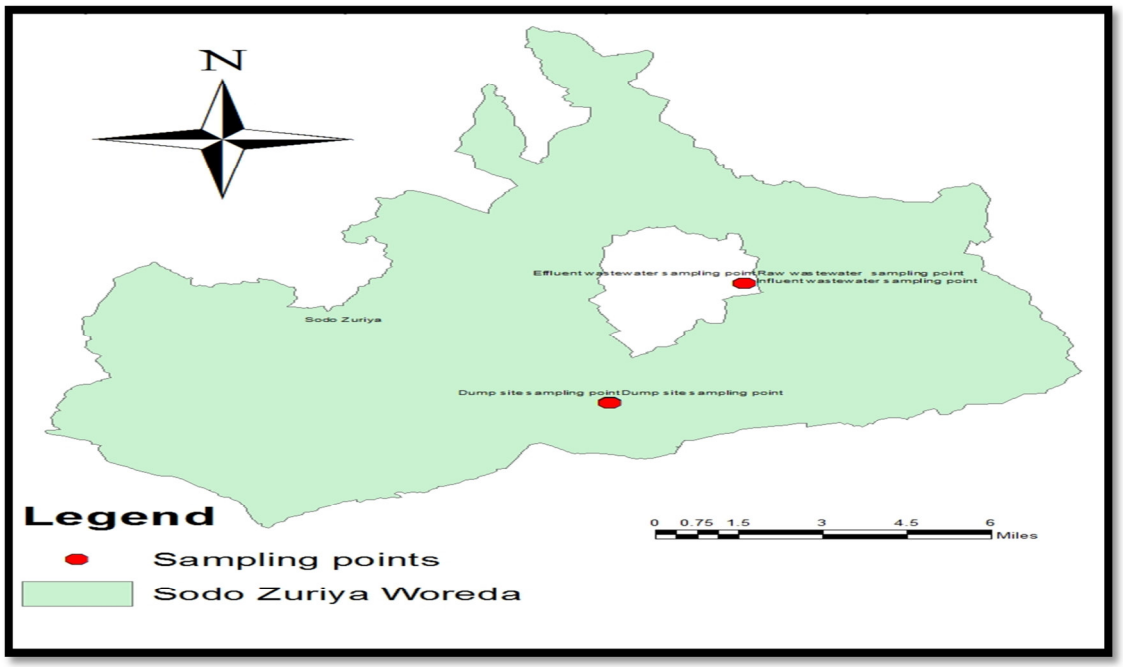

Figure 3: Sample collection site

Samples for the physicochemical and bacteriological characterizations of the wastewater were carried out three times from March-July 2015. At every sampling regime triplicate samples were collected and a total of 60 samples were analyzed as per the guidelines stipulated in standard procedures for water and wastewater sampling [18]. Prior to sampling, the one liter polyethylene bottles were cleaned by incubating them with 10 %(v/v) sulpheric acid solutions for 48 hours in a hot water bath and then washed and rinsed with de-ionized water. They were thoroughly rinsed with the wastewater from the sampling sites before sampling. Samples for heavy metal analysis were fixed by adding 2-3 drops of concentrated sulpheric acid and stored at $4^{o}C$ to minimize re adsorption. Turbidity, conductivity, Total dissolved solid, Temperature, and pH were determined onsite subsequent to their respective sampling. Total dissolved solid, Conductivity, Temperature were measured by dist (Model HI 98311 HANNA). PH of the wastewater was analyzed by a portable pH meter (Model HI 9024 HANNA). Turbidity of the wastewater was analyzed by using turbidity meter. The influent and effluent of hospital wastewater were compared to determine the treatment efficiency of the septic tank. Chemical Oxygen Demand (COD) was measured using COD method 410 (Titrmertric) and Biological Oxygen Demand (BOD_5) was measured according to the standards methods [18]. Dissolved oxygen (DO) of the hospital wastewater and the wastewater of dumpsite was analyzed or measured using modified Winkler method (EPA3602). Total

kjeldahl Nitrogen (TKN), Phosphate (PO_4^{-3}), Sulfate (SO_4^{-2}), Nitrate (NO_3^-) and SS (Suspended solid) were analyzed or measured with the help of Spectrophotometer (DR/2010HACH, Loveland, USA) according to HACH instructions in the Laboratory. Total level of heavy metals (Chromium, Copper, Zinc, Lead, Nickel, Iron, Cadmium, Mercury, and Manganese were measured with Spectrophotometer and atomic absorption spectrophotometer (GF-AAS) according to standard methods [18]. The samples for bacteriological parameter analysis were collected from the hospital wastewater of septic tank and effluent wastewater of dumpsite. Before sampling the bottle was sterilized for about 121^0C for 15 minutes. Then during sampling, burner flame was used to reserve the samples from surrounding bacteria and after sampling the bottle was covered by aluminum sheath to prevent the bacteria from solar radiation. The samples were directly transported to Hawassa University microbiological laboratory in three hour (3hr) sampling period with the help of ice box. Bacteriological parameters were analyzed in Hawassa University microbiology laboratory unit by multiple tube fermentation technique, where the concentrations of Total Coliform and Fecal Coliform bacteria were reported as the Most Probable Number per 100ml (MPN/100ml).

2.3 Data Analysis

The data for all parameters was analyzed by using SPSS version 16 and excel programs. The descriptive data was presented by way of figures and tables (with mean, standard deviation, and range). The sampling points were located by using GPS. Comparison of the mean values of the physico-chemical and bacteriological quality parameters was obtained from the effluent discharged into the disposal (dump) site that was made with the corresponding averages indicated as the maximum permissible levels for the effluent bound to the environment. One-way ANOVA was employed to see significance variation ($p<0.05$) between sampling points for each variable. The removal efficiency of the septic tank for each wastewater quality parameters was calculated using the following formula.

$$Efficiency\ (\%) = \frac{(Cin - Ceff)x100}{Cin}$$

Where: Cin = Stands for the mean value of the parameter measured in the influent.
Ceff = represents for the mean value observed for each parameter in the effluent.

3. RESULT AND DISCUSSION

3.1 Assessment of Physico-chemical and Biological composition of WSRH raw wastewater

The physicochemical, heavy metals and bacteriological parameters were investigated by taking appropriate samples from March to July 2015 from 5 sampling points. The results of nine (9) parameters such as Turbidity, conductivity, Temperature, pH, TDS, TSS, NO_3^-, SO_4^{-2} and PO_4^{-3} had significant difference between sampling points ($p<0.05$). On the other hand, the results of BOD_5, COD, DO, Mn, Fe, Cu, Cr, FC and TC were comparable among sampling points($p>0.05$). Amongst the physicochemical parameters, the average value of BOD_5 (46.17+20.21mg/l), COD (205$\pm$76.48mg/l), TSS (12,788.2$\pm$0.78mg/l),), NO_3^- (2492.67$\pm$0.1mg/l),TKN (11,422.5mg/l), Fe (0.795$\pm$0.01mg/l), Pb (0.042mg/l) were found to be higher than the maximum permissible limit set by Ethiopia Environmental Protection Authority (EEPA, 2003 : USEPA, 2002) while EC (198.08$\pm$2.275NScm-), Turbidity (53.25$\pm$3.68NTU , TDS (98.84$\pm$1.14mg/l) and SO_4^{-2} (4$\pm$2.18mg/l) were below the maximum permissible level. The mean concentration of all heavy metals except Pb and Fe were lower than the maximum permissible level (USEPA, 2002) for effluent discharged to the environment. Similarly, the mean value of TC (1158.335$\pm$515.32MPN/100ml)and FC (1041.67$\pm$ 360.85MPN/100ml were higher than the standard set by (EPA, 2002) effluent discharged into the environment. In addition, the removal efficiency of septic tank was evaluated and presented as TSS (67.08%), BOD5 (54.61%), PO4-3 (33.68%), Cu (95.83%),Mn (66.44%), Cr (60.98%) and Fe (47.47%) %). However, septic tank had poor performance on removing turbidity (9.37%), COD (21%), TDS (27.45%), NO_3^- (-39.00%), SO_4^{-2} (-3.24%), TKN (5.04), TC (14.58%) and FC (20.23).

Table 3: Average concentration of Physicochemical Parameters of WSRH sampling points

Parameters	**Sampling points**				
	A_1	**A_2**	**A_3**	**A_4**	**A_5**
TURB	91.17±1.04	88.77±0.153	81.54±0.446	53.9±5.283	52.6±2.066
COND	427±24.269	327.5±0.5	279.3±0.265	199.77±0.764	196.33±3.786
TEMP	22.5±0.1	23.17±0.153	24.07±0.115	25±1	25.67±0.306
P^H	6.52±0.01	6.77±0.0153	7.22±0.026	7.87±0.042	8.01±0.01
TDS	212.17±14.44	163.77±0.252	139.67±0.153	99.92±0.382	98.17±1.893
TSS	562.1±0.1	220.5±0.5	128.833±0.764	12474.5±0.5	13100.9±0.794
DO	2.63±0.321	2.87±0.153	3.23±0.321	3.4±0.2	2.7±0.361
BOD	204.14±1.030	175.59±113.37	86.18±69.91	46.17±24.432	46.16±15.993
COD	374.67±104.33	317.33±99.143	273.33±75.719	324±58.103	177.33±94.85
PO_4^{-3}	395.1±0.1	260.77±0.153	217.5±0.1	185.27±0.252	2267.5±0.1
SO_{4-}^{2}	120.13±0.153	133.33±7.638	130.83±0.764	5.5±0.5	2.5±2.179
NO_3^-	1.8±0.01	125.93±0.814	88.83±2.466	2245.8±0.1	2739.83±0.208
TKN	740	650	730	20345	2500
Mn	4.733±4.100	1.297±1.124	1.007±0.926	0.0133±0.013	0.055±0.005
Fe	0.573±0.376	0.493±0.256	0.28±0.01	0.66±0.01	0.93±0.01
Cu	1.063±0.920	0.087±0.075	0.024±0.021	0.012±0.002	0.022±0.0025
Cr	0.101±0.146	0.062±0.049	0.033±0.024	0.015±0.003	0.046±0.002
Pb	0.047	0.694	0.051	0.049	0.035
Hg	2.49	4.84	1.052	4.719	11.84
Cd	3.14	1.83	1.28	13.9	15.2
Zn	0.026	0.026	Trace/ND	0.205	0.103
Ni	ND	ND	ND	ND	ND

3.2 Evaluation of the removal efficiency of a Septic Tank of Wolaita Soddo Referral Hospital

As Table 4 reveled that during the study intervals the septic tank of WSRH an average removal efficiency of TC and FC were 14.58% and 20.23% with average effluent count of dumpsite (A_4 and A_5) was 1158.335±515.32 MPN/100 ml and 1041.67±360.85 MPN/100ml respectively which did not attain the effluent Standard (400 counts per 100 ml) set by EPA [19]. (Table 5). According to Tilley et al., [20] a septic tank will remove 50% solids, 40% BOD and 1 –log (99.9999%) reduction of E. coli. According to Afolalu Felix Olugbenga [21], the removal efficiency of a septic tank that treats the liquid waste in Samaru – Zaria, Nigeria and the result showed 40% removal of Fecal coliform. Comparatively, the removal efficiency of the septic tank of WSRH was lower because excessive use of detergents and chemicals (antibiotics/pharmaceuticals) can damage the bacteria in the septic tank of the hospital, lack of desludging, lack of maintainace, lack of pretreatment and improper segregation of waste in the hospital.

Table 4: Removal efficiency of the Septic Tank (%) of WSRH

Parameters/Pollutants	Hospital Wastewater Treating Septic Tank		Efficiency (%)
	Influent	Effluent	
Turbidity	89.97	81.53	9.37
BOD_5	189.87	86.18	54.61
COD	346	273.3	21
TDS	192.47	139.66	27.45
TSS	391.3	128.83	67.08
NO_3^-	63.91	88.83	-39.00
PO_4^{-3}	327.94	217.5	33.68
SO_4^{-2}	126.73	130.83	-3.24
TKN	695	730	-5.04
Mn	3.02	1.01	66.44
Cr	0.082	0.032	60.98
Cu	0.575	0.024	95.83
Fe	0.533	0.28	47.47
TC	1600	1366.67	14.58
FC	1483.35	1183.33	20.23

On the other hand, the BOD and COD removal efficiency of the Septic Tank of WSRH was 54.61% and 21% correspondingly with BOD and COD value of 86.18 ±69.91 and 273.3±75.72 mg/l (Table 4). The removal efficiency of a septic tank that treats black water was studied in Bayelsa State of Nigeria and the result showed 54% BOD, 57% COD and 40% SS removal [22]. According to Ravi Kumar [19], Assessment of the efficiency of sewage treatment Plants was studied in Bangalore the removal efficiency was 94.98% BOD and 76.26 % COD respectively. Relatively, Septic tank in this study had shown low performance of removing BOD and COD (Table 4). The lower removal efficiency of the septic tank for BOD and COD resulted from wastewater from the main hospital of different wards, laboratory and laundry. Hospital contains several organic substances that are resistant to biological degradation [10]. These resistant compounds may affect the biological treatment process of wastewater treatment plant.

Similarly the septic tank in the present study had low performance of removing TSS (67.08%) and TDS (27%) (Table 4). According to Ravi Kumar [23], Assessment of the efficiency of sewage treatment Plants was studied in Bangalore the removal efficiency was 20.01% TDS and 94.51% TSS in that order. The percentage contaminant removals in the Septic tank include 50% BOD removal, 70% TSS, 30% Nitrogen and 40% phosphorus removal [24 &25] The removal efficiency of a septic tank that treats the liquid waste in Samaru – Zaria, Nigeria and the result shows 50.1%, 43.4%, 76.9%, 49.2%, 84.3%, and 36%, of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solid (TDS), Suspend Solid (SS), Nitrate (NO_3^-), and Phosphate (PO_4^{-2}) in that order. Likewise, the septic tank of Wolaita Sodo Referral Hospital (WSRH) had low removal efficiency of TDS and TSS that was mainly due to high suspended solids originated from the hospital wastewater as the wastewater enter in to the septic tank without pretreatment, primary and/or preliminary treatment.

3.3 To ascertain whether the effluent disposed at natural depression in plantation forest meets the established standards

Wolaita Soddo Teaching Referral Hospital wastewater, following to its treatment by the septic Tank and finally the effluent was directly dumped to the receiving environment (dumpsite of Fundunya manmade forest). Determining the amount and nature of contaminants present in the effluent and disposed effluent whether meets or not the established standard is of critical significance.

Table 5: Comparison of Assessed parameters with set standards

Parameters	Unit	Current results of dumpsite effluent (A_4 and A_5)	EEPA (2003), USEPA (2002)
BOD5	mg/l	46.17 ±20.2	≤ 25
COD	..	205± 76.48	≤ 125
TSS	..	12,788.2±0.78	≤ 35
Turbidity	NTU	53.25±3.6	300
EC	NScm$^-$	198.08±2	≤ 1000
SO_4^{-2}	Mg/l	4±1.339	250
NO_3^-	mg/l	2492.67±0.154 1226.384±0.18	≤ 10
PO_{4-}^{3}	mg/l	11,422.5	< 1
TKN	mg/l	0.034	≤ 20
Mn	mg/l	0.795	0.1
Fe	mg/l	0.031±0.003	0.3
Cr	mg/l	0.042	0.1
Pb	mg/l	8.279	0.001
Hg	Ng/l	0.154	0.001
Zn	mg/l	1158.335±515.32	1.33
TC	MPN	1041.67±360.85	400
FC	MPN		400

4. CONCLUSIONS

This study was conducted with the objective of examining the adequacy of hospital wastewater treatment and disposal by Wolaita Soddo Teaching Referral Hospital, the data collected, analyzed and the essential outcomes existing were presented hereunder. From the analyzed physicochemical and bacteriological parameters the results of BOD_5, COD, TSS, TKN, NO_3^-. PO_4^{-3} Fe, Pb, FC and TC were found to be higher than the maximum permissible contaminant level set by EEPA and USEPA. The mean values of NO_3^- in the effluent wastewater from disposal site sampling points (A_4 and A_5) were well exceeded the permissible level set by EEPA. Once nitrates reach the ground water, the only mitigative effect to this contamination is by dilution with the native groundwater. High concentrations of nitrate (greater than 10 mg/l) levels in drinking water wells pose a hazard to the health of infant children who consume the water regularly. Methemoglobinemia or “blue baby syndrome” is

a disease in infants that reduces the blood's ability to carry oxygen and also causes problems during pregnancy. The analyzed heavy metals results showed that their values were within the acceptable range of the guideline set by EEPA and USEPA. However, the result of iron (Fe) and lead (Pb) were greater than the same guideline set by EEPA and USEPA. while the concentration of lead was in excess of the standard limit of 0.001 mg/L which can have the tendency to accumulate in animals and pose a negative effect on human exposure through eating of animals. The efficacy of septic tank in the study area was low in treating hospital wastewater contaminants. The lower removal efficiency of the septic tank was attributed due to the absence of pretreatment, lack of regular desludging, lack of periodic monitoring and lack operation and maintenance program.

There must be appropriate waste management, wastewater treatment and disposal system in the hospital. These can be achieved through the use of the following methods; initially, solid waste should be segregated or separated from liquid waste before discharged in to septic tank. Changing the treatment technology or treatment plant to produce good quality effluent suitable for disposal into the environment is required: there should be proper design and implementation of waste stabilization ponds as anaerobic, facultative and maturation ponds in series which are economical for a wastewater treatment system.

ACKNOWLEDGMENTS

I would like to express my sincere thanks to Humbo Woreda Administration Office and Humbo Woreda Education Office to their financial support for living. I am grateful to Hawassa University Environmental Engineering Department, Hawassa University Biology Department and Hawassa University Chemistry Department for helping me during my laboratory work.

I would like to appreciate my supervisor Dr. Daniel Fitamo and my family members W/r Marta Bitena, Aster Moga, Ato Semaria Moga and Zegeye Moga who encouraged me, in one way or the other during my study.

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