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Bacteriological and Physico-Chemical Characteristics of Hospital Wastewater: the Case of Myung Sung Christian Medical Center and Bethel Teaching General Hospital, Addis Ababa, Ethiopia

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Abstract

Hospital effluents are posing a threat to their proximal environment. However, information on the physical and chemical characteristics of hospital effluents is not adequate. Thus, this study was initiated to evaluate the bacteriological, physical and chemical characteristics of hospital wastewater in Bethel Teaching General Hospital (BTGH) and Myung Sung Christian Medical center (MCM). Samples were collected in triplicates from the selected sites and analysed under a laboratory condition. From the eighteen physico-chemical and bacteriological parameters considered, addition of EM in the hospitals waste water treatment plant (WWTP) improved the pollutants removal performance of ABRs for only three parameters and for seven parameters in the case of AD removal performance. The result also indicated that pollutants removal efficiencies of the two hospitals' waste water treatment plant (WWTP) were in the same range for turbidity (23%-28%), Total Dissolved Soluble (TDS) (23%-27%) and Fecal Concentration (FC) (41%-48%). Therefore, it is concluded that the bacteriological, physical and chemical characteristics of the hospitals' wastewater implied that the waters are significantly polluted. Hence, awareness creation, treatment and environmental interventions should be carried out to mitigate the pollution of the hospitals; wastewater.

***Key words**: Bacteriological Characterization, Bethel Teaching General Hospital, Physico-chemical Characterization, Wastewater Hospital, Myung Sung Christian Medical center*

Introduction

Hospital wastewater is the reservoir of infectious agents and multiple drug resistant microorganisms. If the hospital effluents are not treated, concentrated forms of infectious agents and antibiotic resistant microbes are shed into communities resulting in water borne diseases such as cholera, typhoid fever, dysentery and gastroenteritis (Sharma *et al.,* 2010). These liquid effluents, directly rejected in the network drainage of hospitals, can contribute under certain physico-chemical conditions to the presence of the virus in the urban sewer networks and on the municipal wastewater treatment plant (Casson *et al*., 1997).

Healthcare sewage usually contains a variety of pollution indicators and pathogenic bacteria species that come from patients (Tsai *et al.,* 1998). Hospital effluent contains diverse microorganisms, such as *Samonella* spp., *Shigella* spp., *Haemophilus Influenzae*, Methicillin-Resistant *Stephylococcus aureus*, *Staphylcocci*, *Escherichia Coli* (*E. coli*), *Pseudomonas Arugenosa* and multiple drug-resistant bacteria (Gladwin and Trattler, 1997). Apart from life-threatening pathogens such as the corona virus that caused the symptoms of Sever Acute Respiratory Syndrome (SARS), other virulent bacteria can be transmitted through hospital wastewater include some respiratory pathogens such as *pneumococci* and *haemophilus influenza* (Tsai *et al.*, 1998).

Benin Teaching Hospital wastewater showed high densities of FC and total hetrotophic bacterial population ranges from$1.9x10^{7}$ cfu/mL to $8.3x10^{12}$cfu/mL, also different bacterial population such as: *Klebsiella pneumonia, Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Klebsiella pneumonia, Pseudomonas aeruginosa, Escherichia coli, Serratia marcescens, Streptrococcus faecalis, Proteus vulgaris* and *Bacillis* spp were found in the wastewater (Ekhaise and Omavwoya, 2008). Many of these organisms in themselves are major problems, depending on the route of entry into the human body and the mode of transmission. *Campylobacter jejuni* causes acute gastroenteritis with diarrhea. The pathogenic strains of E. coli are of three types. They are entero-toxigenic, entero-pathogenic, and entero-invasive. All produce acute diarrhea, but by different mechanisms, the fatality rates may range up to 40% in newborns. Outbreaks occur occasionally in nurseries and institutions, and are commonly found among travelers in developing countries (Tsai *et al.,* 1998). Hospital wastewater can be viewed as one of the primary sources of synthetic organics that discharged into the world's aquatic environment (Bruchet *et al.,* 2002). USEPA (1989) has detected 400 toxic and hazardous pollutants in hospital wastewater. Some commonly used chemicals in the hospital environment include sodium hypochlorite (NaOCl) and glutaraldehyde (GA) which has a high potency in inhibiting growth of micro-organisms (Jolibois and Guerbet, 2006). Once NaOCl is disposed as wastewater, even diluted, it can easily and readily react with biological materials, such as proteins and nucleotide bases, producing a wide range of organic chlorinated compounds (USEPA, 1989). Disinfectants or mixtures of active substances as well as surfactants (surface-active agents with a polar head group and a non polar chain) have been recognized as lipophilic, persistent and toxic to aquatic organisms (Schwarz and Vaeth, 1987).

Chemical disinfectants and sterilizers such as alcohol (C_2H_5OH), iodine (I_2), hydrogen peroxide (H_2O_2), formaldehyde and acetone (CH_3COCH_3) are among some chemicals passed regularly in to the wastewater of the hospital sewage network as a part of the hospital routines and activities (Rutala, 1996). Specific solvents used in medical settings include halogenated compounds such as methylene chloride, chloroform, freon, trichloroethylene and 1,1,1-trichloromethane (USEPA, 1989). Healthcare facilities may have been responsible for as much as 5% of all mercury releases in wastewater (Torke, 1994). The contact of hospital pollutants (pathogens, hazardous chemicals, disinfectants, pharmaceuticals and radioactive isotopes) with aquatic ecosystems could have potential negative effects on biological balance of natural environments, pollution of surface waters used for recreational purposes, algal blooms, degradation of aquatic ecosystems, and diminished aesthetic enjoyment (Emmanuel *et al.,* 2005).

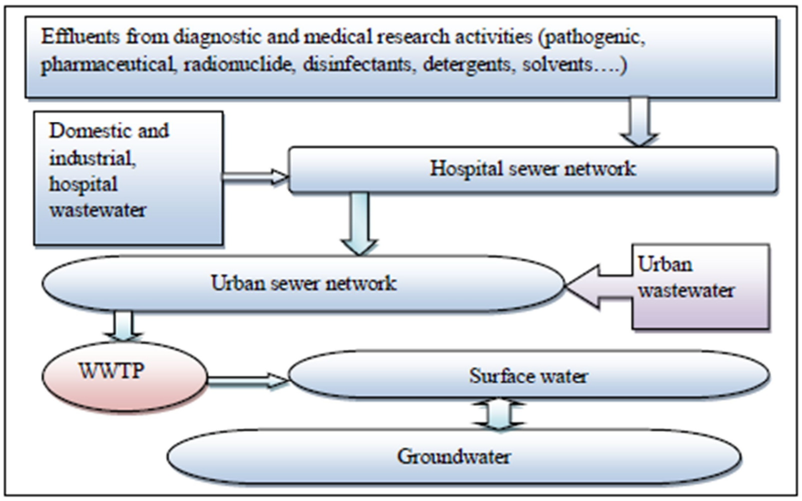

Fig 1: Problem of hospital wastewater discharge directly in to the natural environment.

Humans are particularly exposed by drinking water contaminated with leachate entering the aquifers, surface water and toxic non-biodegradable hospital waste products accumulated in the surface water (WHO, 1999). Figure 1 illustrates the problem of discharging untreated of inadequately treated hospital effluents to the environment. The Objectives of this research was to characterize the bacteriological and physic-chemical composition of the Bethel Teaching General Hospital (BTGH) and Myang Sung Medical (MCM) hospitals wastewater. Thus, the study compares the hospitals effluent with the national wastewater limit values for discharge to water bodies.

Methods and materials

Description of the study area

This study was conducted in Bethel Teaching General Hospital and Myang Sung Christian Medical Center (MCM), Addis Ababa, Ethiopia. Bethel Teaching General Hospital was commissioned in 2000 at Kolfe Keranyo Sub City. Myung Sung Christian Medical Center is found in Gerji area, Bole Sub City (BTGH, 2011; and MCM, 2011).

Study Design

A descriptive study design was employed during October 2010 – September 2011 to gather data for laboratory analysis. A preliminary survey was carried out to be familiar with different aspects of the study area and major data acquisition by laboratory analysis of the selected hospital wastewater samples for determination of the various physico-chemical and bacteriological parameters.

Sampling Sites

The main source of the sample is wastewater from Bethel Teaching General Hospital (BTGH) and Myang Sung Medical Center (MCM) wastewater. Accordingly, samples were collected from influent and effluent of the hospitals Wastewater Treatment Plant for physico-chemical and biological parameters analysis based on standard methods for the examination of water and wastewater (APHA, 1998). Samples were also taken from septic tanks influent and effluent to evaluate the pollutant removal efficiency of septic tanks and to determine the effect of Effective Microorganisms in domestic wastewater treatment.

Sampling Equipment and Interval

All samples for physicochemical tests were collected using a sterilized sampling plastic bottle and for bacteriological analysis sample were collected by sterilized glass bottle. Filtering Apparatus and all laboratory equipments for bacteriological analysis were first autoclaved, at 121^{0}C for 15 minutes including the sampling bottles (APHA, 1998). From each sampling site triplicate samples were collected, raw influent sample was collected at the point before it enters to the treatment plants and raw effluent of wastewater were collected at the point before discharge to municipal drainage system. EM solution was directly poured as indicated in instruction, 1 liter of Effective Microorganisms in 1000 liter of wastewater in to inlet point of the hospitals Wastewater Treatment Plant. Two samples were collected from the wastewater after addition of EM solution from inlet and outlet points based on the interval of the hospitals wastewater HRTs. Samples were collected for three rounds from each hospital. Therefore, a total of 18 samples from both hospitals, i.e., Bethel General Teaching Hospital and Myang Sung Christian Medical Center (MCM) wastewater guest house wastewater were collected and analyzed. With consideration of Quang (2000b) study, Effective Microorganisms was added each day at the dilution rate of 1:1000 in the studied hospitals Wastewater Treatment Plant for five days.

Sampling Volume and Techniques

From each sampling point for bacteriological analysis, a composite sample of 300mL water samples were taken in sterile glass bottles and transported to the laboratory with ice box. For the physicochemical analysis composite water samples of 500mL were collected in plastic bottles, labeled and transported to the AAU Environmental Science Research Laboratory with ice box. Before sample collection the bottles was washed with distilled water and repeatedly rinsed with the wastewater at each sample site. Moreover, for prevention of cross contamination and infection from the hospital wastewater all the necessary personal protective equipment's: gloves, mask, gown and goggle were worn during sample collection and analysis as necessary.

Laboratory analysis

The influent and effluent of the hospital wastewater sample collected for determination of physico-chemical and bacteriological parameters were analyzed in AAU; Environmental Science, Mycology and Microbiology laboratories. Samples were characterized in terms of its physical, chemical and biological composition. The laboratory analysis was done by HACH (2004) procedures, Standard Methods for the Examination of Water and Wastewater (APHA, 1975; 1998) and USEPA (1983) accepted procedures for reporting wastewater analyses.

Results and discussion

Hospital Wastewater Characteristics

A total of 18 physico-chemical and bacteriological parameters were characterized from influent and effluent of wastewater samples of the two hospitals. The following Tables summarized the mean values of the different wastewater quality parameters analyzed in Bethel Teaching General Hospital (BTGH) and Myang Sung Medical Center (MCM) wastewater, respectively.

Physico-chemical Characteristics of Hospital Wastewater

Temperature

As indicated in Table 4.1 and 4.2 the minimum and maximum temperature in the hospital effluents was 22.9 ^{0}C and 24.7 ^{0}C, respectively; which is below the EEPA (2003) standard limit (40 ^{o}C). The difference in temperature between influent and effluent was more than 2^{0}C for MCM wastewater, this might cause by heating or cooling of the wastewater in the digester and weather conditions.

Percent Hydrogen (pH)

As explained in Table 1 and 2 the pH values were in the optimum range. A slight decrease of pH was observed from the load to the effluent during both treatment systems of MCM. This decrease in pH from the influent to effluent could be due to low alkalinity production in the system. The ability to generate more alkalinity may depend on the nature of the wastewater content of carbonate, bicarbonate, hydroxide, silicate and phosphates compounds which through metabolism generate alkalinity (Metcalf and Eddy, 2003). The hospitals effluents pH range (6.22-7.14) comply with EEPA (2003) discharge limit (6-9) and USEPA (1989) discharge limit (6.5-8.5).

TSS

The average minimum and maximum TSS concentration in the two studied hospitals effluents was 84±23.5 and 128±16.6 mg/L, respectively. The BTGH effluent was in level of EEPA (2003) discharge limit but MCM effluent was higher than the limit (128.3 mg/L), which can be caused by a high intensity of loading TSS from residential wastewater. However, final disposal system of the studied hospitals is into municipal drainage systems, with in the permissible level (600 mg/L) of USEPA (1989) for public sewers. A study in Iran showed similar TSS value with the studied hospitals in a higher range of 47-479.5 mg/L (Sarafraz et al., 2006). While, the TSS content of hospital wastewater in Thailand was 115 mg/L (Puangrat and Nattapol, 2010).

TDS

The minimum and maximum TDS concentration of the hospitals effluents was 243±64 and 597±34.8 mg/L (Table 1 and 2), which is below the value of the discharge limit 3000 mg/L (EEPA, 2003). In the study conducted from southwest Nigeria hospital wastewater showed average TDS value 570 mg/L was similar to BTGH effluent TDS value (597 mg/L) (Okunola and Olutayo, 2011). Moreover, a study on the children hospital found in Bangkok showed a TDS value range of 340 - 1720 mg/L (Wangsaatmaja, 1997).

Turbidity
The hospital effluents turbidity value was range of 103-183 JTU. Which is higher compare to the study on Hawassa Referral Hospital wastewater the minimum turbidity was 84 NTU and the maximum was 112 NTU with average turbidity of 97.3 NTU (Simachew Dires, 2008). The primary factors for higher turbidity concentration in the wastewater are organic matters, TSS and flow rate of the wastewater as stated by Metcalf and Eddy (2003).

Table 1: Physico-chemical and bacteriological characteristics of Bethel Teaching General Hospital (BTGH) wastewater, (Mean ± SD).

Parameters**	Influent *	Effluent
Temperature (^{0}C)	23.6±6.7	24.7±4.7
pH	6.8±0.2	6.81±0.5
EC	1164±92.3	1129±77.4
Turbidity, JTU	238±55	183±63
TSS	97.3±19.14	84±23.5
TDS	815±64.8	597±34.8
S^{2-}	351±20.4	531±72.9
SO_4^{2-}	81.7±7.2	52±5.2
NH_3-N	21.4±7.5	20.4±1.8
NO_3- N	39.7±4.3	9.5±0.5
NO_2- N	30.4±5.1	19.5±1.9
TN	54.7±4.7	42.7±7.9
TP	11.9±0.97	5.9±0.5
PO_4^{3-}	11.3±5.63	8.13±3.9
COD	347±24.5	116±30
TC (cfu/100)	$4.2x10^6±5x10^5$	$3.6x10^6±5x10^4$
FC (cfu/100)	$4.1x10^5±5.7x10^4$	$2.16x10^5±3.7x10$
BOD_5	288±38.1	69±3.3

**All units are mg/L unless otherwise mentioned; ** The mean values in each parameters are compared with the international standards (EEPA, 2003; IFC, 2002; USEPA, 1989) (See Appendix 1 and 2)*

Electrical Conductivity
The mean value of EC in the influent and effluent of BTGH was 1164 and 1129. While, average EC value in the influent of MCM was 450 and 365 in the hospital effluent. Even if there is no specific limit value of EC for discharge into inland waters in Ethiopia, many municipalities requires that industries and similar enterprises which discharge sewage to the wastewater, net conductivity is not allowed to be higher than 500 (Azab, 2008). EC value of Bethel Teaching General Hospital (BTGH) wastewater effluent was beyond the required limit which might indicate a high (H+, OH-, nutrients) ion concentration in the BTGH wastewater. Table 1 reveled that higher nutrients value in Bethel Teaching General Hospital (BTGH) wastewater comparing with MCM wastewater, this implies the more dissolved molecules generated during digestion the higher the EC value will be.

Sulfate (SO_4^{2-}) and Sulfide (S^{2-})
The wastewater concentration of SO42- in BTGH and MCM effluent was 52±5.2 mg/L and 15±3.6 mg/L, respectively. This was lower from EEPA (2003) discharge limit of 1000 mg/L. Other study showed similar concentration of SO42- 22.76 and 19.15 mg/L in two sampling points carried out in University of Benin Teaching Hospital (Ekhaise and Omavwoya, 2008). The concentration of S2- in effluent of Bethel Teaching General Hospital (BTGH) and Myang Sung Medical Center (MCM) wastewater was 531±72.9 and 100±20, respectively; which was higher than EEPA (2003) limit of 2 mg/L. This might be caused by the hospitals complete anaerobic Wastewater Treatment Plant system which encourages the growth of more anaerobic bacteria. These bacteria reduce sulfur compounds such as sulfate, there by producing sulfides (Moosa *et al.,* 2002).

Biochemical Oxygen Demand (BOD_5)
As described in Table 4.1 and 4.2, the average BOD5 in Bethel Teaching General Hospital (BTGH) influent were 288 along with 69

mg/L effluent concentration, in MCM the average BOD5 influent was 144.3 mg/L and effluent concentration was 86.5 mg/L. Even if there is no specific discharge limit for healthcare wastewater in Ethiopia with comparing the hospitals effluent to the average BOD_5 discharge limit (80 mg/L) of industrial sectors (EEPA, 2003).

The BOD5 of Myang Sung Medical Center (MCM) wastewater effluent is a bit higher than the limit which might cause by a higher organic matter loading rate from the residential effluent or high ammonia level in the wastewater as Table 4.1 showed the NH3-N value in Bethel Teaching General Hospital (BTGH) wastewater effluent was above the permissible limit of EEPA. However, the BOD5 values of the studied hospitals was lower than the average raw wastewater BOD5 value of the seven hospitals (242.25 mg/L) in Hormozgan Province (Sarafraz *et al.,* 2006) and also lower than Rezaee *et al.* (2005) hospital effluent BOD5 value 270 mg/L.

Table 2: Physico-chemical and bacteriological characteristics of Myang Sung Medical Center (MCM) wastewater, (Mean ±SD).

Parameters influent**	Residential effluent	Residential influent	Hospital influent	Hospital effluent
Temperature ^0C	23.73±5.14	23.1±4.6	20.2±0.85	22.93±2.53
pH	6.78±0.38	6.4±0.08	7.14±0.82	6.22±0.1
EC,	253.5±1.82	217±5.3	450.3±85.9	365±63
Turbidity, JTU	200.67±10.1	152±5.7	142.3±41.2	103±32.97
TSS	350.6±9.8	236.3±8.3	283.3±18.3	128.3±16.6
TDS	364±12.6	212±37.3	315.2±60.17	243.03±63.9
s^{2-}	360±24.5	218±12	200±15.33	100±20
SO_4^{2-}	18±2.51	8.5±0.98	27.67±7	15±3.6
NH_3-N	27.6±13.2	25±18.5	6.5±1	5.4±4.3
NO_3- N	14.0±0.56	11.7±0.68	30.7±5.5	14.7±0.6
NO_2- N	50.33±2.5	24.6±5	30.03±6	16.7±2.8
TN	93.3±5	67±4.17	21.7±2.8	12.7±1.5
TP	28.3±9.57	23.8±8.05	11.62±3.6	9.84±2.57
PO_4^{3-}	8.93±6.09	8.90±7.9	4.47±0.76	2.87±1.89
COD	532.6±29	427±27.9	309.6±25	169±13.9
TC (cfu/100)	$2.5x10^7±3.6x10^6$	$2.2x10^6±3.4x10^5$	$2.6x10^6$ $±1x10^6$	$12.9x10^5±2.1x10^4$
FC (cfu/100)	$6x10^7±1.3x10^6$	$3.4x10^6±6.3x10^5$	$4.03x10^5±5.8x10^4$	$2.3x10^5±4.5x10^4$
BOD_5	243.2±20.7	180.23±14	144.3±12	86.5±13.5

**All units are mg/L unless otherwise mentioned; ** The mean values in each parameters are compared with the international standards (EEPA, 2003; IFC, 2002; USEPA, 1989) (See Appendix 1 and 2)*

COD

The average minimum and maximum COD concentration of the studied hospitals effluent was 116 mg/L and 169 mg/L, respectively, which is below the discharge limit to industrial effluent 250 mg/L (EEPA, 2003). The studied hospitals COD concentrations showed lower value when compared to other studies; Dhulikhel Hospital in Nepal the average value of the influent COD was 262 mg/L (Bista and Khatiwada, 2004), Pauwels and Verstraete (2006) study reported a hospital effluent COD value of 1067 mg/L.

BOD_5/COD Ratio

In this study the biodegradability of the raw wastewater was estimated and the initial value of BOD5/COD ratio of Bethel Teaching General Hospital (BTGH) influent and effluent was 0.82 and 0.59. The Myang Sung Medical Center (MCM) wastewater BOD5/COD ratio of the guest house influent and effluent was 0.46, 0.42. While the hospital influent and effluent sample was 0.47 and 0.51, respectively. It has been reported by Franceys et al. (1992), the biodegradation starts immediately and runs rapidly with a ratio of BOD5/COD in the range over or equal to 0.5. With a BOD5/COD < 0.5, there is a possibility for chemical substances which have low biodegradability to slacken or delay the biological process; while a value lowers than 0.05 indicates that the effluent is practically non-degradable. According to Metcalf and Eddy (2003) typical value for the ratio of BOD5/COD for untreated municipal wastewater are in range from 0.3 to 0.8 the studied guest house wastewater are in specified range. The two hospitals wastewater represented relatively enviable biodegradability with the exception of MCM influent which shows lesser biodegradability value but by acclimation of microorganisms in the digester the effluent shows a higher BOD5/COD ratio with a better biodegradability. High biodegradability of organic matters is very desirable from the viewpoint of wastewater treatment and promotes the efficiency of wastewater treatment plants (Metcalf and Eddy, 2003).

Nitrogen Ammonia (NH3-N)

The average NH3-N of Bethel Teaching General Hospital (BTGH) wastewater effluent was 20.4±1.8 mg/L and 5.4±4.3 mg/L for MCM effluent (Table 4.1 and 4.2). According to Ethiopia standards for industries effluent discharge limits to inland water (EEPA, 2003) the value of NH3-N is 5mg/L which is above the guideline for both hospitals effluent. The term "free ammonia" is used when naturally occurring ammonia like raw sewage (urea and fecal material) is present in wastewater or when chloramines are used for disinfection, according to Hahn et al. (1994) Chloramine T (CAT), p-CH3C6H4SO2NClNa 3H2O, is used in hospitals as a disinfectant and for sterilization of endoscopy instruments. The portion of ammonia that has not combined with chlorine exists as either NH4+ or NH3-depending on the pH and temperature of the water. At typical wastewater pH of 7.0-7.8 and temperature of 12-24 0C, more than 96% of ammonia is in the ionized form of ammonium (NH4+). As the pH and temperature increase, the amount of NH3 increases and the amount of NH4+ decreases. Waste water treatment plant of Bethel Teaching General Hospital (BTGH) and Myang Sung Medical Center (MCM) wastewater are typically anaerobic (absence of oxygen), conversion of organic nitrogen to ammonium nitrogen is rapid and nitrogen remains predominately as ammonium in effluent.

Nitrate (NO3-N) and Nitrite (NO2-N)

The average NO_3^-N and NO_2^-N of BTGH effluent was 9.5±0.5, 19.5±1.9 mg/L (Table 4.1), respectively. MCM effluent value of NO_3^- N and NO2-N was 14.7±0.6 and 16.7±2.8 mg/L, respectively (Table 4.1). The amounts of nitrate in both of the studied hospitals effluents were below the discharge limit for industrials effluent (EEPA, 2003) which is 20 mg/l. Even if there was no discharge limit value for nitrite in EEPA (2003) guideline, a higher value of nitrite than nitrate can be shown in the two hospital wastewater, which can be caused by the anaerobic decomposition when oxygen is not available as hydrogen accepter the microorganisms use nitrate as a final electron acceptor (Korom, 1992).

Total Nitrogen (TN)

Total nitrogen of Bethel Teaching General Hospital (BTGH) wastewater effluent was 42.7±7.9 mg/L while, Myang Sung Medical Center (MCM) wastewater effluent value of TN was 12.7±1.5 mg/L, which is lower than the discharge limit for both effluents (EEPA, 2003). Comparing the result in the two study area to that of Puangrat and Nattapol (2006) in Dong Thap general hospital, the influent concentrations of TN was 49.3 mg/L and 30.6 mg/L of effluent. Hawassa referral hospital wastewater average TN input into the treatment plant was 93.3 mg/L, and 34.74 mg/L in the hospital effluent (Adane Sewhunegn, 2011).

Total phosphorus (TP) and Orthophosphate (PO_4^{3-})

The value of TP and PO43-in the influent of Bethel Teaching General Hospital (BTGH) wastewater was 11.9 and 11.3 mg/L with 5.9 and 8.13 mg/L values in the effluent. Myang Sung Medical Center (MCM) wastewater influent value of TP and PO43- was 11.62 and 4.47 mg/L while the effluent value was 9.84 and 2.87 mg/L respectively, both hospitals effluent of TP value were below the discharge limit (EEPA, 2003). Comparing the result with Adane Sewhunegn (2011) study conducted in Hawassa referral hospital, the hospital raw wastewater TP was 45.73 mg/L and PO43- was 26.19 mg/L. While, in Simachew Dires (2008) study revealed that TP of 78.5 mg/L and PO43- value of 52 mg/L in the raw hospital wastewater. Both studies showed that TP and PO43- value of Hawassa referral hospital raw wastewater was higher than Bethel Teaching General Hospital (BTGH) and Myang Sung Christian Medical (MCM) hospital raw wastewater. The findings of this research showed that heavy metals characteristics of hospital wastewater are above the acceptable level. This corresponds with the reports of AAEPA (2010) data shown in Table 3 the heavy metals concentrations of Bethel Teaching General Hospital (BTGH) and Myang Sung Medical Christian Center (MCM) wastewater were under the national effluents discharge limits to water bodies even higher level of Fe (2.37 mg/L) in Bethel Teaching General Hospital (BTGH) wastewater and higher level of Ag (0.12 mg/L) in MCM wastewater observed.

Table 3 : Heavy Metals Concentration (mg/L) of Bethel Teaching General Hospital (BTGH) and Myang Sung Christian Medical Center (MCM) wastewater raw wastewater.

Heavy metals (mg/L)	BTGH	MCM
Ca	0.0001	0.0001
Pb	0.0001	0.0001
Cr	0.0001	0.012665
Zn	0.224943	0.18825
Fe	2.372	0.7184
Ag	0.0001	0.1193

**The mean values in each parameters are compared with the international standards (EEPA, 2003; IFC, 2002; USEPA, 1989) (See Appendix 1 and 2)*

Heavy metals analysis from the Hawassa referral hospital raw wastewater by Simachew Diress (2008) verified that the average concentration of Cu, Ni and Zn was 0.04 mg/L, 0.07 mg/L and 2.5 mg/L, respectively. While the concentration of Cd, Pb and Ag in the raw wastewater was below 0.0001 mg/L. In Okunola and Olutayo (2011) study, the hospital effluent Pb, Zn, Cu, Mn, Fe, Ni, Cd and Cr concentrations were 32.1, 23.10, 2.22, 3.26, 5.45, 0.01, 8.9, 4.6 mg/L, respectively and all of the metals value were above the Nigeria EPA discharge limit except Ni. In another study done in Nigeria to identify the genotoxicity of hospital wastewater; the result showed that presence of certain sample constituents most of toxicants and some of the constituent elements were mutagens and carcinogens. Some of the genotoxic effect of the wastewater might cause by synergistic reaction of the chemical combination with heavy metals which will be more destructive than the individual effect (Okunola and Olutayo, 2011). Around three thousand types of pharmaceutical drugs are used worldwide, either in domestic premises or hospitals (Kummerer, 2001), many analgesics, beta-blockers, anti-depressants, caffeine, antibiotics; antiviral or anti-fungal drugs not fully metabolized are excreted by the patients and thereby enter the common flow of the sewage with the wastewater generated from the hospital sanitary systems (Halling-Sorensen et al., 1998), which are capable of causing ecological and environmental destructions, especially when the levels of those drugs have exceeded the tolerable limits (Kummerer and Helmers, 2000).

Bacteriological characteristics of Hospital Wastewater

Total Coliform (TC)

As indicated in Table 4.1 and 4.2 the average number TC in Bethel Teaching General Hospital (BTGH) and Myang Sung Christian Medical Center (MCM) wastewater hospitals' effluents was 3.6x106 cfu/100 mL and number of TC in MCM effluent was 12.9×10^5 cfu/100 mL. The numbers of TC bacteria found in both of the hospital effluents was higher than the EEPA standard which is 400 cfu/100 mL. Relating the result to other studies, the studied hospitals have lower TC number; the minimum and maximum numbers of TC in the wastewater of Razi Hospital and Bahrami Hospital was $2.2 \times 10^7$and 3.8×10^7 MPN/100mL (Mesdaghinia *et al.,* 2009). Children's Hospital located in Bangkok 45×10^6 MPN/100mL of TC was obtained in the effluent of the hospital waste water (Wangsaatmaja, 1997).

Feacal Coliform (FC)

According to WHO (2006) for unrestricted irrigation the treated wastewater contain no more than 1000 FC per 100 mL and based on IFC (2007) liquid effluent concentration of FC for health care facilities to discharge to surface water it must be less than 400 MPN/100mL, the considered hospitals exceed the specified rang. Similar result was observed in study of Bista and Khatiwada (2004) the FC in effluent of Dhulikhel Hospital was 3×10^5 MPN/100mL and reported that high counts of bacterial load reflected the level of pollution in the environment that is an indication of the amount of organic matter present.

Residential Wastewater Characteristics

According to USEPA (2002) and Metcalf and Eddy (2003) the residential wastewater physico-chemical and bacteriological characteristics are so far in the range of typical concentrations of untreated domestic wastewater except the value of nitrogen and phosphorus. A typical concentration of ammonia in raw sewage must be in the range of 4-13 mg/L (Metcalf and Eddy, 2003) but the study area raw sewage value was 26.7 mg/L (Table 2), might caused by typically anaerobic (absence of oxygen) conversion of organic-nitrogen to ammonium-nitrogen is rapid and nitrogen remains predominately as ammonium in septic tank effluent. According to Metcalf and Eddy (2003) the concentration of total phosphorus in untreated domestic wastewater is in the range of 4-7 mg/L but the residential wastewater has a value of phosphorus which was 28mg/L imply high rate usage of phosphate containing chemicals like detergents, when phosphate containing detergents are used in households can increase the level of phosphate concentration in the wastewater (Jonathan, 2001). Based on Table 4.2 the septic tank effluent is in typical concentration range of domestic wastewater; for pH (6.4-7.8), BOD_5 (118-189mg/L) and lower than the range for FC (106-10^7 cfu/mL) as specified by USEPA (2002).

Conclusion

From the findings of this study, it is concluded that most of the studied pollutants effluents were found to be below the national wastewater effluent limit values for discharge to inlands water, except the level of NH_3-N and TC. The two hospitals wastewater samples showed high biodegradability of organic substances, which is very desirable from the viewpoint of wastewater treatment and promoting the pollutant removal efficiency of the wastewater treatment plants. From eighteen physico-chemical and bacteriological parameters, the Bethel General Teaching Hospital's magnitude of pollutants removal efficiency was below 50% for most of the parameters except nitrate (76.1%), COD (66.4%) and BOD_5 (75.9%). In Myang Sung Christian Medical Center (MCM), the concentration of the specified pollutants was found considerably significant for few parameters such as TC (93.7%), COD (58.7%), TSS (54.7%) and NO_3-N (52.2%). The current status of physico-chemical characteristics and microbial load might have been caused by the longer HRT for complete degradation of the substrate.

Recommendations

It is recommended from the finding that judiciously combined utilization of Effective Microorganisms with supplementary treatment methods for realizing safe treatment efficiencies. Raising awareness, followed by government subsidy in the area of research could be a great help to the overall control in the pollution problems caused by hospital wastewater. Strict monitoring of these healthcare facilities by regulatory agency should be implemented as well as environmental agencies visit to the particular treatment plants can be made more mandatory. As a body to safeguard the public's health, hospitals need to take an active role in recognizing the impact and hazards posed by their wastewater discharged towards the aquatic and terrestrial ecosystems and, most importantly, carry out proper and effective measures. In order to achieve effective wastewater control from hospitals, collaboration among healthcare professionals, management personnel and the environmental protection agencies are necessary. Further studies should be carried out on characterization of hospital wastewater.

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Appendices

Appendix A: Hospital wastewater discharges limit

Appendix A.1: Guidelines for discharging hospital wastewater to inland waters

Parameter	EEPA, (2003) Emission Value (mg/L)	IFC, (2002) Emission Value (mg/L)	USEPA, (1989) Emission Value (mg/L)
pH	6 – 9units	6 – 9units	6.5-8.5units
Temperature	40°C	_	_
BOD5	80	50	10
COD	250	250	100
TSS	100	20	600
TDS	3000	_	500
TKN	80	_	_
Total ammonia	30	_	_
NH3-N	5	_	10
NO3-N	20	_	10
Dissolved phosphorus	5	_	_
TP	10	_	5
Fats, oils and grease	20	10	_
Cd	1	0.1	0.005
Cr	2	_	_
Fe	10	_	_
Pb	0.5	0.1	0.1
Hg	0.001	0.01	_
Ag	1	_	_
Zi	5		2
Cl, total residual	1.5	0.2	_
Phenols	1	0.05	_

***Sources**: EEPA (2003) standards for industrial effluent discharges to inland waters, International Finance Corporation (IFC, 2002) emission limit value of healthcare facility wastewater to municipal or other sewerage systems and USEPA (2001) quality of wastewater acceptable for discharging in to surface water was considered for this study.*

Appendix A.2: Typical composition of untreated domestic wastewater

Contaminates	Concentration		
	Weak	**Medium**	**Strong**
TSS	350	720	1 200
TDS	250	500	850
Fixed	145	300	525
Volatile	105	200	325
Suspended solids	100	220	350
Fixed	20	55	75
Volatile	80	165	275
Settleable solids mL/L	5	10	20
BOD5	110	220	400
TOC	80	160	290
COD	250	500	1 000
Total Nitrogen	20	40	85
Organic	8	15	35
Free Ammonia	12	25	50
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus (total as P)	4	8	15
Organic	1	3	5
Inorganic	3	5	10
Chlorides	30	50	100
Sulfate	20	30	50
Alkalinity (as CaCO3)	50	100	200
Grease	50	100	150
Total coliforms No/100 ml	10^6-10^7	10^7-10^8	10^7-10^9

All units are mg/L unless otherwise mentioned.

***Source**: Adapted from Metcalf and Eddy (2003). Wastewater Engineering, , 3rd edition.*