COMPARISON OF WASTEWATER QUALITY FROM HOSPITALS IN KUWAIT

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ABSTRACT

The goal of study is to characterize wastewater discharged from healthcare institutions. Raw wastewater was collected from three hospitals in Kuwait including Al-Razi, Al-Sabah, and Maternity Hospital. The collected samples were analyzed for physical, chemical and microbiological parameters. The laboratory and field analysis results indicated inconsistent quality of wastewater, which depends on the medical specific field of the hospital. The highest values of total organic carbon (TOC) and chemical oxygen demand (COD) as well as total dissolved solids (TDS) were obtained for wastewater generated by Al-Razi Hospital, which is specialized in orthopaedics (bones and joints). Moreover, the mean value of oil and grease concentration for wastewater of this hospital was four times higher than values for other two hospitals, probably due to oily treatment for rehabilitation after broken limbs. Regarding nitrogen compounds concentration the highest values were found for the wastewater from Maternity Hospital (pregnancy and baby deliveries), which is under Ministry of Health supervision. It is recommended, to construct separate onsite treatment units for each hospital (general and pediatric, as well as orthopaedics, maternity) with specific design to treat pollutants of each hospital wastewater, instead of pumping wasted liquids to municipality wastewater treatment plants.

Keywords: wastewater, hospitals, chemical analyses

1 INTRODUCTION

Hospital wastewater is significantly dangerous due to its contain of pharmaceutically active compounds and even radioactive elements. Wastewater from each hospital in Kuwait is discharged to public municipal sewerage without any primary treatment. This hospital wastewater is pumped to Ardiya Primary Treatment Plant (removal of solids, grid, sand, grease and oil). After that the wastewater is pumped to Sulaibiya Wastewater Treatment and Reclamation Plant where the secondary biological treatment (biological nutrient removal) and ultra filtration as well as reverse osmosis membrane technology are applied. Reported efficiency of pharmaceutics removal for Sulaibiya WWT&RP is 97 % in accoradance with Aljami, 2014. For other plants in Kuwait such efficiency of removal has been unknown. El Morhit et al., 2015, investigated wastewater from hospitals in Marocco and they found that mean value for chemical oxygen demand (COD) was 828.4 mg/l, which did not exceed the maximum foreseen for domestic wastewater. Wastewater from healthcare institutions usually contains disinfectants, antibiotics, pharmaceuticals and magnetic resonance imaging (MRI) contrast agents. Residues of pharmaceuticals are present in all wastewater treatment plants' effluents. Pauwels and Verstraete, 2006, discussed many aspects of chemicals present in wastewater, which belong to groups like antibiotics, disinfectants, pharmaceuticals and MRI contrast agents. Novo and Manaia, 2010, studied factors influencing antibiotic resistance in municipal wastewater treatment plants and confirmed that longer hydraulic retention time corresponded to higher bacterial removal rates but found rates were not efficient enough.

In Kuwait, there is lack of information regarding data bank with characterization of wastewater from hospitals. Alajmi, 2014, studied removal of the pharmaceuticals (antibiotics) such as Metronidazole, Trimethoprim, Sulphamethoxazole, Paracetamol and Ranitidine from the wastewater coming to Sulaibiya WWT&RP in Kuwait. The antibiotics are used to treat different human organs and infections. The authors have chosen these pharmaceuticals as the most frequently used in Kuwait and mainly they are used as painkillers, Alajmi, 2014. Priyatno et al., 2013, investigated wastewater from three hospitals in Malang City in Indonesia and they reported COD in the range 110 to 351 mg/l and low total suspended solids (TSS) in the range of 43 to 83 mg/l. Al-Ajlouni, 2012, evaluated wastewaters discharged from twelve hospitals in Jordan. They found high COD values (725-1356 mg/l) and wide range for TSS (45-1419 mg/l). Many parameters were higher than Jordan average values for municipal wastewater parameters. Hospital wastewater characteristic and its treatment in north of Iran was investigated by Amouei et al., 2012, and they stated that final effluents do not meet irrigation water standards. In Greece, Kotti et al., 2013, compared a hospital and municipal wastewater and they found that pH and COD values were higher for hospitals but TSS, ammonia and phosphate much lower than in municipal wastewater. Iranian researchers Mesdaghina et al., 2009, described wastewater characteristic for local hospitals and they found that TSS ranged from 72 to 383 mg/l and COD/BOD_5 ratio in the range of 1.62 to 1.87. They found hospital wastewater similar to municipal so these wastewaters are sent to sewage network. The main objective of this paper is characterization of hospital wastewater from three Kuwaiti hospitals as Al-Sabah (general treatment), Maternity and Al-Razi (orthopaedics) and comparison of their parameters with typical municipal sewage characteristic.

2 MATERIALS AND METHODS

In Kuwait municipal sewage is fully mixed with hospitals' wastewater as there is not any primary treatment for this wastewater. Samples were collected from manholes at outlet pipes of hospital wastewater before they joined municipal sewerage. The sampling method was manual and grab samples were collected during 2017. Sampling was carried out on weekly basis. Onsite wastewater field measurements were carried out including temperature, pH, electrical conductivity (EC) and dissolved oxygen (DO). The volume of collected samples was 2 liters and they were stabilized before transportation to Sulaibiya Research Plant laboratory of KISR in Sulaibiya area, Kuwait. The collected samples were analyzed for physical parameters (total suspended solids-TSS), chemical parameters (total dissolved solids-TDS, sulfides, total nitrogen (TN) and ammonium (NH_4^+)), organic parameters (total organic carbon (TOC), chemical oxygen demand (COD) and organic nitrogen) and bacterial parameters (total coliform (TC) and faecal coliform (FC)). Total coliform and faecal coliform were examined by membrane filter method and results are presented in MPN per 100 ml. The location of three discussed hospital is presented in Fig.1. During sampling in the field and laboratory analyses personal protective equipment (PPE) was applied and also H_2S alarm devices were used to protect sampling and laboratory staff.

Figure 1. Location map for Sabah , Al-Razi a and Maternity Hospital .

All wastewater parameters including bacteria were analyzed in accordance with standard methods for water and wastewater examinations (APHA, 2017). Basic data of three hospitals are presented in Table 1.

Table 1. Summary of hospitals data in this study.

No.	Name of Hospital	Specialization	Number of beds	Under supervision
1	Al-Razi	orthopedic surgery	267	MoH
2	Al-Sabah	general, pediatric	438	MoH
3	Maternity	maternity	375	MoH

MoH – Ministry of Health

3 RESULTS AND DISCUSSIONS

The mean values of the obtained laboratory results for wastewater samples collected from three hospitals are presented in Table 2. Metcalf and Eddy (2013) categorized the wastewater into three groups based on the strength of their composition into weak, medium and strong (Table 3). Moreover, obtained mean values of wastewater were compared with Kuwait Environment Public Authority (KEPA) standards for waters discharged to public sewerage (Table 4). The mean value of pH parameter for wastewater samples collected at Maternity Hospital was found 6.8, while the mean pH values for the remaining two hospitals were ranged between 7.8 and 7.9 (Fig.2). The pH values of Maternity Hospital wastewater indicated acidic water environment, while the pH values for wastewater from other two hospitals showed alkaline water environment. The mean values of pH parameter for the wastewater collected from three hospitals were meeting KEPA (2017) standards (Table 3) and in Fig.2, where minimum and maximum are plloted. The acidity or alkalinity of the wastewater reflects the type of medical activities in hospital during sampling periods. Probably in Maternity Hospital the staff use more acids, so pH was lower than in other hospitals. The mean values of DO for wastewater collected from Al-Sabah, Al-Razi and

Maternity Hospitals were found to be 5.27 mg/l, 3.78 mg/l and 1.17 mg/l, respectively (Fig.3). The lowest value for DO was found at Maternity Hospital and the highest value of DO was found at Al-Sabah Hospital. The DO results indicated relatively anaerobic wastewater condition for Maternity Hospital while DO results of Al-Sabah Hospital represent aerobic conditions (i.e. might be due to presence of oxidant compounds such disinfection materials such as chlorine).Todd, D. (2005), classified the salinity of the water into four groups based on their total dissolved solids values. These are fresh water class (0-1,000 mg/l-TDS), brackish water class (1,000-10,000 mg/l-TDS), saline water class (10,000-100,000 mg/l-TDS) and brine water class (>100,000 mg/l-TDS). The TDS values for the wastewater from Al-Sabah, Al-Razi and Maternity hospitals were found to be 502 mg/l, 1712 mg/l and 360 mg/l, respectively. The highest value for Al-Razi Hospital wastewater was found probably due to daily application of gypsum powder, which is used for bones operations. Based on Todd (2005) classification, the wastewater salinity for both Al-Sabah and Maternity Hospital were classified as fresh water (<1,000 mg/l-TDS), while wastewater salinity of Al-Razi Hospital was classified as brackish water (> 1,000 mg/l-TDS) and TDS values for the three hospitals were presented in Fig.4. The TOC and COD values for the wastewater of the three hospitals were tabulated in Table 2, and plotted in Fig.5. The mean COD values for the wastewater ranged from 233 mg/l to 633 mg/l for the three hospitals. On the other hand, the mean TOC values for the wastewater ranged between 161 mg/l and 1822 mg/l. According to Metcalf and Eddy (2013) classification (Table 3), based on COD and TOC values, the composition of water is classified as medium wastewater strength for samples of Al-Sabah Hospital, while for Al-Razi Hospital its wastewater composition belongs to strong strength. Strong and medium wastewater strengths were found for Maternity Hospital based on COD and TOC values, respectively. All the COD values obtained from wastewater of three hospitals were meeting KEPA (2017) for discharging water into sewers (Fig.5 and Table 4).

Table 2. Mean Values for Wastewater Parameters from Three Hospitals.

Parameter	Al-Sabah Hospital	Al-Razi Hospital	Maternity Hospital
Temperature (ºC)	24.7	26	24.2
pH	7.87	7.9	6.8
EC (µS/cm)	1040	3500	710
DO (mg/l)	5.27	3.78	1.17
TSS (mg/l)	58	58	65
TDS mg/l)	502	1712	360
COD (mg/l)	233	556	633
TOC (mg/l)	161	1822	562
Sulfides (mg/l)	0.21	0.23	0.105
NH_4-N (mg/l)	9.6	9.9	20.64
Organic nitrogen (mg/l)	0.6	0.3	41.76
Total nitrogen (mg/l)	10.25	10.43	65.06
Total coliform bacteria (MPN/100ml)	$>10^7$	$>10^7$	$>10^7$
Faecal coliform bacteria (MPN/100ml)	$>10^3$	$>10^4$	$>10^4$

Table 3. Typical Composition of Untreated Domestic Wastewater (Metcalf and Eddy, 2013)

Contaminants	Unit	Concentration		
		Weak	Medium	Strong
Total solids (TS)	mg/l	350	720	1200
Total dissolved solids (TDS)	mg/l	250	500	850
Fixed TDS	mg/l	145	300	525
Volatile TDS	mg/l	105	200	325
Chlorides	mg/l	30	50	100
Sulfate	mg/l	20	30	50
Alkalinity (as $CaCO_3$)	mg/l	50	100	200
Total suspended solids (TSS)	mg/l	100	220	350
Fixed TSS	mg/l	20	55	75
Volatile TSS	mg/l	80	165	275
Settleable solids	ml/l	5	10	20
BOD	mg/l	110	220	400
TOC	mg/l	80	160	290
COD	mg/l	250	500	1000
Total Nitrogen (TN)	mg/l	20	40	85
Organic nitrogen (ON)	mg/l	8	15	35
Free ammonia	mg/l	12	25	50
Phosphorus (total as P)	mg/l	4	8	15
Organic P	mg/l	1	3	5
Inorganic P	mg/l	3	5	10
Oil & Grease	mg/l	50	100	150
Total coliform bacteria	No per 100 ml	10^6-10^7	10^7-10^8	10^7-10^9
Volatile organic compounds (VOC)	µg/l	<100	100-400	>400

In this study, the total nitrogen was assumed as summation of concentrations of ammonium and organic nitrogen. High concentration values of total nitrogen (65.06 mg/l) was observed at Maternity Hospital, while low total nitrogen values were observed at both Al-Sabah and Al-Razi hospitals (10.25 mg/l - 10.4 mg/l). Based on Metcalf and Eddy (2013) classification, the wastewater composition with respect to total nitrogen from both Al-Sabah and Al-Razi Hospitals were classified as low strength, while their total nitrogen values for Maternity Hospital is consider as strong. In general, most of the concentration of total nitrogen was reflected in high ammonium concentration and low organic nitrogen values (Table 2, Fig.6). These data indicated nitrogen mineralization processes had occurred, where the organic nitrogen was transformed to ammonium (Metcalf and Eddy, 2013). With respect to microbial parameter for wastewater collected from three hospitals, the total coliform bacteria counts were found to be $>10^7$ mpn/100ml, while the feacal coliform bacteria counts ranged ($>10^3$mpn/100ml - $>10^4$mpn/100ml). According to Metcalf and Eddy (2013) classification and based on total coliform bacteria counts, the wastewater composition from three hospitals belong to medium and strong strength.

Although, the COD, TSS and pH are meeting KEPA (2017) standards, the other parameters, such as faecal coliform, E. Coli bacteria for all hospitals, as well as electrical conductivity (EC) for Al-Razi hospital wastewater do not meet KEPA standards.

Table 4. **Guidelines for Water Discharged into Sewers (KEPA, 2017)**

Pollutant	**Symbol**	**Unit**	**Maximum Limit**
Biological oxygen demand	BOD_5	mg/l	500
Chemical oxygen demand	COD	mg/l	700
Total suspended solids	TSS	mg/l	300
pH	pH	-	6.5-8.0
Electrical conductivity	EC	µS/cm	2000
Phenol	Total Recov. Phenol	mg/l	1
Fluorides	F	mg/l	15
Sulfides	S	mg/l	10
Arsenic	As	mg/l	0.1
Cadmium	Cd	mg/l	0.1
Cyanides	Cn	mg/l	0.1
Chromium	Cr	mg/l	1.0
Nickel	Ni	mg/l	0.2
Mercury	Hg	mg/l	0.002
Copper	Cu	mg/l	0.5
Zinc	Zn	mg/l	2.0
Lead	Pb	mg/l	0.5
Silver	Ag	mg/l	4.0
Tar and tar oil		mg/l	Nil
Floating oil and grease		mg/l	5
Emulsified oil and grease		mg/l	5
E.Coli	E.Coli	CFU/100 ml	500
Faecal coliform	FC	CFU/100 ml	1000
Egg parasites			Nil
Worm parasites			Nil

CFU – Colony Forming Unit

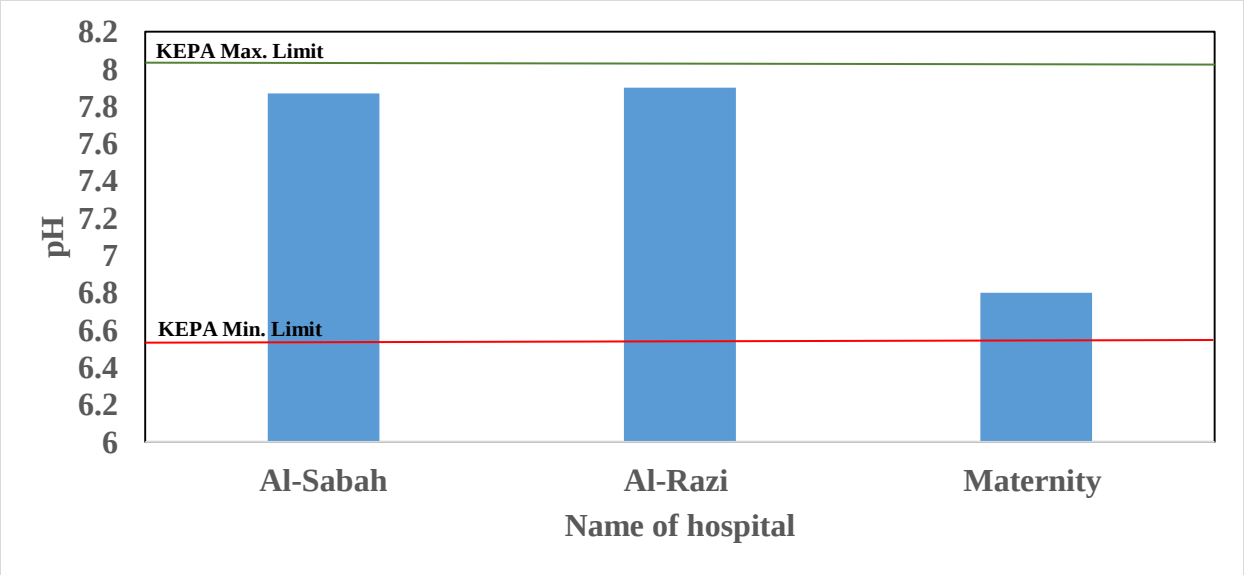

Figure2. pH values for wastewater from three hospitals.

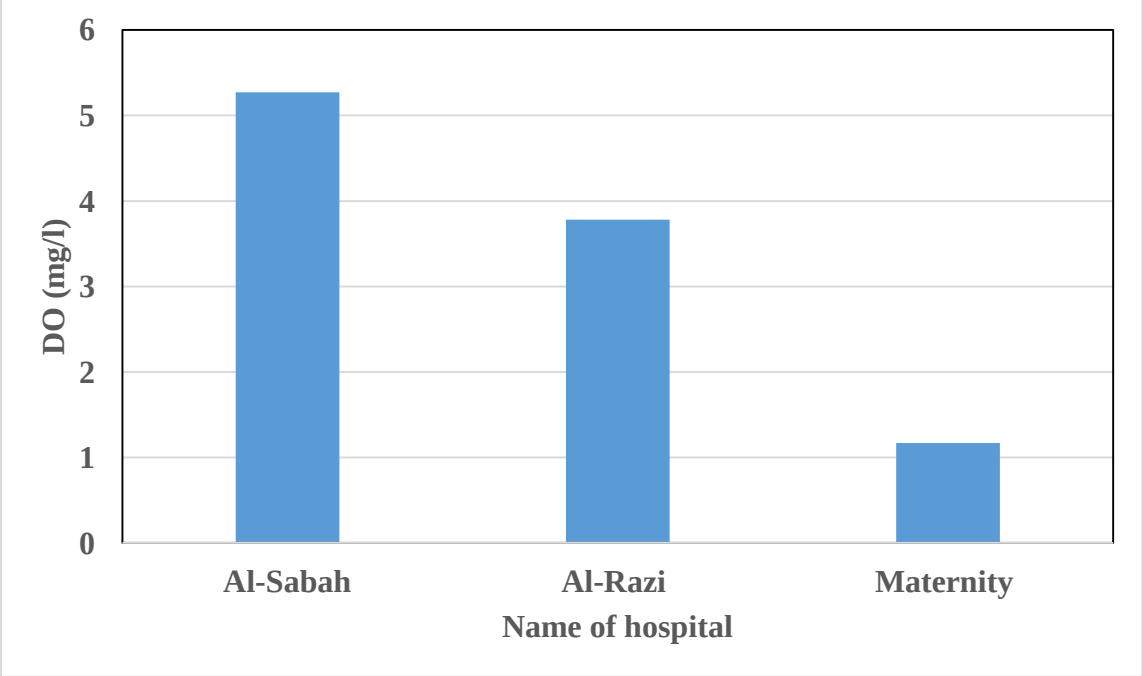

Figure 3. Dissolved oxygen values of wastewater from three hospitals.

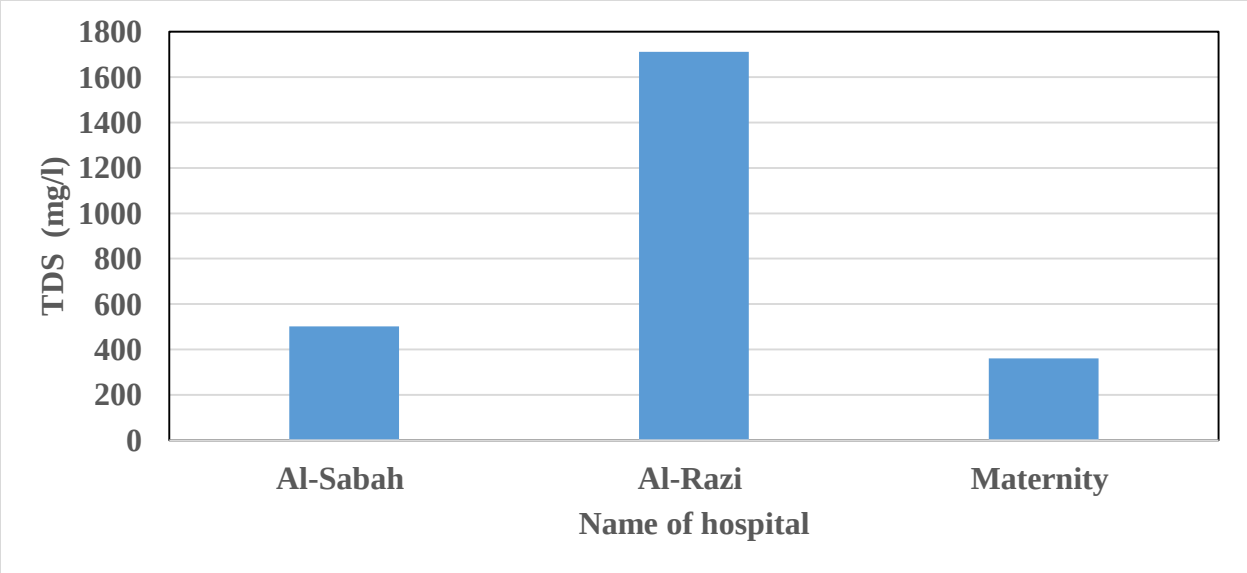

Figure4. Total dissolved solids values of wastewater from three hospitals.

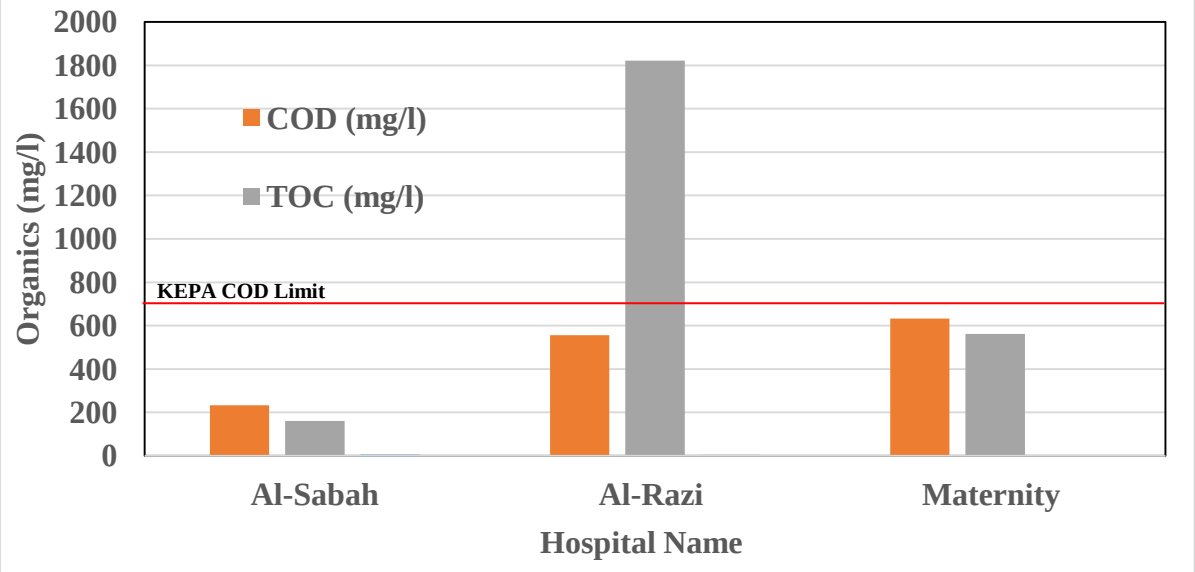

Figure5. Chemical oxygen demand and total organic carbon values for wastewater from three hospitals.

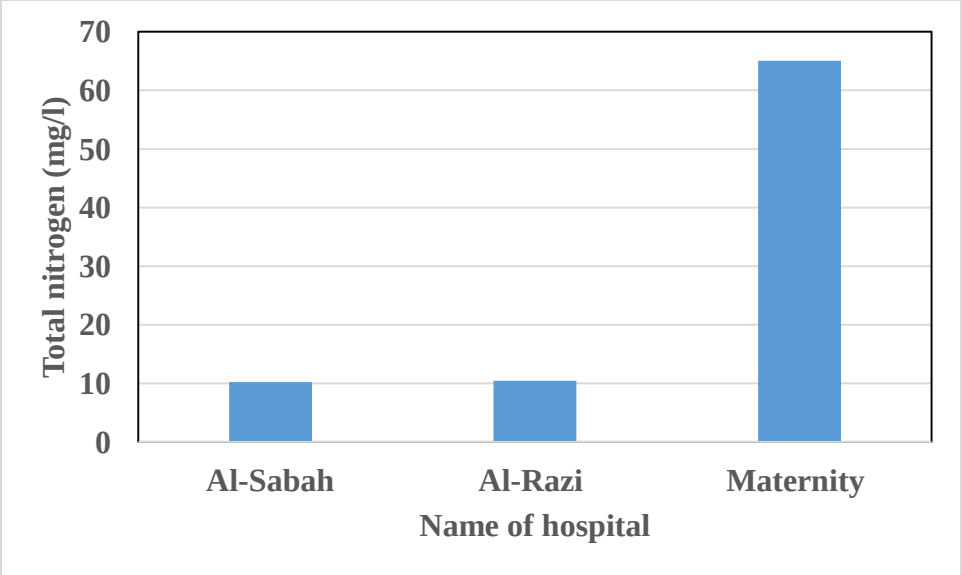

Figure 6. Total nitrogen concentrations in wastewater from three hospitals in Kuwait.

4 CONCLUSIONS

Research study was carried out to characterize the wastewater generated from three hospitals including Al-Sabah, Al-Razi and Maternity Hospital, Kuwait. Wastewater field measurements were carried out including temperature, pH, electrical conductivity (EC) and dissolved oxygen (DO). Wastewater samples were collected on weekly basis. The field measurements results indicated that fresh water to brackish water quality associated with slightly acidic to slightly basic wastewater under low oxidizing environment. Based on COD values for wastewater collected from three hospitals, Metcalf and Eddy (2013) classified the composition of the wastewater between medium and strong with regards to their strength. The highest values of TOC, COD and TDS were obtained for wastewater generated by Al-Razi Hospital while, the highest TN values were found for the wastewater from Maternity Hospital. All the wastewater parameters except EC, total and faecal coliform bacteria concentrations were not meeting KEPA standards for discharging water into sewers. In general, the parameters of wastewater generated from hospital reflect the activities in that hospital during sampling events.

RECOMMENDATIONS

The following recommendations were suggested for future works:

- Long-term monitoring program for the quality of wastewater generated from all hospitals,
- The wastewater parameters should include other aspect
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- s such as pharmaceutically active compounds, radioactive materials, heavy metals,
- Onsite treatment systems should be installed near hospitals for contaminated sites before discharging wastewater to the sewer system,
- Data base should be established with respect to quality and quantity of wastewater generated from hospitals.

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