AFRICA CENTER OF EXCELLENCY FOR WATER MANAGEMENT

ADDIS ABABA UNIVERSITY

ASSESSMENT OF EFFLUENT CHARACTERISTICS AND WASTEWATER MANAGEMENT PRACTICES IN SELECTED HOSPITALS OF ADDIS ABABA, ETHIOPIA

BY

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THESIS APPROVAL AHEET

This is to certify that the thesis prepared by **Biniyam Bekele**, entitled: **Assessment of effluent Characteristics and Wastewater Management Practices of the Selected Hospitals of Addis Ababa, Ethiopia** submitted in partial fulfillment of the requirements for the degree of Master of water supply and sanitation fulfills the regulations of the University.

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Table of Contents

List of Tables

List of Figures

Appendixes

Acronyms

AACGEGDC	Addis Ababa City Government Environmental and Green Development Commission
AWWTT	Advanced West Water Treatment Technology
ACEWM	African Center of Excellence for Water Management
AOP	Advanced Oxidation Processes
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen demand
ECs	Emerging Contaminants
FAO	Food and Agriculture Organization
FDRE	Federal Democratic Republic of Ethiopia
HRT	Hydraulic Retention Time
HWW	Hospital Wastewater
ICP-MS	Inductively coupled plasma-Mass spectrometric
MWWTP	Municipal West Water Treatment Plant
MBR	Membrane bioreactors
MOH	Ministry of health
NEQS	National Environmental Quality Standard
SPHMMC	St. Paulo’s Hospital Millennium Medical Collage
TASTH	Tekur Anbesa Specialized and Teaching Hospital
TC	Total Coliforms
TN	Total Nitrogen
TP	Total Phosphorus
TDS	Total Dissolved solids
TSS	Total Suspended Solids
WHO	World Health Organization
WWTP	Waste Water Treatment Plant

Abstract

Pollutants from hospital wastewaters are becoming serious issue in both developing countries of the world. There is a need to evaluate the quality of wastewater discharged from hospitals with regulatory standards. In response, this study investigates the wastewater generation, characteristics and sewage management practices in seventeen selected hospitals in Addis Ababa, Ethiopia. Descriptive study was employed to understand the status of wastewater management practices. Wastewater sampled weekly from August 10/2020 to August 24/2020. Two public hospitals were used to analysis of heavy metals, bacteriological and other physico-chemical wastewater parameters were analyzed using standard methods and the results were compared with effluent permissible limit standard of the City (AACGEPGD). pH, Conductivity, Turbidity and Total coliform levels were in the range of 6.8-7, 1058-1390 µS/cm, 60-152 NTU and >2400 MPN, respectively. The range of other parameters include total suspended solids; 100-550 mg/L, total solids; 692-1528 mg/L, total dissolved solids; 410-1428 mg/L, chemical oxygen demand; 93-443 mg/L, biological oxygen demand; 29-118 mg/L, total organic carbon; 2-9 mg/L, total nitrogen; 1-18 mg/L, total phosphate; 13-40 mg/L and sulfate; 16-48 mg/L, mercury; 0.003-0.21 mg/L, manganese; 0.05-0.93 mg/L, zinc; 0.02-0.85 mg/L and iron; 0.7-4.89 mg/L, were investigated. The results indicated that the effluent quality of the presented hospitals for most wastewater parameters such as; EC, TSS, TDS, BOD_5, COD, TP, TN and Total coliforms were above the standard permissible limit of the city (AACGEPGD). Therefore, the surveyed hospitals must need to adopt preferable wastewater treatment plant up to the existing standards.

Key word- Hospital Waste Water, Wards Effluent, Wastewater Management

1. INTRODUCTION

1.1 Background

The ultimate goal of wastewater management is protection of public health and these will help to secure the economic, social and political activity of the country. On the near future, due to on increased global population size and potential drought may lead to shortage of water supply, these will also be expected to increase the demand of water recycling (Leslie et al., 2015). Now a day's pollutant from hospital wastewater is serious issue in both developed and developing countries in the world due to their qualitative and quantitative characteristics (WHO, 2011).

Hospitals discharge considerable amounts of chemicals and microbial agents through their wastewaters. It was estimated that hospitals generate on average 750 liters of wastewater by bed and a day (Verlicchi, 2018). Due to activities in diagnostic and research laboratory or medication excretion, the most expected type pollutant which can be present in the hospital wastewater are pharmaceuticals, disposed of chemicals and infected secretions. Many of these chemical compounds may resist and pass conventional wastewater treatment plants where they end up in surface and ground waters where they can influence the aquatic ecosystem (Emmanuel, 2002). Furthermore, the interaction of microbial agents originating from infected secretion or laboratories and pharmaceutical wastes will lead to the development of multi-resistant microbial strains such as antibiotic resistance microbes (Pauwels *et al*., 2006).

The report by the expert in water environments, DHI (BioBooster, 2016) states that significant quantities of specialized pharmaceuticals and chemicals are used in hospitals and most of these pharmaceuticals are excreted by patients via urine and feces and therefore end up in the wastewater. Several studies have focused on their occurrence in wastewater and freshwater and on their toxicity toward aquatic non-target organisms (algae, invertebrates and fishes) (Fent et al., (2006), Luis (2019)). In the same time is obvious that different types of pathogenic microorganisms will exist in the hospital wastewater, therefore finally the presence of these substance in the wastewater will allow the microbes to develop resistant for diverse types of antibiotics. 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 (Guardabassi and Dalsgaard, 2002). This problem is also happening here in Ethiopia, in southern region of the country the research by Sintayehu et al., (2014) shows that the wastewater from the studied hospital is examined for the presence of drug resistance bacteria and many types of bacteria's during his research had detected and being developed resistance for some antibiotics and also, he states in detail that the expansion of these pathogens in the environment could affect the community health and economy.

Most biological wastewater treatment plants are designed to remove biodegradable organic material, but not designed to remove low concentrations of synthetic pollutants (North, (2005), Leslie, (2015) Luis et al., (2019)). Studies also indicates that pretreatment of hospital wastewater via only biological treatment plants and discharging to domestic wastewater sewage system is not a sufficient solution due to the micro-pollutant content of hospital wastewater (Verlicchi et al., 2010). On the other hand's, scenarios had observed in countries like; Australia, Iran, Egypt, India, Japan, South Africa, and Thailand. However, in many other developing countries, such as Algeria, Bangladesh, Congo, India, Nepal, Pakistan, Taiwan, and Vietnam were seen that they are practicing discharging the effluent directly to nearby environment or co-treating with MWWTP (Al Aukidy et al., (2018), www.wepa-db, (2013)) This will help pollutants from hospitals appear at effluent of municipal wastewater treatment plant (Nicole and Deziel, 2014).

1.2 Statement of the problem

Addis Ababa has up flow anaerobic sludge blanket reactor and open lagoon stabilization pond treatment plants, namely; Kaliti and Kotebe. Kaliti treatment plant is designed basically to treat domestic wastewater, whereas it also treating some industrial effluent (Van Rooijen and Taddesse (2009) AACGEPGDC (2016)). Since MWWTP are design to treat organic type of polutants, co-treatment of hospital wastewater with municipals wastewater may affect the existing municipal wastewater treatment plant efficiency (Nicole and Deizel, 2014). and according to the research report by Eyasu and Hamere (2017) the current wastewater treatment systems are not potentially treat the existing wastewater properly. Even though there is lack of reliable and documented data, most of hospitals in Ethiopia particularly in Addis Ababa city, they are seems connecting their effluent to the municipal seaware system as well as disposing to the city wastewater treatment plant via WW trucks.

On the other hand, most of the time in some part of Addis Ababa city during wet season overflowing of wastewater from the seaware system is common and noticeable problem, therefore if hospitals effluent is connected directly to the municipal seaware system, is noticeable that it will have a potential to over flow pollutants from the system or may link to nearby rivers. In Addis Ababa, there is a big river named by Akaki which cross some part of the city and flows in the southern direction of Aba-samuel Lake (Worku and Giweta, 2018) and the river is feeds by more than nine perennial rivers which comes from the city catchments (Melaku et al., 2007). The research report shows that the rivers in the city (Addis Ababa) are highly polluted with different substances which can affect the environment and human health (Eyasu and Hamere, 2017) and the researchers besides states that, the most pollutants source are hospitals, but the report was not include and indicate that specifically which hospitals are the source and vastly discharging the pollutants. So that assessment on hospitals wastewater management practice is essential and should be done.

To manage hospitals effluent in cost effective manner, since wastewater generated from hospital is a collection from different units of the hospital, is better and recommended to consider which hospital unit is highly pollutant source and treating separately (Nadeem et al., 2019). The research by Akin and Beril (2016) which were conducted on evaluating of hospital laboratory wastewater quality by assessing for the concentration of pathogens, heavy metals, and organic materials and the results has been considered that as there was a significant change the degree of contamination to the final hospital effluent. And also the study result for quality of hemodialysis ward effluent shows that with high concentrations of nitrites, phosphates, sulfates, ammonia, and total nitrogen, as well as elevated conductivity, turbidity, salinity, biochemical oxygen demand and chemical oxygen demand and were exceed the thresholds standards of WHO (Mokhtar et al., 2020). Whereas studies didn't address and characterize all hospital's unit effluent quality. Accordingly, it needs to conduct further studies to investigate different hospitals ward effluent quality.

As many researcher's states, the major problem for well monitoring of hospitals effluent management practices in the existing conditions, there is lack of pollutant emission level standards on national level and most of countries in the world specifically for hospitals effluent, there is no organized standards on national level (Nadeem et al., 2019). On this study period also, there were no developed standards at national level of Ethiopia (EFDRE), whereas there was pollutant emission standard as the city level (Table-11) by "Addis Ababa City Government Environmental Protection and Green development Commission" which can be applicable for different sectors such as; Hotels, Schools, Health facilities, Real estates, Condominiums and others, but they are yet on process for implementation. And due to lack of reliable data which are explored and documented on this area, both the governing body and the owners of the hospitals doesn't seems considering the problem and sees when they are taking action, particularly it need to assess and document the wastewater management practice and the quality of hospitals waste effluents.

1.3 Research question

- How is wastewater managed in selected hospitals?
- Is the wastewater management practice effective or not?
- What are the estimated generation volume of wastewater in selected hospitals?
- What kind of heavy metals and Physico-chemical elements are present in each unit of hospital and final effluent of selected hospitals?

1.4 Objective of the study

1.4.1 General objective

The general objective of the study was to assess the wastewater management practices of selected hospitals in Addis Ababa, Ethiopia and characterize the quality of wastewater released from two biggest City Hospitals.

1.4.2 Specific objectives

- To assess the wastewater management practices and generation of the selected hospitals (17) in Addis Ababa.
- To characterize the biological and physico-chemical properties (heavy metals, total coliforms, biological and chemical oxygen demand) of wastewater from the hospital units of two biggest city hospitals (Tikur Anbesa and St. Paulo's Hospital).
- To investigate how the various hospital units influence the quality of final hospitals effluent.

1.5 Scope of the work

There is a need to evaluate the quality of wastewater discharged from hospitals with regulatory standards. In response, this study investigates the wastewater generation, characteristics and sewage management practices in seventeen selected hospitals in Addis Ababa, Ethiopia. In addition, the study focuses on evaluation of the quality of the hospital unit's effluent.

1.6 Limitation of the work

- Unwillingness of few hospitals to provide information such as; type of medicines consumption and take wastewater samples which makes this research.
- Challenge of getting HPLC and GC-MS to fully characterize the type and estimate amount of individual pharmaceutical wastes in Ethiopia.

2. LITERATURE REVIEW

The book which deals on Safe management of wastes from health-care activities (A. Pruss, 1999) and on the part of discussions about Collection and disposal of wastewater, states that Wastewater from health-care establishments is a similar quality to urban wastewater, but may also contain various potentially hazardous components, like Microbiological pathogens, Hazardous chemicals, Pharmaceutical and Radioactive isotopes. And also, the book had discussed the potential sources to generate these pollutants as follows;

- Microbiological pathogens including bacteria, viruses, and helminthes, which are easily transmitted through water can be produced by wards treating patients with enteric diseases and is a particular problem during outbreaks of diarrheal disease.
- Larger quantities of hazardous chemicals can be generated from cleaning and disinfection operation rooms.
- Sewage from hospital pharmacies and from the various wards can be more important source for pharmaceutical contaminant including antibiotics and genotoxic drugs and oncology departments are the source for radioactive isotopes.

2.1 Quantitative and Qualitative characteristics of hospital wastewater

2.1.1 Hospital wastewater generating volume

Hospitals consume an important volume of water per a day and the amount of contaminated water produced from is relies up on various components; bed numbers, general administration exhibit inside, number and type of units and wards, establishment administration arrangement (Verlicchi et al., 2010). The amount of wastewater discharged from hospitals is estimated based on per capita production of bed and in America 1000 liters/person/day may discharge (Ibeh I., 2011). The value generally admitted for hospitals varies from 400 to 1200 liters/day/bed (Mehrdad et al., 2014). The hospital which had 2000 beds have investigated generating total of 2400 m^3/day which is approximately 1200 L/bed/day (Bashir and Jindal, 2018). Verlicchi (2018) states that healthcare facilities found worldwide are most time expected to discharge a volume of 200–1,200 L /bed/day wastewater, somehow this may vary between 400 and 800 L/bed/d).

2.1.2 Microbiological contaminants from hospital wastewater

Wastewater from industries like hospitals, as they are health care facilities is expected to have different pathogenic microorganisms such as; virus, bacteria, parasite and other various microbial components. The bacteriological characterization of hospital effluents typically includes the assessment of indicators of fecal contamination and pathogens. The presence of fecal coliforms in wastewater is regarded as an indication of fecal contamination, therefore the presence of pathogenic fecal microorganisms will be expected.

The study investigated the hospital waste management practices in eight randomly selected hospitals located in Damanhur City of El-Beheira shows that the mean number of TC has been more than 2400 MPN per 100 ml in raw wastewater and 831 MPN per 100 ml in treated wastewater (El-Salam, 2009). And also, the study on wastewater from hospital and the effluent from clinical laboratory unit shows that E. coli levels varied between 9×10^2 and 8×10^4 cfu/100ml ranges on different study period (Beril, 2016).

The research at southern region of Ethiopia, at the effluent of the Hawasa referral hospital the average bacterial count of total coliforms and fecal coliforms was $5.12 \times 10^7 \pm 7.3 \times 10^5$ cfu/100m1 and $1.8 \times 10^7 \pm 5.8 \times 10^5$ cfu/100 ml, respectively throughout the investigation period (Dires, 2008).

2.1.3 Physico-Chemical Characteristics of hospital wastewater

Different type of detergents, disinfectants, laboratory reagents and medical treatment wastes are the major influencing substance to the physico-chemical quality of hospitals effluent. Electrical conductivity, Temperature, pH, turbidity, total nitrogen (TN), total phosphorus (TP), sulfate (SO_4^{2-}), COD, BOD_5, TSS and TDS are the most wastewater parameters which are used to assess and characterize wastewater quality (WHO, 2011 and Verlicchi P. , 2018).

The study reports shows that hospital laboratory wastewater observed that average BOD and COD values for study period were 75.3 mg/L, and 934.2 mg/L respectively. As a result, it was seen that COD/BOD ratio could reach to a range of 10 to 12 in hospital clinical laboratory wastewater. This suggested that mostly the laboratories accounted for the amount of chemically oxidizable organic matter in the hospital wastewater. TSS value varied between 98 - 162 mg/L ranges in the hospital laboratory waste water (Akin et al. 2016). The mean value of TSS, BOD and COD in effluent wastewater of all studied hospitals was 296, 400 and 616 mgL-1 respectively on the study reported by (Amouei1 et al. 2012).

The book which review over 20 articles from the world including the research from Ethiopia indicate that physico-chemical characteristics of hospital wastewater shows the average value of total suspended solids (TSS) is between 150 and 500 mg/l, and total nitrogen is between 30 and 100 mg/l (Verlicchi, 2018). Generally the most common macro-pollutants (BOD5, COD and SS) in HWW are two up to three higher than in the urban wastewater (Verlicchi et al., 2010).The raw wastewater from Hawasa referral hospital in Ethiopia had been observed with significant concentration of organic matters and the average concentration of COD and BOD_5 were 545.7 + 13.4 mg/L and 230 + 8.1 mg/L, respectively (DIRES, 2008).

The study by Mountassir et al., (2017) shows that the ammonia content is 96 mg / L at site 1 and 1.15 mg /L at site 2, and nitrate is 3.55 mg /L at S1 and 2.37 mg /L for S2. The study in Ethiopia by Simachew Dress (2008) shows that the average concentration of ammonium, nitrate, nitrite, total nitrogen, total phosphorous and orthophosphate from the raw wastewater of the hospital was 91.4 + 9.6 mg/L, 0.97 + 0.4 mg/L, 1.1 + 0.1 mg/L, 126.1 + 6.1 mg/L, 78.5 + 6.6 mg/L and 52 + 6.2 mg/L, respectively. The concentration of total phosphorus and chloride in HWW had detected in high concentration than in UWW (Emmanuel, 2002).

For average concentration of different Physico-chemicals parameters such as; BOD_5, TSS, TDS, TOC and COD in the table-1 below are reported on different research papers as that can be detected from hospitals effluent. Since the studies are conducted at different hospitals with different service capacity, the results for the presented parameters are wide-ranging.

Table-1 Average concentration of some WW parameters in hospitals effluent

References	BOD_5 (mg/l)	COD (mg/l)	TOC (mg/l)	TSS (mg/l)	TDS (mg/l)
(A. Amouei1, 2012)	400	616	ND	296	ND
Emanuel et al. 2001	603	855	211	ND	ND
(Abdoliman et al., 2015)	545	918	ND	411	ND
(Bashir, 2018)					
At effluent of three hospitals					
➢ **At Civil hospital**	134	384	ND	240	790
➢ **At CMCH hospital**	ND	1067	ND	531	1540
➢ **At ESIC hospital**	105	320	ND	160	890
(Verlicchi, 2018)	2575	7764	31-180	116-3260	ND
(Astha Kumari, 2020)	300	500	ND	150-160	ND
(AACGEGDC, 2020)					
➢ **Yekatit 12 Hospital**	133	434	ND	561	420
➢ **Tekur Anbesa Hospital**	98	359	ND	174	225

ND= Not Determined

2.1.4 Heavy Metals from hospital effluent

The main heavy metals found in hospital effluents are gadolinium (Gd), mercury (Hg), and platinum (Pt). Other heavy metals such as Cd, Cu, Fe, Ni, Pb, and Zn typically present similar concentrations as the reported in municipal effluent (Verlicchi, 2018). Hospital's effluent may have varied type of heavy metals and the source for heavy metals in HWW can be from different hospital service activities and other broken equipment's (Table-2).

The study by Mountassir et al., (2017) for heavy metals showed compliance with the WHO standards and also the study shows from hospital wastewater for the results of heavy metal concentrations are presented and compared with the study place national effluents quality standards and shows that concentration of all heavy metals was within permissible range except Cadmium in one of the studied hospitals (Muhammad, 2014).

Table-2 The most common source for heavy metals in HWW (Kummerer,2009)

Heavy Metal	**Source**

Mercury	• Broken thermostats
	• Dental treatments
	• Blood pressure monitoring device (Sphygmomanometers)
	• Cantor and Miller Abbot Tubes (used to clear gastrointestinal restriction)
	• Other sources include;
	  ○ Staining and tissue fixative chemicals in hospital laboratories (carbol-fusion and Zehl Nelson solution)
	  ○ Cleaning solutions

Leads	• Medical laboratories • Lead piping's
Manganese	• Dry cell batteries which used to operate hospital instruments
Zinc	• Dietary supplements • Medications • Zinc oxide ointment
Iron	• Surgical tools • Corrosion of old drainage pipes made of iron • Iron containing drugs
Cadmium, Chromium, Copper, Nickel and Zinc	• Laboratory chemicals

Heavy metals (copper, nickel and zinc) from the raw wastewater of Hawasa referral hospital, had demonstrated with an average concentration of, 0.04 + 0.01 mg/L, 0.07 + 0.02 mg/L and 2.5 + 0.5 mg/L, respectively. The zinc content in the discharges of the hospital clearly exceeds the contents of the other heavy metals investigated. While the concentration of cadmium, lead and silver in the raw wastewater was below 0.0001 mg/L (Dires, 2008).

2.2 Management practice and optional Treatment Technologies for Hospital Wastewater

2.2.1 Hospital wastewater Management Practice

According to WHO (1999) for safe hospital wastes managements there should be legislative, regulatory and polices on national levels which clearly states the need for safe hospitals waste management practice specifically for different types of wastes with standard treatment methodologies. Usually this will concern and developed by national health minsters and national environmental protection agencies, to apply pressure for their implementation.

To achieve polices goals, nations should come with clear technical guidelines and the policy may contain the following points:

- The drawback of improper management of health-care wastes,
- The reason why hospitals need to implement safe health-care waste management practice in their establishment,
- Directing recommended types of treatment and disposal technique for each waste categories,
- Warning against unsafe management practice, such as treating and disposing of hazardous health-care wastes practice with municipals wastes,
- Management responsibilities within and outside health-care establishment,
- Assessment of the cost of health-care waste management,
- Key steps of health-care waste management; minimization, separation, identification, handling, treatment and final disposal waste; technical specification for implementation of each step should be described in separate technical guidelines,
- Record-keeping and documentation of environmental impact assessment,
- Training requirements,
- Rules governing the protection of workers health and safety.

For proper monitoring and evaluating of hospitals effluent emission level, there should be standards for maximum emission level of pollutants which must developed at national levels. As many researches states, most of countries in the world even Europeans, that they don’t have national standards specifically for hospitals effluent emission level (Nadeem et al. S. U., 2019). Whereas to set standards the baseline should be the intended use of wastewater, it can be; protection of ecosystem, for recreation and aesthetics, for drinking water supply and for agricultural purpose (WEPA, 2017), therefore standards may varies based on this scenarios and with the ultimate goal of reducing the community and the environmental pollution risk. On the other hands to meet this and if there is pollutant emission at effluents, there should be policies and regulation which can force industries and others various organizations to maintain the emission standards. Here are some emission limit standards which are practicing in some other countries (Table-3 and Table-4).

Table 3. Emission limits standard for some WW parameters which are adopted in other countries

References	***PH***	***BOD$_5$ mg/l***	***COD mg/l***	***TSS mg/l***	***TP mg/l***	***TN mg/l***	***Total coliform***
China EPA *(Astha et al., 2020)*	6 - 9	< 300	< 500	<40			1000-5000 individual/L
Iran EPA *(Abdoliman et al., 2015)*	5 - 9	< 30	< 60	< 40	< 4	< 15	1000 MPN/100mL
Taiwan EPA *(Huan-Shu-Shui-Tzu, 2014)*		< 30	< 100	< 30			
Different countries EPA *(www.wepa-db, 2013)*							
For NO of bed > 31	6-9.5	< 30	< 120	< 30			
For NO of bed 1 to 30	6-9.5	< 40	< 130	< 40			

Table 4. Standards for some others WW parameters (mg/l)

Parameters	Max. Concentration			Parameters	Max. Concentration		
	A	B	C		A	B	C
phosphorous	1.0			Cyanide	0.1		
silver	0.1			Copper	0.5		
Zinc	0.1	2	5	Lead	0.2	0.05	
Free Chlorine	1.0			Nickel	0.2	0.1	
Chloride	500			Mercury	0.005	0.005	0.005
Iron	2.0			Manganese	1.0		0.1
Arsenic	0.25			Cadmium	0.03	0.01	
Barium	1.0						

A= Standard which is practicing in different countries (www.wepa-db, 2013)

B= Standard by Iran Environmental Protection Agencies (IEPA) (Abdoliman et al., 2015)

C= Standard by Ghana Environmental protection Agencies (Ntinana et al., 2014)

The standard by China EPA which is presented on table-3 is specifically for hospitals effluent and the author states that in anticipation of his review, china were the only country who had developed standard specifically for HWW and most other countries use standards of international organizations (Astha et al., 2020). Table-5 is presented standards for maximum emission limit of effluents which are developed by different International organization (WHO, FAO[1] and IFC/WBG) who are working on human and environmental health protection and the standard is designed for municipals wastewater treatment plant effluent.

Table 5. Effluent emission limit standards by international organizations

NO.	*Name of parameters*	*WHO*	*FAO[1]*	*IFC/WBG*
1	pH	6 - 9	6.5 - 8	6 - 9
2	Conductivity(µS/cm)	*NI*	70 - 300	NI
3	Turbidity	*NI*	*NI*	*NI*
4	TSS(mg/l)	50	*NI*	50
5	TDS(mg/l)	1000	450-2000	NI
6	DO(mg/l)	NI	NI	NI
7	BOD(mg/l)	80	NI	30
8	COD(mg/l)	150	NI	125
9	NH3(mg/l)	NI	NI	0.1
10	TN(mg/L)	NI	5 - 30	10
11	TP(mg/L)	NI	NI	2
12	Sulfide(mg/l)	NI	NI	1
13	Sulfate(mg/l)	400	NI	NI
14	Oil and Grease(mg/l)	10	NI	10
15	Copper (mg/l)	0.2	0.2	0.5
16	Chromium(mg/l)	0.1	0.1	0.5
17	Cadmium (mg/l)	0.01	0.01	0.1
18	Nickel (mg/l)	NI	0.2	0.5
19	Iron (mg/l)	NI	5	3.5
20	Manganese (mg/l)	NI	0.2	NI
21	Lead (mg/l)	0.1	5	0.1
22	Zinc (mg/l)	NI	2	2
23	Total Coliform (cfu/100 ml)	400	NI	400

Source; (Ramos et al., 2019), (International Finance Corporation/World Bank Group , 2007)
NI= Not indicated

2.2.2 Treatment technologies for hospital wastewater

The ultimate objective of selecting and implementing preferable wastewater treatment technologies at effluents is reduce and eliminate pollutants before reaching the surrounding environment. Therefore, it must select with intensive care with farther investigation of expected pollutants at the existing effluents. Most of the time treatment plants are select and design based on their removal efficiency of Oxygen demanding substance, Pathogens, Nutrients, and Inorganic and Synesthetic organic chemicals.

There are different methods for municipal wastewater treatment. However many researches indicate that hospital wastewater need to have exceptional treatment technology due to its unique qualitative nature. For instance the research by Pauwels (Pauwels, 2006) states that hospital wastewater constitutes a major discharge of chemicals and residues of pharmaceuticals compounds had detected in several WWTP effluents and this is due to their ineffective removal by the conventional systems (Nicole and Deziel, 2014). The physico-chemical properties (insolubility, volatility, polarity, influencing absorbability, biodegradability and stability) of pharmaceutical compounds makes difficulties in removing from wastewater (Verlicchi et al., 2010).

As explained in the figure-1, the final effluent of hospitals is expected to be combine effluent for both infectious and none infectious wastewaters which originates from different sources (Nadeem et al., 2019). Therefore, is recommended to segregate each effluent and manage differently before connecting to influent of wastewater treatment plant. Management scheme for hospitals waste water source effluents before reaching to the influent WWTP is recommended to be as follows.

- ✓ Effluent of bathing and washing unit, need to have grit removal.
- ✓ Wastewater from toilets (faces/urine) unit, should stay in septic tank.
- ✓ Type of highly infectious wastewater, should have pre-disinfection.
- ✓ Radioactive wastewater, to storage decay.
- ✓ Wastewater from kitchen, at effluent the unit there should be grease removal.
- ✓ Chemicals wastewater must neutralize or dilute before connecting to WWTP or must store separately or transport to chemical treatment facility.
- ✓ Storming water, is preferable to separate from others sewage system and influent of WWTP.

Hospital Wastewater

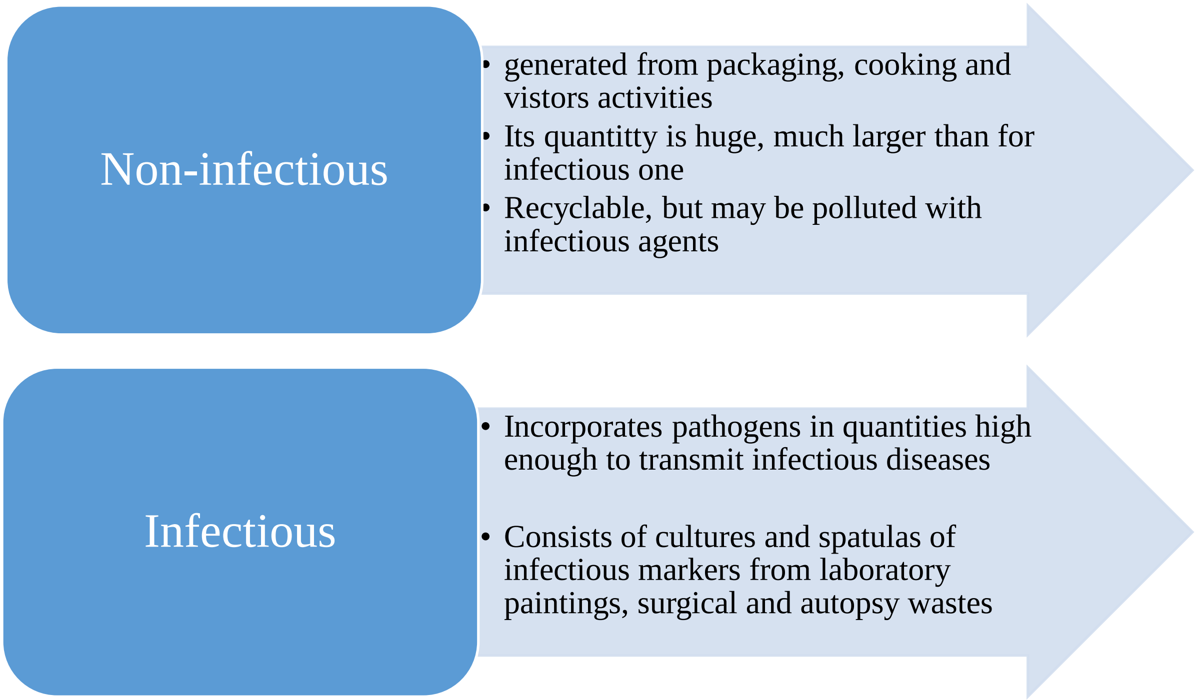

Figure 1- Systematic diagram showing types of hospital wastewater

Conventional systems such as activated sludge, biological activated carbon and microalgae system are somehow successful on removing of some type emerging contaminants, but to make these systems more effective on removing ECs it need to use those couple with other specific chemical and physical treatment process (Mohammad et al., 2007). Conventional activated sludge system did not meet the regulatory standard for effluent COD of 125 mg l/L most of the time. Its COD removal efficiency was 88%. The plate membrane bioreactor delivered an effluent with a COD value of 50 mg/L or less, and attained an efficiency of 93% (Pauwels, 2006). The effect of toxic substance on microbial media will reduce the removal efficiency of conventional activated sludge on HWW treatment process and to reduce the toxicity of the wastewater is recommended to use conventional activated sludge couple with rice husk (integrated fixed film activated sludge) and was seen that increased the removal efficiency of COD as better than conventional activated sludge (Mehrdad et al., 2014). According to Simachew Dires (2008) waste stabilization ponds were not effective in treating hospital wastewater and they also states that the value for total and fecal coliforms, COD, BOD_5, total nitrogen, ammonium, total phosphorus and phosphate which were above the permissible level.

Therefore for effective removal of pollutants from hospitals effluent, is recommended to use advanced wastewater treatment technologies (AWWTT). The advanced type of wastewater treatment approaches, such as; (1) Membrane bioreactors (MBRs), (2) Biogenic Mn Ox-coated coir fiber, chlorination, (3) UV radiation, (4) Ozonation, (5) sponge membrane bioreactor coupled with ozonation process and (6) oxidation ponds are effective wastewater technology to remove pharmaceutical compounds from hospital wastewater and most of this WWT mechanisms are recommended in various studies in the published literatures as well as by WHO (WHO, 2011). Relatively to conventional treatment mechanisms, the advanced one is more effective on removal of pathogens and will have efficiency to reduce the concentration of total coliforms to 2-100 MPN/100ml (Stefano, 2010). On the other hands to increase the removal efficiency of AWWTT, different research papers indicates and suggest that it will be effective when applied combined advanced systems together and some scenarios are presented on Figure-2 to indicate the efficiency of some combined advanced systems (MBR/Membrane bioreactor, GAC/Granulated activated carbon, PAC/Powdered activated carbon, UV radiation, FP/Fenton process and OP/Ozone process) which were referred from different published papers for the efficiency of using combined advanced wastewater treatment technologies (Nadeem et al., 2019).

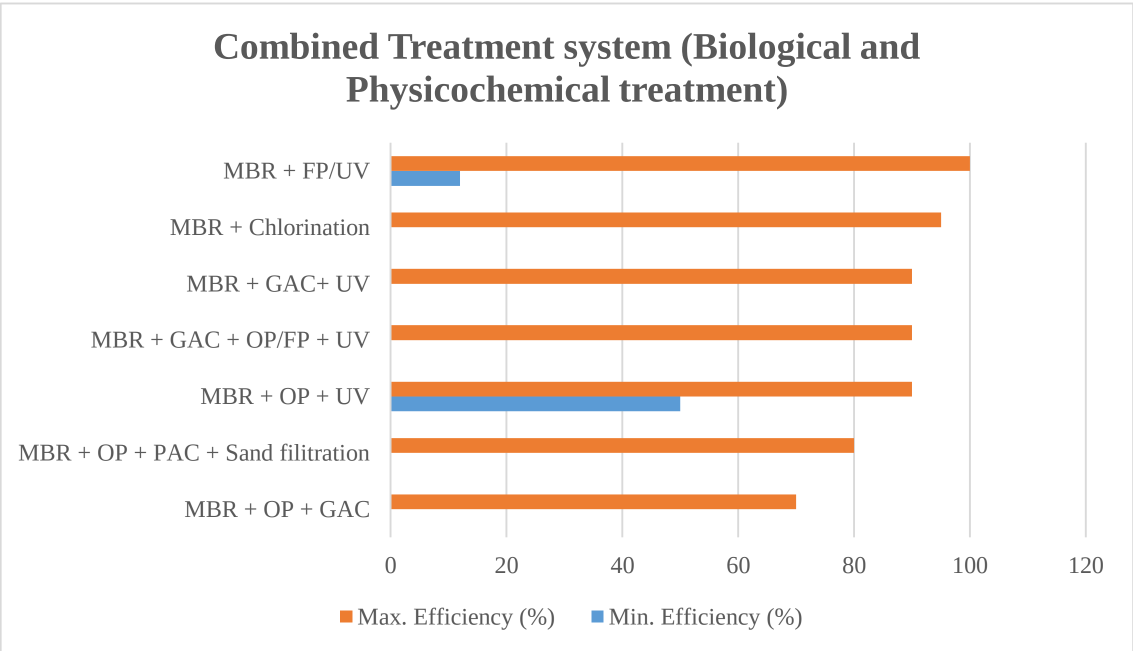

Figure 2 Combined AWWTT for Biological and Physico-chemical matter (Nadeem et al., 2019).

Membrane bioreactors (MBRs) combined with advanced oxidation processes (AOPs) and activated carbon filtration have been the most studied systems in most of Europe countries (Luis et al., 2019) . Luis and his associates try to show on their research that the efficiency Biogenic Mn Ox-coated coir fiber technology for hospital wastewater treatment for different antibiotics (such as azithromycin, ciproflaxin, and clindamycin) were all completely removed after 24-hour reaction with MnOx-coated coir fiber. Application of MBR combined with activated sludge process is now gaining wide acceptance for HWW treatment due to its high removal capacity for bacteria and antibiotics. However, installation, operation, and maintenance cost of MBR process is relatively higher than other conventional wastewater treatment. Technical and economic issues of HWW treatment plants need to be discussed to develop an efficient and cost-effective way (Astha et al., 2020).

Sponge membrane bioreactor (Sponge-MBR) combined with ozonation process was performed to remove the antibiotics which frequently existed in the hospital wastewater, antibiotics were eliminated about 45-93% (Thi-Kim-Quyen et al., 2019) and based on the result which they obtain on their research they states that the efficiency of Sponge-MBR coupled with ozonatio shows effective to treat Hospital wastewater.

Ozonation is one of the method which is becoming satisfactory and cost effective to remove different micro-pollutants (Hansen et al., 2016) and many of others states that they are found ozonation is efficient for disinfection, deodorization and de coloration, and also for effective elimination pharmaceutical compounds, personal care products, and endocrine-disrupting chemicals in surface water and wastewater (Yong-Gu et al., 2019). Ozone is highly oxidant agent which can be applied to treat wastewater and effective in removing of microorganisms, inorganic and organic pollutants (Rodriguez1, 2008).

Ozone can degrade and remove pharmaceuticals by reacting with their part of molecular compounds such as amine nitrogen, sulfur, activated aromatic ring, and carbon-carbon double bond (Keisuke et al., 2006). The reaction can be through the action of secondary oxidant (hydroxyl radicals) which will produced when ozone become in aqueous solution (Mohammad et al., 2007). The partial reaction of ozone with pharmaceutical may produce other by-products which are short chain carboxylic acids such as oxamic, pyruvic, maleic and oxalic acids (Fares et al., 2016). To accelerate the reaction of ozone and to reduce by-products, is recommended to use H_2O_2 prior to ozonation, removing some organic pollutants before ozonation, applying optimum ozone dosage and maintaining accurate ozonation time.

3. METHODOLOGY

3.1 Description of the Study Area

The study was conducted in the capital city of Ethiopia (Addis Ababa). The city is located with GPS coordinates of 9^0 0' 19.4436" N and 38^0 45' 48.9996' E (Figure-3). The city has a complex mix of highland climate zones with an average relative humidity of 63 % and the temperature may vary annually from 8 to 22 ^{0}c. As the capital city of the country, Addis Ababa has rapidly growing rate and becoming the center for different industries and businesses, this made the city densely populated with estimated size of 4.8 million (WUP, 2020). The high urbanization rate in the city also increases the demand of facilities like health institutes. There are fifty two hospitals in the city which are established on different levels (Referrals/Specialized) and apprehended by government and none governmental (private) organizations.

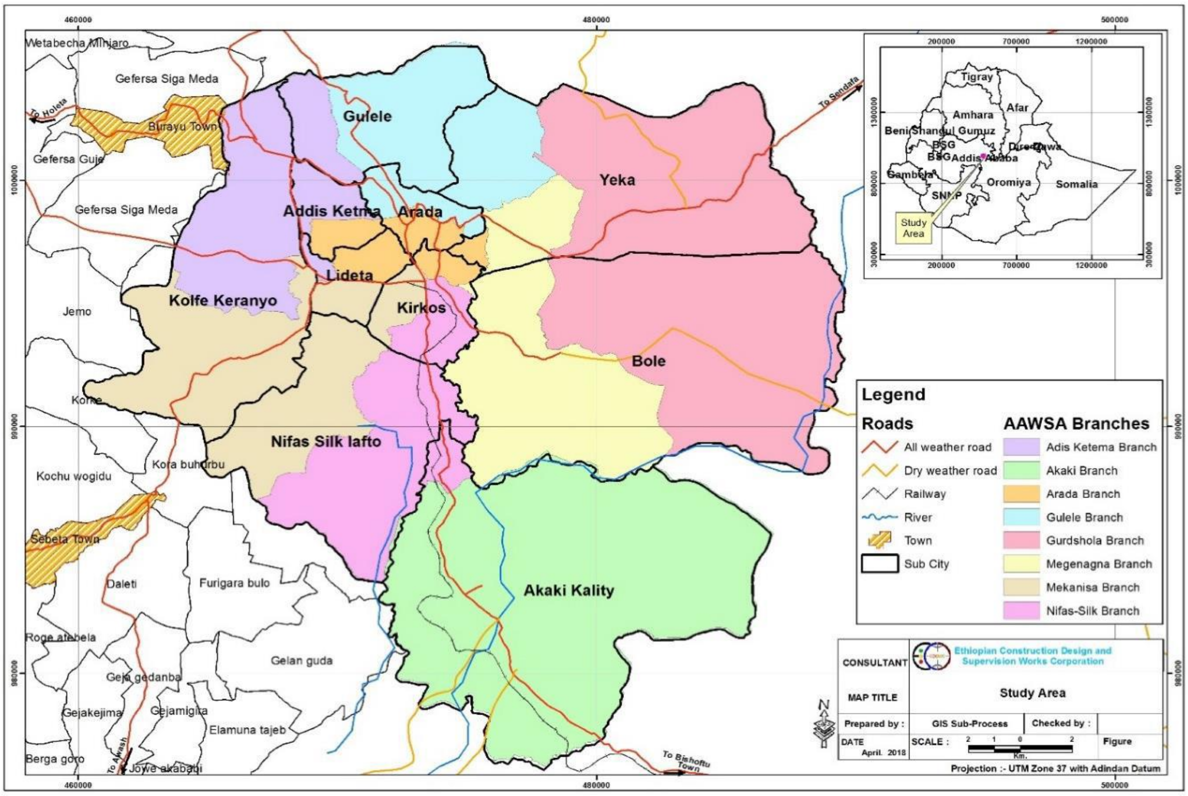

Figure 3- Map of Addis Ababa, Ethiopia / source (Assefa et al., 2018)

This study has focused on six private hospitals and eleven public sector hospitals, generally on total number of seventeen hospitals listed in Table-6, which are purposely selected and located in different sub-city of Addis Ababa. In order to determine the quality of hospitals effluent, the study had majorly focused on two public sector hospitals namely; Tekur Anbesa specialized teaching hospital (TASTH) and St. Paulo's hospital millennium medical college (SPHMMC), which are specialized and teaching hospitals in the city and also largest on their bed capacity and service load too.

Table 6. List of hospitals assessed for waste water management

	HOSPITAL NAME(CODED)	ORGANIZATION	ADDRESS
1	St. Paulo's Hospital	Governmental	**Addis Ketema Sub City**
2	TekleHaymanot Hospital	Private	
3	TekurAnbesa Hospital	Governmental	
4	Migbare Senay Hospital	Private	
5	Girum Hospital	Private	
6	Ras Desta Hospital	Governmental	**Arada Sub City**
7	St. Gebriele Hospital	Private	**Bole Sub City**
8	Yekatit 12 Hospital	Governmental	**Gulele Sub City**
9	Petrose Hospital		
10	Zewditu Hospital	Governmental	**Kirkos Sub City**
11	Gandi Hospital	Governmental	
12	Haleluya Hospital	Private	
13	Alert Hospital	Governmental	**Kolfe Sub city**
14	Betel Teaching Hospital	Private	
15	Police Hospital	Governmental	**Lideta Sub City**
16	Tor Hayloich Hospital		
17	Minilik Hospital	Governmental	**Yeka Sub City**

Tekur Anbesa specialized and teaching hospital is located in Addis Ketema subcity, 9^0 $01^{/}$ $12.9^{//}$ N and 38^0 $44^{/}$ $58.58^{//}$ E. The hospital was built in 1972 G.C and becomes the only training center for medical doctors. TASTH has 632 beds and giving service for an annual average patient flow of 480,670.

St. Paulo's hospital is located in Addis Ketema sub city, coordinate 9^0 $02^{/}$ 51^0 N, 38^0 $43^{/}$ $41^{//}$ E. The SPHMMC hospital was built by Emperor Haile Selassie-I in 1969 GC with the help of the German Evangelical Church, now held by government (MOH) and the hospital has 1500 beds and giving service for an annual average patient flow of 600,000. It has a catchment population of more than 5 million and serving many peoples comes from other regions of Ethiopia. St. Paulo's hospital now a days become specialize hospital and leading by fast expansion and getting an accreditation by starting new health care services.

3.2 Assessment of Wastewater management practices

For surveying the wastewater management practices of the selected hospitals, primary data were collected by using a structured questionnaire (See appendix-A) which was developed based on WHO guidelines for "Safe Management of Wastes from Health-care Activities" (WHO, 2011). Accordingly, data was gathered via interview and discussion with concerned body of the hospitals. In addition, field observation was also used to collect data in relation to wastewater management practices of hospitals.

During field observation, the selected hospitals were assessed for the presence of wastewater treatment plant, its location from wards or offices and also site selection for wastewater sample collection. The following information's was gathered for further analysis;

- If the hospitals have wastewater management unit.
- If the type of wastewater (Black water, Grey water and Storm water) from hospital are collected and managed separately.
- Number of patient flow per day.
- Number of beds.
- Peak hour and day in relation to flow of patients.

Descriptive type of study was employed to describe the status of waste water management practices at each of the selected Hospitals. In addition, hospitals' monthly and annual water consumptions was collected from the hospitals and also from Addis Ababa Water and

Sewerage Agency (AAWSA). Accordingly, the wastewater generation volume of the selected hospitals was also determined by analyzing the collected data.

3.3 Assessing the Wastewater Characteristics of Selected Hospitals

Based on the collected primary data and field observation, hospitals which have high bed number, availability of preferable sampling site location and to present the worries effluent quality of hospitals, two governmental hospitals were selected. Accordingly, wastewater from final outlets were sampled from Tekur Anbesa specialized teaching hospital and St. Paulo's hospital millennium medical college. In addition to the final hospitals' wastewater outlet (P-4 and T-1), effluents from three units (i.e.P-1, P-2, and P-3) of SPHMMC hospital was also collected for analysis as shown in Table-7.

Table 7- Location of Wastewater Sampling Site

Sample code	Sampling points
P-1	Sample from combined effluent of different wards of SPHMMC(ICU/pediatrics/obstetrics and gynecology wards)
P-2	Sample from Laboratory unit of SPHMMC
P-3	Sample from kidney transplantation and dialysis ward of SPHMMC
P-4	Sample from final wastewater outlets of St. Paulo's Hospital
T-1	Sample from final effluent of Tekur Anbesa specialized and teaching hospital

The characteristics of the collected wastewater samples were analyzed at Horti Coop lab, (Bishoftu Ethiopia), Addis Ababa University (Addis Ababa institute of Technology in environmental engineering laboratory) and microbiology laboratory of St. Paulo's hospital millennium medical college.

3.3.1 Sampling procedure

Composite wastewater samples were collected twice a day for three consecutive Mondays (starting from August 10/2020). Samples were collected in the morning (between 10:00AM-11:00AM) and afternoon (2:00PM-3:00PM). Sample collection time was carefully chosen based on the result obtained during wastewater management survey for hospitals pick patient flow and service load profile. Wastewater samples were collected by using brown plastic bottles and designated P-1, P-2, P-3, P-4 and T-1 (table-7). On each sampling day, 5 wastewater samples; from three different hospital units of SPHMMC (P-1), from final WW outlet point of TASTH and SPHMMC hospital, 3, 1 and 1 samples respectively were collected. A total of 15 samples on all sampling days were collected. Wastewater from SPHMMC discharged to the municipal sewer system is via different outlet pointes, therefore composite grabs samples were taken from each outlet points at the same sampling hours.

From each sampling site and on each sampling time, at five minutes interval, 3x300ml of grabs samples were collected and combined together (composite samples). In order to preserve if there are volatile organic compounds, sample containers were filled with zero head-space and also to avoid contaminations of the sample until analysis, samples were temporarily stored in an ice box and transported to respective laboratories and refrigerated at 4^{o}c.

3.3.2 Wastewater Sample analysis methods

On this study different types of laboratory test methods were applied and as presented below for measured WW parameters, In-situ and Ex-situ analysis methods were applied. For all test methods standard operating procedure (SOP) of (APHA, 1998) were used, Appendix-B.

3.3.2.1 In-situ analysis methods

The pH of composite samples was measured on site using calibrated Electrometric method/pH meter (VOLTCRAFT PH-100ATC) according to APHA, 1998 standard procedure. Electric conductivity (EC) was measured using conductivity Meter (Qcond 2200) according to methods outlined in APHA, 1998.

3.3.2.2 Ex-situ analysis methods

Total Suspended Solids (TSS), Total Dissolved Solid (TDS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total organic carbons, Total Nitrogen (TN), Total Phosphorous (TP), and Sulfate (SO42-) are parameters which were subjected to Ex-situ analysis and were measured at Environmental Engineering Laboratory of School of Chemical and Bio Engineering, Addis Ababa University.

Gravimetric method was applied for both Total Suspended Solids (TSS) and Total Dissolved Solid (TDS) determination according to methods indicated in APHA, 1998/2540-D.

Biological Oxygen Demand (BOD), were measured by using Respirometric Method and Winkler Method with azide Modification based on APHA, 1998/5210-B.

Chemical Oxygen Demand (COD), was estimated by closed reflux method using COD digester (Digestion) and Spectrophotometry (APHA, 1998/522-C).

For Total Nitrogen (TN) and Total Phosphorous (TP) analysis Persulfate Digestion, the automated cadmium reduction method 4500-NO3-F (APHA, 1998) and the automated ascorbic acid reduction method 4500-P F (APHA, 1998) methods, respectively were applied.

Concentration of heavy metals such as Copper (Cu), Chromium, Total(Cr), Cadmium (Cd), Nickel (Ni), Iron (Fe), Manganese (Mn), Lead (Pb), and Zinc (Zn) were determined using Inductively Coupled Plasma (ICP-OES) Method at Horti Coop lab, Bishoftu, Ethiopia.

Microbial parameters (Total Coliform) were analyzed using most probable number (MPN) method (APHA, 1999) at microbiology laboratory of SPHMMC hospital.

3.3.3 Statistical Analysis

Descriptive statistics such as; minimum, maximum, mean and standard deviation values were employed. Figures and tables were prepared by Microsoft Excel.

4. Results and Discussion

4.1 Hospital wastewater generating volume

For specific year 09/2018 – 08/2019 G.C, annual water consumption of hospitals was employed to estimate the wastewater generating volume. The estimation was calculated by assuming 80 % of water consumed is converted to wastewater generating volume (Von, 2007) (Nagaland Health project, 2018). Annual water consumption and number of beds that the selected hospitals deployed are shown by coding the hospitals in Table-8.

Table-8 Hospitals Annual water consumption and number of beds

Hospital (Coded)	Average annual patient flow (2018/2019)	No of beds (2019)	Annual water consumption (m^3)	` WW Generating volume	
				m^3 /year	l/bed/day
H-1	412,000	365	37883	30,306	227
H-2	8161	84	18,562	14,850	484
H-3	97,200	159	25,758	20,606	355
H-4	42,790	41	15,400	12,320	823
H-5	17,264	110	18,000	14,400	359
H-6	27191	44	11,000	8,800	548
H-7	260,058	369	43298	34,638	257
H-8	180,000	272	34,000	27,200	274
H-9	145,000	297	30,000	24,000	221
H-10	10,800	164	38592	30,874	516
H-11	18,245	75	16,500	13,200	482
H-12	600,000	700	75563	60,450	237
H-13	20,000	59	13,500	10,800	502
H-14	480,670	700	99,433	79,546	311
H-16	282,828	390	30663	24,530	172
H-15	35,100	450	33,316	26,653	162
H-17	230,000	232	24119	19,295	228

The surveyed hospitals wastewater generation volume was in the range of 162 – 823 l/bed/day, table-8. The daily generation rate of hospitals in developed countries is in the range of 400 - 1200 l/bed/day, where as in most developing countries was observed between 200 and 400 l/bed/day (Mishra et al., 2016, Al Aukidy et al., 2018). The result on this study shows that 35.3 % of surveyed hospitals have daily WW generating is more than 400 l/bed/day, 5.9 % of hospitals observed with generating volume of wastewater, below 200 l/bed/day and the remains 59 % of hospitals generate between 200 and 400 l/bed/day.

Variation in quality, quantity and handling method of hospitals effluent is not only among countries, also it could vary within country (Astha et al., 2020). In this study also among the investigated hospitals, variation on wastewater generating volume per bed/day were observed. The result shows that the generating volume of wastewater relatively to governmental hospital, at private hospitals was higher and the daily WW generating volume were in the range of 359 – 823 l/bed/day and 162 – 516 l/bed/day at private and governmental hospitals, respectively.

The number of beds at surveyed private hospitals were less than the governmental hospitals, whereas the quantity of wastewater generating volume from most of the private hospitals was larger, probably it is due to the status of hospitals service level. For instance, the bed service of private hospitals for inpatients is observed with private toilet and shower, whereas at most of the investigated public sector's hospitals there were communal toilet and showers. Therefore, this can be an indicator for that on the coming near future, if the quality of hospitals service level increased, hospitals at the surveyed city will have a large quantity of WW production and high environmental impact, if they are not treating their effluents in well system.

4.2 Wastewater management practices of selected hospitals

The collected data from selected hospitals (17 in number) were analyzed and assessment of their wastewater management system were undertaken. Accordingly, the surveyed hospitals were evaluated for segregation of the type of wastewater (Blackwater and Greywater) and storm waters and also for their wastewater disposing mechanism, Table-10 and the investigated results are aimed to point out and report the surveyed hospitals wastewater management practices.

According to WHO guideline for management of wastes from health care facilities, is recommend that hospitals need to separate storm waters from Blackwater and greywater as well as Blackwater and greywater can be collected and managed by combined system (Chartier et al., 2014), whereas these study result shows that only 70.6 % of the surveyed hospitals are disposing wastewater separately from storm water. And most (94.1%) of the presented hospitals were disposing wastewater directly to the environment without pretreating and only one hospital was treating wastewater before discharging to the municipal sewer system. From those 94.1% of hospitals which were discharging their wastewater without pretreatment, some (29.4%) of hospitals are disposing wastewater directly to nearby rivers, some of (29.4%) disposing to the city sewer wastewater treatment plant by off-site transportation. The remaining hospitals (35.3%) are disposing directly to municipal sewer system. The detailed information about the fate of wastewater generated from surveyed hospitals are indicated in table-9.

From the surveyed private hospitals, 83.3 % of hospital were practicing wastewater management by storing in septic tanks and finally disposing by off-site transportation to the city sewer treatment plant. Even though the final destination of the surveyed hospitals wastewater is to the city municipal wastewater treatment plant, as most research papers states that is also unsafe type of WW management practice, since the type of pollutants in the hospitals effluent (emerging contaminants) cannot be easily removed by treatment plants which is designed to treat only municipals wastewater (Verlicchi, 2018).

Table 9- Treatment scenario of effluents in studied hospitals

Hospitals Code	WW disposing/Management Systems adopted till date
H-1	Stored in septic tank and transported to MWWTP
H-2	Released to municipal sewer system after sewage treatment plant (MBR) (See Appendix-D)
H-3	Directly connected to municipal sewer system
H-4	Stored in septic tank and transported to MWWTP
H-5	Directly discharged to nearby river (big Akaki river)
H-6	Stored in septic tank and transport to MWWTP
H-7	Directly discharge in to nearby river (Kebena river)
H-8	Stored in septic tank and transport to MWWTP
H-9	Directly discharge to nearby river (little Akaki river/Mekanisa)
H-10	Directly connected to municipal sewer system
H-11	Releasing to municipal sewer system after Sand filtration
H-12	Directly connected to municipal sewer system
H-13	Stored in septic tank and transport to MWWTP
H-14	Stored in retention tank and discharge to big Akaki river
H-15	Directly connected to municipal sewer system
H-16	Directly connected to municipal sewer system
H-17	Directly discharged in to nearby river(Bante Yeketu river)

In addition to the required that hospitals must need to providing wastewater pretreatment systems at their effluent, according to the advice of WHO for environmentally sound wastewater management practice, hospitals also must need to have management units staffed with professionals who are specifically for management of wastewater and concerned to assure the quality of the hospital effluent according to the existing pollutant emission limit standards (WHO, 2011). Accordingly, the surveyed hospitals had evaluated for the presence of wastewater management unit and in spite of the presence of infection control and environmental units, in all of the studied hospitals there was no proper wastewater management practices and possible to say were risky practice for their surrounding environment.

Table 10- The surveyed hospitals wastewater management practice

Wastewater segregation	No. of Hospitals	Percentage
Is segregation of WW practiced:		
Yes	12	70.6
No	5	29.4
If yes, what is segregated:		
Blackwater (sewage)	-	-
Greywater (sullage)	-	-
Storm water	12	70.6
Wastewater disposing techniques	**No. of Hospitals**	**Percentage**
Is WW treatment practiced before the final effluent:		
Yes	1	5.9
No	16	94.1
If yes, type of WW treatment		
Conventional WWT	1	5.9
Advanced WWT	-	-
If no, where is the destiny of WW:		
Stored in septic tank, Off-site transportation	5	29.4
Directly connected to Municipals Sewerage System	6	35.3
Directly connected to nearby river	5	29.4
Connected to MSS after WWTP	1	5.9
WW off-site transportation	**No. of hospitals**	**Percentage**
Off-site WW transportation practicing:	5	29.4
By using their own WW truck	-	-
By using the city WW truck service	5	100
By using private WW truck Service	-	-
Do hospitals have WW management unit	**No. of hospitals**	**Percentage**
Yes	17	100
No	-	-

4.3 Physico-chemical and Microbial characteristics of Wastewater from selected hospitals

Wastewater sample collected from St. Paulo's millennium medical college hospital (SPHMMC) and Tekur Anbesa specialized teaching hospital (TASTH) were analyzed for parameters such as; pH, electrical conductivity, turbidity, total nitrogen (TN), total phosphorus (TP), sulfate (SO_4^{-2}), COD, BOD_5, TOC, TSS, TDS. The final effluents (Wastewater leaving the hospital compound) of both the investigated hospitals WW sample were analyzed for Total coliforms and heavy metals such as; Mercury (Hg), Manganese (Mn), Zinc (Zn), Lead (Pb), Copper (Cu), Arsenic (Ar), Cadmium (Cd) and Iron (Fe). The mean, standard deviations (Appendix-E), minimum and maximum values of the study results were considered and the investigated minimum and maximum results (Table-11) was discussed and compared against maximum effluent standard limit of Addis Ababa City Government Environmental and Green Development Commission (AACGEGDC).

Table 11- Minimum and Maximum results for some investigated physico-chemical parameters

Parameters	**Sampling Sites**										**AACGEGDC Standard level**
	P-1		**P-2**		**P-3**		**P-4**		**T-1**		
	Min	**Max**	Min	**Max**	Min	**Max**	Min	**Max**	Min	**Max**	
pH	6.4	7.6	7.3	8.6	7.3	7.7	6.8	7	6.7	6.9	**6 - 9**
EC (µS/cm)	58	1890	230	1970	31	1950	1058	1390	606	1990	**800**
Turbidity (NTU)	19	283	51	254	9	93	60	152	58	105	**300**
TSS(mg/L)	270	376	72	630	140	224	100	550	250	372	**60**
TS(mg/L)	588	3184	816	2500	2032	2852	692	1528	1208	1500	**NIL***
TDS(mg/L)	316	2902	744	1870	1842	2628	410	1428	908	1250	**1200**
COD(mg/L)	44	227	276	374	188	594	93	443	242	324	**200**
BOD(mg/L)	11	44	32	113	35	170	29	118	64	101	**80**
TOC(mg/L)	2	8	1	7	1	4	3	9	2	5	**NIL***
TN(mg/L)	3	43	6	9	4	10	11	18	1	5	**15**
TP(mg/L)	5	8	15	23	0.2	6	13	40	1	3	**10**
SO_4^{-2}(mg/L)	37	51	40	52	36	40	16	48	53	66	**500**

NIL*: No Indicated Limit

4.3.1 pH

As the results presented in table-13, the maximum pH value of wastewater at the effluent of kidney dialysis and transplantation units and at the combined effluent of SPHMMC hospital unit (ICU/pediatrics/obstetrics and gynecology wards) were slightly alkaline, for pH value of (P-3); 7.7 and (P-1); 7.6, respectively. Whereas the pH at effluent of the hospital (SPHMMC) Laboratory were highly Alkaline for pH value of 8.6, while at the final effluent of SPHMMC minimum and maximum pH value of 6.8 and 7 were recorded. At the final effluent of TATH hospital were slightly acidic for minimum pH of 6.7 and maximum pH of 6.9.

The pH of wastewater at each sampling site of the presented hospitals ranged from 6.4 to 8.6 and as most researches shows that hospitals wastewater is generally alkaline, somehow this may change and increase or decrease the pH values due to intensive use of detergents in hospitals and the value may ranges between 6.2 to 10 (Beril, 2016). On this study also Weekly variation of pH values had seen (see; Appendix-E) and this can be due to the variation on the type and the concentration of detergents which hospitals used throughout their service time. According to the city WW discharge standard limits, which are stated on the Table-11, the pH of WW at the effluent of the presented hospitals were within in the permissible level (6 - 9).

4.3.2 Electrical conductivity (EC)

The values of electric conductivity at the surveyed hospitals final effluent and hospital unit effluent were rages between 31 µS/cm and 1990 µS/cm, table-13. At each sampling stations; P-1, P-2, P-3, P-4 and T-1 the value of EC was in the range of 58 – 1890 µS/cm, 230 – 1970 µS/cm, 31 – 1950 µS/cm, 1058 – 1390 µS/cm and 606 – 1990 µS/cm, respectively. Electric conductivity of wastewater may vary from one ward effluent to the other effluent of the hospital wards. From surveyed hospital units of SPHMMC, the highest value of electric conductivity (1970 µS/cm) were at effluent of laboratory unit (P-2) and when the result is compared to the other hospital units (P-1 and P-3), were slightly lower. On the research paper by (Ntinana et al., 2014) had indicate that concentration of phosphate or nitrate and ions of various metals in wastewater are the factors which can regulate the electric conductivity of wastewater and also the authors explain that variation on the type or the load of detergents and disinfectants such as; sodium hypochlorite and chlorine can fluctuate the electric conductivity of the hospital’s effluent. The maximum value of EC at the final wastewater outlet of SPHMMC hospital (P-4) and TASTH (T-1) were 1390 µS/cm and 1990 µS/cm, respectively. At the final wastewater outlet of SPHMMC a weekly variation in the range of 1058 - 1390 µS/cm EC value were observed and at TASTH hospital final effluent, on each sampling days; day-1, day-2 and day-3 with wide variation 1990 µS/cm, 606 µS/cm and 970 µS/cm, respectively were examined.

The mean value of EC at the final wastewater outlet of the presented hospitals were observed with small variation, SPHMMC= 1221 µS/cm and TASTH= 1188 µS/cm (Appendix-E). On this study result when the final effluent of SPHMMC hospital EC value compared to the effluent of the hospital wards (P-1, P-2 and P-3), was lower. Possibly it is dilution effect, since the final effluent of the hospital is the combine outlet for all the other hospital units' effluent.

Previously (AACGEGDC, 2020), reported that the EC of wastewater collected from Tekur Anbesa hospital, during the dry season of the city (Addis Ababa), were under permissible limit of the city standard, with EC values of 299 µS/cm. Whereas on this study according to AACGEGDC standard, the wastewater quality of both the investigated hospitals effluent for EC were above the maximum permissible limit (800 µS/cm).

4.3.3 Turbidity

The minimum and maximum turbidity of wastewater at P-1, P-2, P-3, P-4 and T-1 were in the range of 19 – 283, 51 - 254, 9 – 93, 60 – 152 and 58 – 105 NTU, respectively. The highest turbidity was observed from wastewater sample of SPHMMC laboratory unit (P-2). On this study, turbidity of wastewater at final outlet of SPHMMC (P-4) and TATH (T-1) was registered with small average result variations, 114 and 87 NTU respectively. The result shows at all investigated hospitals effluent locations, turbidity of hospitals wastewater was under the permissible limit of AACGEGDC (300 NTU).

4.3.4 Total solid (TS), Total suspended solid (TSS) and Total dissolved solid (TDS)

The quality of wastewater can be expressed by the concentration of different parameters. Suspended and dissolved solid are the most representative parameters for the presence of organic and inorganic substances. The concentration of total dissolved solid (TDS) is used to describe the presence of inorganic salts and small amount of organic matters in water solution and as the concentrations of TSS in wastewater increased there will be also an increase the volume of biochemical oxygen demand, this may affect the process of biological WW treatment plants (Al-Enazi and Majida, 2016). And also according to the book which reviewed different research articles which were dealing on characterization of hospitals wastewater, states that the concentration of TSS in hospitals wastewater may range between 116 – 3260 mg/L (Verlicchi et al., 2010).

On this study from sampling stations of SPHMMC hospital, minimum and maximum concentration of total suspended solid (TSS), 72 and 630 mg/L respectively, were recorded at the effluent of laboratory unit. At the final effluent of SPHMMC and TASTH hospitals, the minimum concentration of TSS, 100 and 250 mg/L, respectively and also a maximum of 550 and 372 mg/L, respectively were detected. When this results compared against to the effluent standard limit of AACGEGDC for TSS; 60 mg/L, table- 11, the studied hospitals effluent quality for concentration of total suspended solids were above the limit value.

From the sampling station of investigated hospitals a minimum of 316 mg/L and maximum of 2902 mg/L of total dissolved solid were examined at combined effluent of SPHMMC hospital wards (ICU/pediatrics/obstetrics and gynecology wards). The maximum concentration of TDS at the final wastewater outlet of SPHMMC and TASTH hospital were 1428 and 1250 mg/L, respectively. Therefor according to the city permitted emission level for TDS; 1200 mg/L the effluent of the studied hospitals were higher.

The result in this study shows that total solids in studied hospitals final effluent ranges between 692 and 1528 mg/L and comparatively, from the investigated hospitals the concentration of total solid were higher at the final effluent of SPHMMC hospital. Also based on different references which are indicated in table-1, effluent of hospitals for the concentration of total solid may range between 225 and 1540 mg/L.

4.3.5 BOD_5, COD and TOC

If the presence of solid matters in the wastewater are highly biodegradable organic matters, this will be supportive to reduce the load of final WWTP since they can easily remove by biological wastewater treatment plant. BOD_5 and COD are the most indicator parameters for biodegradability of organic matters. According to different research papers the concentration of BOD_5 and COD at hospitals effluent may ranges between 16 – 2575 and 39 – 7764 mg/L, respectively (Amouei1 et al.,2012/2015, Bashir et al.,2018, Astha et al.,2020, Verlicchi , 2018). Similarly, in the research conducted at Tekur Anbesa Hospital final effluent characteristics, during the dry season of the city (Addis Ababa), the concentration of BOD_5 was 98 mg/L (AACGEGDC, 2020) , which is slightly lower than the result found in this research.

These research has also examined the concentration of BOD_5 and COD in the WW of each sampling stations of the hospitals. The analysis results shows that the minimum and maximum concentration BOD_5 at the effluent of SPHMMC hospital units; ICU/pediatrics/obstetrics and gynecology wards (P-1), Laboratory unit (P-2) and kidney dialysis unit (P-3) were 11 – 44, 32 – 113 and 35 – 170 mg/L, respectively. Comparatively to the combined effluent of SPHMMC hospital wards (P-1), higher biologically oxidize able organic matters were found in WW sampled from station P-2 and P-3. On each sampling days, variation on the concentration of BOD_5 were observed, Figure-4. At the final effluent of SPHMMC and TASTH hospitals, a minimum BOD_5, 29 and 64 mg/L and with a maximum concentration of 118 and 101 mg/L of BOD_5, respectively were recorded. The investigated hospitals final effluent quality, for the concentration of BOD_5 were above the permissible limit of the standard by AACGEGDC (80 mg/L).

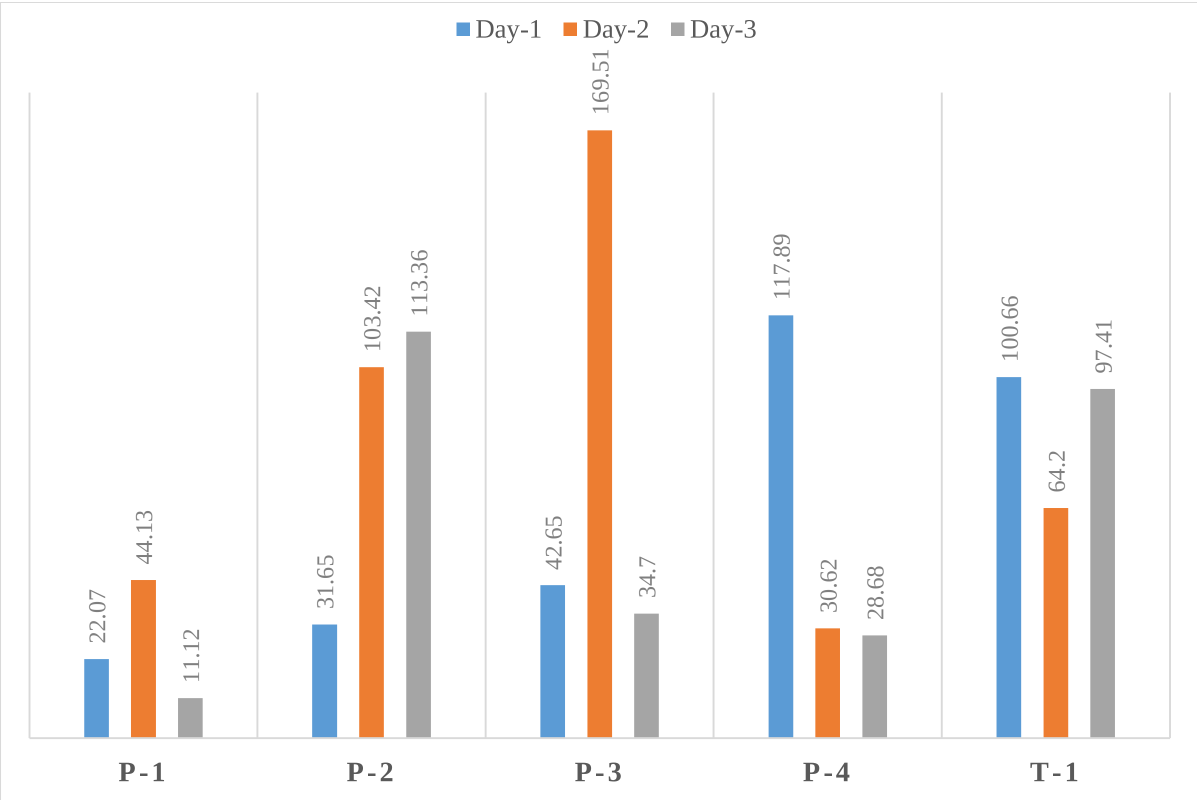

Figure 4- Concentration of BOD_5 (mg/L)

The results in Table-11 shows that, concentration of COD at the studied sampling stations were in the range of the 44 – 594 mg/L. The maximum COD concentration was examined at the effluent of kidney dialysis unit (P-3) of SPHMMC hospital and the minimum concentration of COD, 44 mg/L with a maximum of 227 mg/L was seen at the combined effluent of the hospital wards (ICU/pediatrics/obstetrics and gynecology wards). On the sampling days, at the sampling stations of P-1, P-3 and P-4, high variation of COD concentration were observed, Figure-5. From the final wastewater outlet of SPHMMC and TASTH hospitals, COD concentration were observed within the range of 93 - 443 mg/L and 242 - 324 mg/L, respectively. The maximum results of COD concentration at final effluents of the studied hospitals can be pointers that hospitals need to adopt wastewater treatment mechanism at their effluent, since the quality of their effluent for COD concentration is above the standard limits of AACGEGDC (200 mg/l).

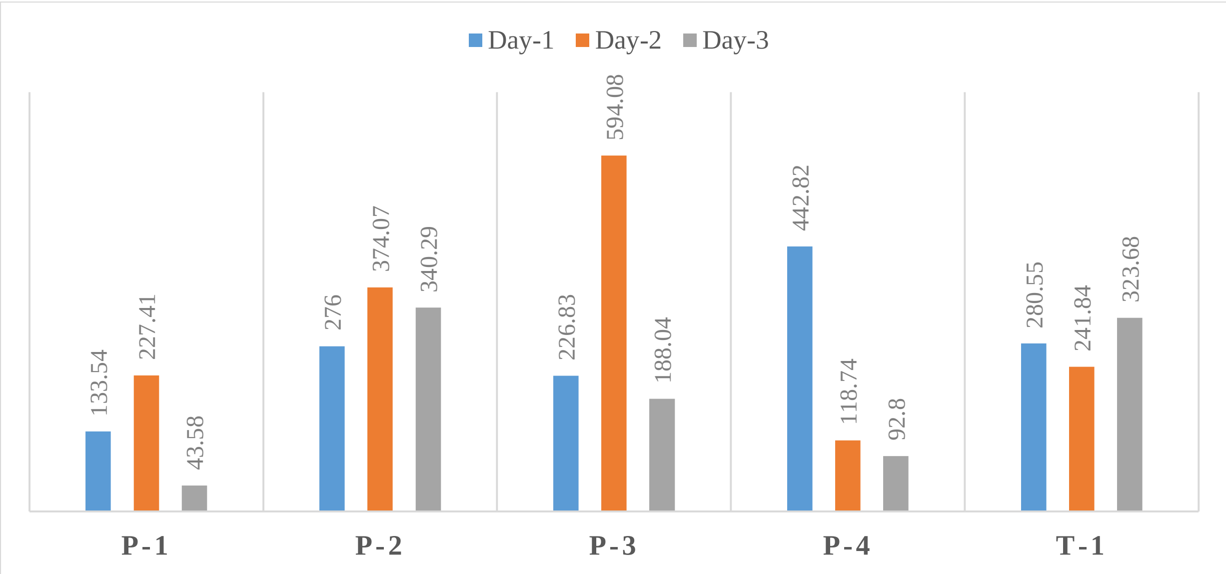

Figure 5- Concentration of COD (mg/L)

The study analysis result for total organic carbon (TOC) in the hospitals wastewater samples, was observed with smaller concentration, which were in the range of 1- 9 mg/L, whereas according to some other researches, the concentration of TOC in the hospitals wastewater can be in the range of 31 - 211 mg/L (Verlicchi, 2018, Emmanuel E. 2001). Generally at the studied sampling stations P-1, P-2, P-3, P-4 and T-1 a minimum of 2 mg/L, 1 mg/L, 1 mg/L, 3 mg/L and 2 mg/L of TOC with a maximum of 8 mg/L, 7 mg/L, 4 mg/L, 9 mg/L and 5 mg/L respectively, were observed. The results on each sampling days as shown on figure-8 below, were detected with some concentration variation.

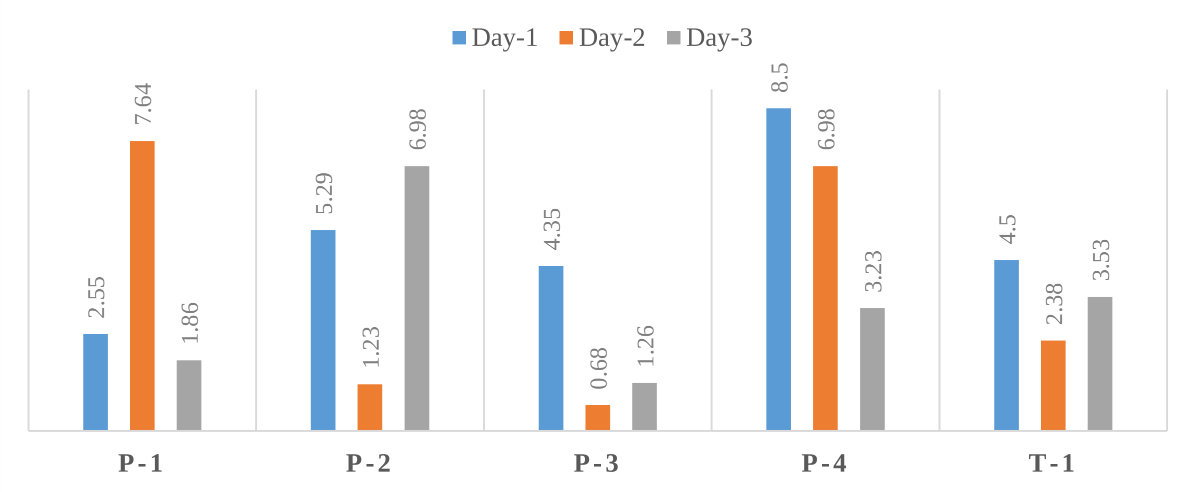

Figure 6- Concentration of TOC (mg/L)

4.3.6 Total Nitrogen (TN)

On this study the concentration of total nitrogen was ranges between 3 – 45 mg/L, 6 – 9 mg/L, 4 – 5 mg/L, 11 – 18 mg/L and 1 – 5 mg/L, at P-1, P-2, P-3, P-4 and T-1 sampling stations, respectively. Detergents, unmetabolized nitrate containing drugs that are excreted through urine and unused drugs which are disposed to the drains, can be the source of nitrogen hospitals effluent (Ntinana et al., 2014). Most research papers had indicated that hospital effluent may contain nitrogen concentration in the range between 60 – 230 mg/L (Verlicchi et al., 2010). The result shows that at the combined effluent of SPHMMC hospital unit (ICU/pediatrics/obstetrics and gynecology wards), the concentration of TN relatively to the others hospital units of St. Paulo's hospital millennium medical college were higher.

From the final effluent of St. Paulo's (P-4) and Tekur Anbesa (T-1) hospitals, comparatively the concentration of total nitrogen with wide variation was recorded, Appendix-E and the possible reason might be, that the wastewater from TASTH hospital stay in retention tank before reaching to the final hospital effluent. The concentration of TN from both hospitals final effluent were compared with the permissible limit of AACGEGDC (15 mg/L) and the result indicated that the concentration of TN at the effluent of SPHMMC is above the standard limit.

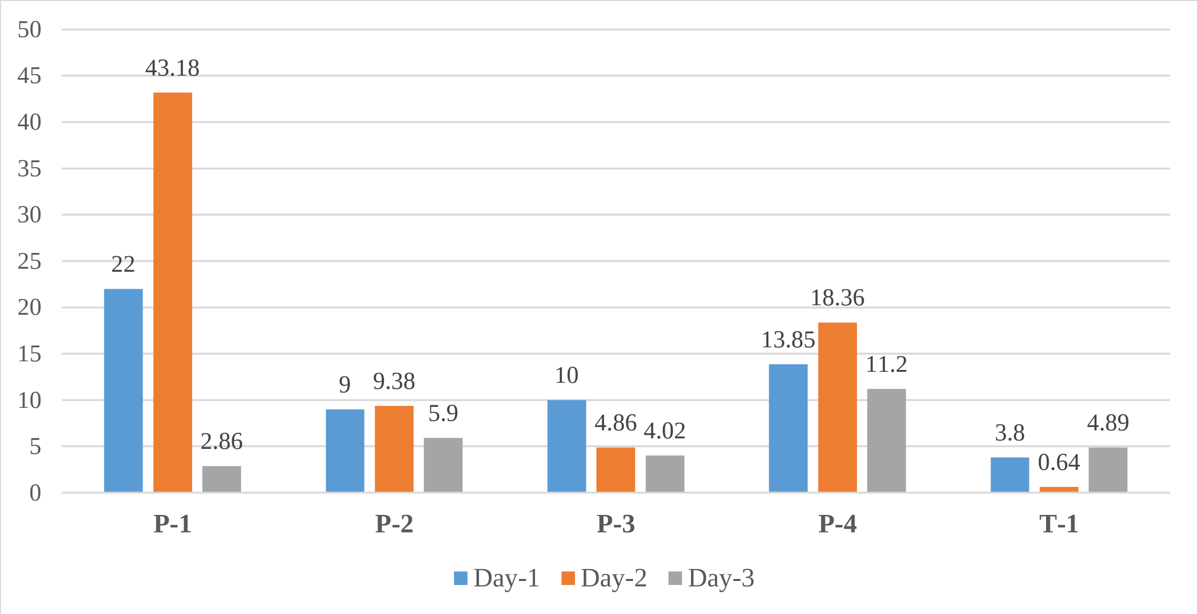

Figure 7- Concentration of TN (mg/L) at each sampling site and on sampling day

4.3.7 Total Phosphate (TP)

At the sampling stations of SPHMMC hospital, the concentration of total phosphate were between 0.2 – 40 mg/L and comparatively from the hospital units, concentration of total phosphate at the effluent of laboratory unit (P-2 = 23mg/L) were higher. The smallest concentration of TP (P-3 = 0.2 mg/L) were measured from the effluent of kidney transplantation and dialysis ward of the hospital. The weekly analysis result shows that, between each sampling days, there were a higher TP concentration variation, Figure-8.

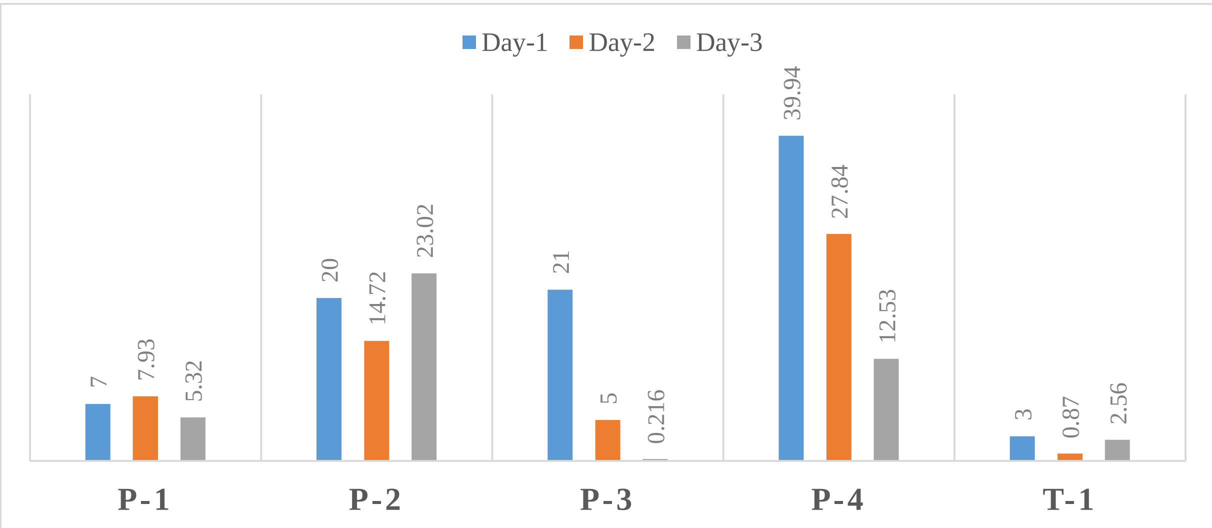

Figure 8- Concentration of TP (mg/L) *at each sampling site and on sampling day*

The maximum concentration of TP at final effluent of SPHMMC and TASTH hospitals were 40 and 3 mg/L, respectively and a minimum 12.53 and 1 mg/L of TP, respectively were also detected at the final effluent of the hospitals. The maximum concentration result of TP, at the final effluent of SPHMMC shows that the level of TP at the hospital effluent had exceeded the permissible limits of the AACGEGDC (10 mg/l) and the quality of wastewater from TASTH hospital for total phosphate were within the permissible level.

4.3.8 Sulfate (SO_4^{-2})

Minimum SO_4^{-2} of 37, 40, 36, 16 and 53 mg/L with maximum of 51, 52, 40, 48 and 66 mg/l concentration of sulfate from sampling stations of P-1, P-2, P-3, P-4 and T-1, respectively. The higher concentration of sulfate were detected from the final effluent of TASTH hospital (T-1 = 66 mg/L). From the selected sampling site of SPHMMC hospital the concentration of sulfate were higher at the effluent of laboratory unit (P-2 = 52 mg/L). Whereas the maximum concentration of sulfate at the final wastewater effluent of SPHMMC were 48 mg/L. Among each sampling days (Day-1, Day-2 and Day-3), except from the first week (Day-1) analysis of wastewater sample from the final effluent of SPHMMC hospital (P-4 = 16.44 mg/L) which were smaller from the other sampling days (day-2 and day-2), figure-9. The standard by AACGEGDC allows up to 500 mg/l of SO_4^{-2} for hospitals and for other industries effluent, accordingly the concentration of SO_4^{-2} at each sampling site of these study were seen within the limit.

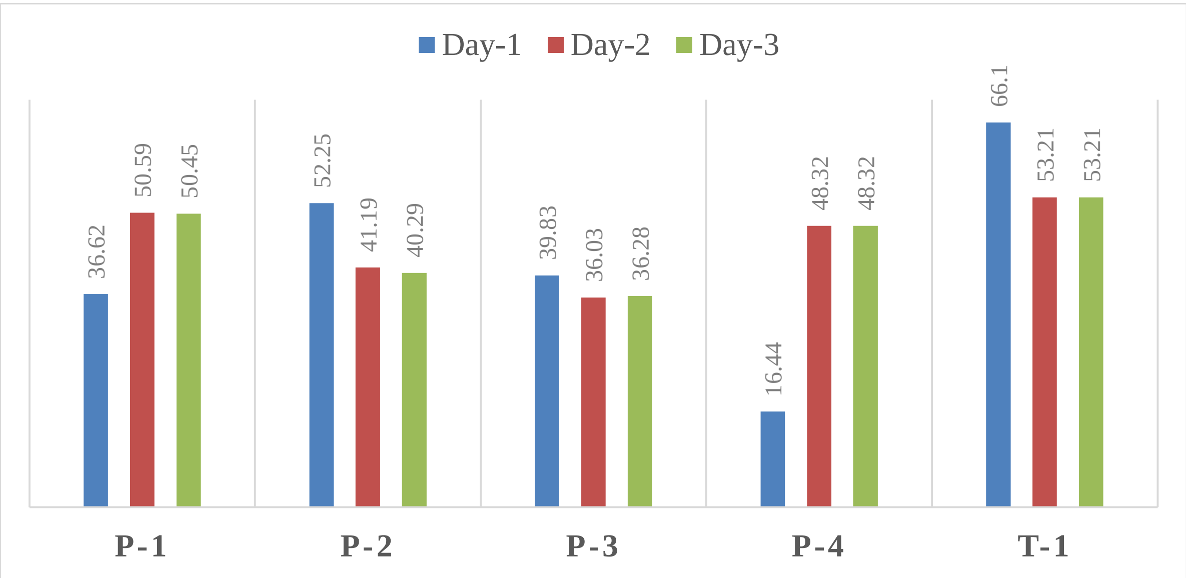

Figure-9- Concentration of SO_4-2 (mg/L)

4.3.9 Heavy Metals

All types of heavy metals (As, Pd, Zn, Cd, Hg, Cu, Fe, Mn and Cr) that can be expected to be present in hospitals wastewater were analyzed at both St. Paulo's millennium medical college hospital (P-4) and Tekur Anbesa specialized teaching hospital (T-1) final effluent. Among the surveyed stations. Heavy metals, at the effluent of TASTH hospital were with concentration of Hg; 0.205±0.006 mg/L, Mn; 0.933±0.036 mg/L, Zn ; 0.847±0.014 mg/L and Fe; 4.898±0.029 mg/L. And this were higher concentration when compared to the final effluent of SPHMMC hospital (P-4), Table-12. At the final effluent of SPHMMC hospital, 0.003±0.001 mg/L, 0.046±0.001 mg/L, 0.024±0.001 mg/L and 0.701±0.032 mg/L of Hg, Mn, Zn and Fe, respectively were examined. At both hospitals effluent, the remains type of heavy metals, such as; lead, arsenic, cadmium and copper were below the detection limit and also the concentration of all measured heavy metals were below the emission permissible level of AACGEGDC standard, table-12.

Table 12- Heavy metals at hospitals final effluent (SPHMMC and TASTH)

Sampling Site	**Parameter (mg/L)**					
	Hg	**Mn**	**Zn**	**Pb**	**Fe**	**Cd**
SPHMMC (SC_1)	0.003±0.001	0.046±0.001	0.024±0.001	< 0.001	0.701±0.032	< 0.022
TASTH (SC_5)	0.205±0.006	0.933±0.036	0.847±0.01	< 0.001	4.898±0.029	< 0.022
AACGEGDC Standard	**-**	**5**	**5**	**0.5**	**10**	**<1**

4.3.10 Total Coliform Unit of Wastewater

Hospitals effluent is expected to have various microbial content and most microbes can be pathogens. Even though total coliform is not specifically an indicator for the type of microbes, determination of total coliform unit is recommended method to indicate for the presence of broad concentration of fecal contaminants microbes in wastewater samples (Rajwinder et al., 2020). And for this study the collected wastewater samples were analyzed for total coliform units and the final effluent of both surveyed hospitals were investigated with high concentration of Total coliforms (> 2400 MPN/100ml).

5. Conclusion and Recommendations

5.1. Conclusion

The final effluent of the surveyed hospital is a combined outlet for different effluent of the hospital units, such as; different medical wards (like; dental service units/ENT and OPD), administration units, cafeterias and student dormitories which might generate high wastewater quantity with low pollutant load. Therefore, at the final effluent of the hospital, wastewater from hospital units which have high pollutant load will diluted with the effluent of those hospital units which have low pollutant load and this will reduce or vary the concentration of pollutant at hospitals final effluent with time variation. The results on this study also indicated that the final effluent of the surveyed hospital, when compared to the effluent of the hospital units, some of the measured wastewater parameters concentration was lower (Appendix-E).

The type and amount of chemicals which are used in hospital units are various and this is expected to affect the hospital units' effluent characteristics and become varied from one hospital unit to the other. The average values of the sampling days had been considered to compare and present the detected result values variation on the effluent of the surveyed hospital units (Appendix-E). Accordingly, Electric Conductivity, Turbidity, TOC, TN, TP and SO_4^{-2} were higher at effluent of SPHMMC Laboratory unit (P-2). The study also found that the mean values of TDS, COD and BOD_5 at the effluent of kidney transplantation and dialysis ward (P-3) were higher when compared to the other surveyed hospital units of SPHMMC (P-1 and P-2). The remains measured wastewater parameters, such as; total solids, total dissolved solids and pH were higher at the combined effluent of ICU, pediatrics, obstetrics and gynecology wards (P-1).

The study results shows that, most of the qualitative indices such as; EC, TSS, TDS, BOD_5, COD, TP, TN and Total coliforms were above pollutant emission permissible limit of the city standard (AACGEPGDC). Whereas during field visit of this study, unrestricted discharging of untreated hospitals wastewater to nearby rivers were observed, which can potentially pollute the environment and easily deliver pathogens to the community. Therefore for proper wastewater management practice of hospitals, there should be standard regulations which can help to assess and monitor hospitals effluent quality periodically and to take actions on those hospitals who are not obeying the rules.

5.2. Recommendations

This study had identified gaps on wastewater management practices of the selected hospitals. Accordingly based on the finding and the required future works on hospitals effluent, some recommendations are presented below.

- ✓ To meet the existing effluent standard of the city (AACGEPGDC) and to keep the surrounding environment safe, the surveyed hospitals must implement preferable pretreatment technique at their effluent.
- ✓ There should be wastewater management units, staffed with skilled man powers.
- ✓ Identifying the main pollutant source from hospitals units and pretreating separately is essential for cost effective effluent management.
- ✓ The study has observed that at hospitals effluent, there could be daily variation of pollutant concentration. Therefor increasing sampling day and characterizing hospitals effluent is essential.
- ✓ Further investigations on determination of pharmaceutical compounds at hospitals effluent and at surrounding rivers must be done.

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Appendix A Questionnaire for primary data collection

Data collection Questionnaire for assessment of hospitals

Wastewater management

Hospital Name ____

Sub city ______________________________ Worreda _______

Hospital Level

○ Referral ○ Specialist ○ General

Hospital Owner

○ Government ○ Private

1. Service data

1.1. Total number of existing beds _______

1.2. Number of bed on the future years if there is a plan for expansion _____

1.3. Number of beds in wards

1. _____ Beds in ______________________ ward.
2. _____ Beds in ______________________ ward.
3. _____ Beds in ______________________ ward.
4. _____ Beds in ______________________ ward.
5. _____ Beds in ______________________ ward.
6. _____ Beds in ______________________ ward.

If others ____

____

____

1.4. Number of patient flow

________/ Year ________/ month _____/ day

1.5. Number of patient flow on the future if there is estimated data ______ in ___ _____coming year

Annually patient flow rate_________%

1.6. Peak day of patient flow

◯ Monday ◯ Tuesday ◯ Wednesday ◯ Thursday ◯ Friday

Other ____

1.7. Peak service time on the peak day of patient flow__________________________

2. Water consumption

	September	october	November	December	January	February	March	April	May	June	July	August
m3/month												

____________ m^3/ year (summation of month consumption)

3. Wastewater management practice

3.1. Do the hospital have wastewater management unit?

◯ Yes ◯ No

If yes, do the staffs have job descriptions?

◯ Yes ◯ No

If yes, do they check the effluent characteristics on scheduled based?

◯ Yes ◯ No

If yes, in how many times ____

3.2. Does the type of wastewater (Black water, Grey water and Storm water) which is collected from the hospital units manage separately (segregated properly)?

◯ Yes ◯ No

Farther explanation ____

3.3. Is there any waste water treatment plant?

◯ Yes ◯ No

If yes, what type of treatment plant is____________________________________

What is the capacity of the plant? _______________________________________

If the answer is no for question 3.3, how is the wastewater management practice?

◯ is directly connected to the municipal seaware system.

◯ is directly discharge in to nearby river.

Which river (name) _____________________________________

◯ Stay in septic tank and transport by truck in to municipal wastewater treatment plant.

__________Times per year and the truck service is by ________________

Further explanation ____

3.4. Is there any legislation which forced the hospital to manage the waste water management practice based on standard by the governing body?

○ Yes ○ No

If yes, do the hospital follow the standard? Yes/No

If there is legislation and the hospital do not follow and implement it, what the reason?

____

3.5. Is there any future plan to manage the waste water properly and protect the environment from pollution?

○ Yes ○ No

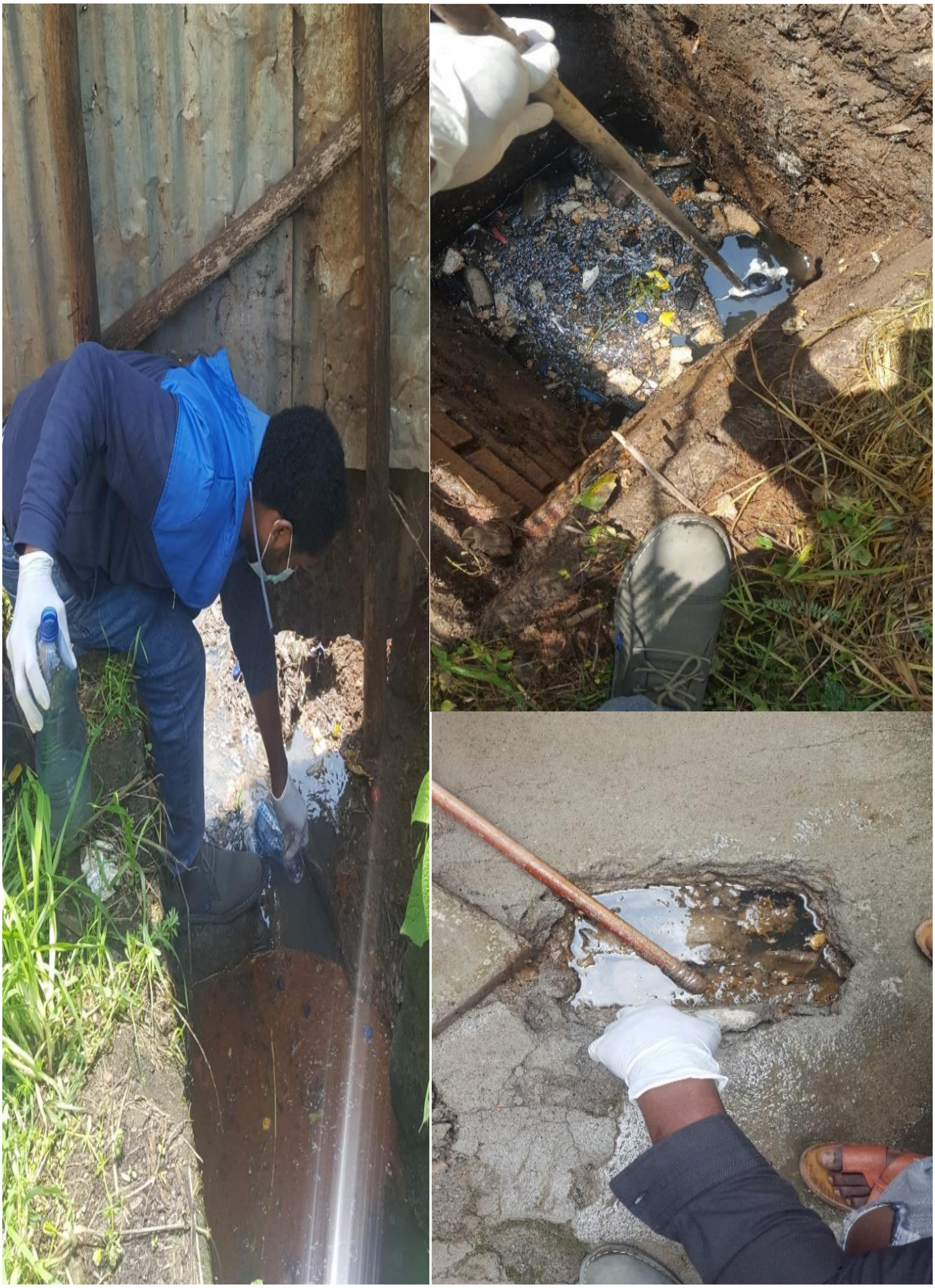
If yes and there is any need of support from the government ___________________

____

Appendix B Summary of Analysis Methods

No.	**Parameters**	**Methods**	**Standard Method**
1	PH	Electrometric method/ PH Meter	4500-H (APHA, 1998)
2	E. Conductivity	Nephlerometric method/ Conductivity Meter	2510-A (APHA, 1998)
3	Turbidity	Nephlerometric method/ Turbidimeter	2110-B (APHA, 1998)
4	Total Suspended Solids (TSS)	Gravimetric method	2540-D (APHA, 1998)
5	Total dissolved solids (TDS)	Gravimetric method	2540-C (APHA, 1998)
6	Chemical Oxygen Demand (COD)	Closed Reflux colorimetric method	5220-D (APHA, 1998)
7	Biological Oxygen Demand (BOD)	Respirometric Method	5210-D (APHA, 1998)
8	Total Organic Carbon (TOC)	Cobustion-infrared method	(APHA, 1998)
9	Total Nitrogen (TN)	Persulphate digestion method and the automated cadmium reduction method	4500-G/4500-F (APHA, 1998)
10	Total Phosphate (TP)	Persulphate digestion method and the automated ascorbic acid reduction method	4500-B.5C/4500-F (APHA, 1998)
11	SO_4^{-2}(mg/L)	Turbidometric	4500-SO_4^{-2} E (APHA, 1998)
12	For all measured heavy metals	Inductively coupled plasma (ICP-OES)	3500 (APHA, 1998)
13	Total Coliform	Multiple Tube Fermentation Technique	(APHA, 1999)

Appendix C: Picture captured during wastewater sample collection from SPHMMC



Appendix D Treatment plant (MBR) at Hospital Coded by H-2

Appendix-E Average Values for Day-1, Day-2 and Day-3 analysis

Parameters	**Sample codes**				
	P-1	P-2	P-3	P-4	T-1
pH	7.1 ± 0.6	7.8 ± 0.7	7.4 ± 0.2	6.9 ± 0.1	6.8 ± 0.1
Conductivity (μS/cm)	770 ± 982	1290 ± 930	898 ± 97	1221 ± 166	1188 ± 717
Turbidity (NTU)	110 ± 150	177 ± 110	47 ± 42	114 ± 48	86 ± 25
TSS(mg/L)	309 ± 58	287 ± 300	185 ± 42	287 ± 235	307 ± 61
TS(mg/L)	1488 ± 147	1765 ± 862	2347 ± 441	1060 ± 427	1373 ± 149
TDS(mg/L)	1179 ± 149	1478 ± 636	2163 ± 412	773 ± 568	1065 ± 173
COD(mg/L)	147 ± 4	211±11	320±16	216 ± 3	282 ± 11
BOD(mg/L)	25 ± 1.07	78 ± 4.63	80 ± 2.01	58 ± 1.15	87 ± 2.85
TOC(mg/L)	3.81 ± 0.21	4 ± 0.12	2 ± 0.24	6 ± 0.14	4 ± 0.23
TN(mg/L)	23 ± 1.31	19 ± 0.25	6 ± 0.4	14 ± 0.31	3 ± 0.15
TP(mg/L)	7 ± 0.93	19 ± 0.35	9 ± 0.27	27 ± 0.24	2 ± 0.08
SO_4^{-2}(mg/L)	45 ± 1.1	44 ± 0.8	37 ± 0.58	37 ± 0.59	58 ± 0.33

Appendix-F Name of surveyed hospitals

S/N	HOSPITAL NAME	CODED	ORGANIZATION	ADDRESS
1	Alert Hospital	H-1	Governmental	Kolfe Sub City
2	BetelHospital	H-2	Private	Kolfe Sub City
3	Gandi Hospital	H-3	Governmental	Kirkos Sub City
4	Girum Hospital	H-4	Private	Addis Ketema Sub City
5	Haleluya Hospital	H-5	Private	Kirkos Sub City
6	Migbare Senay	H-6	Private	Addis Ketema Sub City
7	Minilik Hospital	H-7	Governmental	Yeka Sub City
8	Petrose Hospital	H-8	Governmental	Gulele Sub City
9	Police Hospital	H-9	Governmental	Lideta Sub City
10	RasDesta	H-10	Governmental	Arada Sub City
11	St.Gebriele	H-11	Private	Bole Sub City
12	St. Paulo’s	H-12	Governmental	Addis Ketema Sub City
13	TekleHaymanot	H-13	Private	Addis Ketema Sub City
14	Tekur Anbesa	H-14	Governmental	Addis Ketema Sub City
15	Tor Hayloich	H-15	Governmental	Lideta Sub City
16	Yekatit 12	H-16	Governmental	Gulele Sub City
17	Zewditu Hospital	H-17	Governmental	Kirkos Sub City