TREATMENT OF ORGANIC MATTER AND SULFIDES FROM HOSPITAL WASTEWATER IN KUWAIT

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ABSTRACT

A study was carried out to assess the removal efficiency of organic matter and odorous compounds of sulfides group from the wastewater of hospitals in Kuwait using aeration with activated sludge technique. Samples were collected from the outlet of wastewater from Maternity Hospital. The collected samples were transferred to the laboratory of Sulaibiya Research Plant (SRP) of KISR. Each sample was divided into three parts: the first part of the sample was analyzed to obtain characteristic of hospital wastewater, while the second and third samples were mixed with activated sludge from Kabd Wastewater Treatment Plant and underwent aerobic treatment for 12 and 24 hours periods in two bioreactors using a different intensity of aeration. In the first bioreactor, the dissolved oxygen was kept on the level of 2 mg/l, while in the second 4 mg/l. Wastewater and effluents samples were analyzed for the examination of the following parameters as chemical oxygen demand (COD) and sulfides. Based on obtained results of analyses, the removal efficiency of wastewater parameters were calculated mainly for COD and sulfides. The laboratory results indicated that after a hydraulic retention time of 24 h, the mean values of sulfide removal efficiency increased from 82.54 to 93.85%, when DO increased from 2 to 4 mg/l, respectively. Under the same previous operating conditions, the mean value of COD removal efficiency was increased from 93.03 to 95.02 %. To obtain the best effluents the biological process should be extended aeration type with HRT 24 h at DO 4 mg/l. The obtained results will be recommended as the base for treating wastewater from hospitals in package units before discharging to sewage network.

Keywords: Hospital wastewater, Activated sludge, Sulfides

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1 INTRODUCTION

The goal of the project presented was to find out how much aerobic activated sludge can reduce the concentration of pollutants responsible for odor as well as other organic pollutants, which can be treated by microbiological processes. In Kuwait, all of the hospital wastewater is treated in municipal sewage treatment plants. Hospital wastewater flows by gravity to the nearest wastewater pumping station and is pumped to wastewater treatment plant afterwards.

The oxidation of odorous compound as ammonium and sulfides can be done in biological way. For ammonia, there is a reaction called nitrification. Two types of bacteria are responsible for nitrification: nitrosomonas and nitrobacteria.

Nitrosomonas bacteria oxidize ammonia to nitrite product (Metcalf & Eddy, 1991). Nitrite is afterwards converted to nitrate by nitrobacter. Approximate equations for these reactions can be expressed as follows:

$$55NH_4^+ + 76\,O_2 + 109\,HCO_3^- \rightarrow C_5H_7O_2N + 54\,NO_2^- + 57\,H_2O + 104\,H_2CO_3 \quad (1)$$

$$400\,NO_2^- + NH_4^+ + 4\,H_2CO_3 + HCO_3^- + 195\,O_2 \rightarrow C_5H_7O_2N + 3\,H_2O + 400\,NO_3^- \quad (2)$$

Hydrogen sulfide as a main case of sulfides can be biologically oxidized to sulfuric acid as follows:

$$H_2S + 2\,O_2 + \text{bacteria} \rightarrow H_2SO_4 \quad (3)$$

The hospital wastewater in Kuwait is treated only in municipal wastewater treatment plants but the effluents obtained contain residues of pharmaceuticals (Carballa et al., 2004; Kolpin et al., 2002; Kummerer 2001; Petrovic et al., 2003 and Snyder et al., 2003). Efficiency of hospital wastewater treatment were investigated all over the world (Amouei et al., 2012; Alrhmoun et al., 2014; Beier et al., 2012; Mohammed and Al-Rassul Ali, 2012; Kootenaei and Rad, 2013; Kovalova et al., 2012; Mesdaghinia et al., 2009; Prayitno et al., 2014; Prayitno et al., 2013; Spinova et al., 2013; Su et al., 2015 and Razaee et al., 2005). From their works, there is confirmation that conventional wastewater treatment systems usually do not have the satisfactory efficiency and researchers indicate necessity of pretreatment of such healthcare institutions' effluent before discharging to municipal plants. Su et al. (2015) indicates advantage of rotating biological contractor over conventional methods. Beier et al. (2012) have found many advantages of membrane bioreactor technology for treatment of hospital and healthcare institutions' wastewater. In the frame of this project, activated sludge method will be studied as most economical among existing methods. Wiest et al., 2017 carried out the study of specific hospital wastewater treatment for two years confirming that pharmaceuticals are not completely removed by conventional activated sludge method and they recommended separate treatment of such wastewater preferably on-site of hospitals. Tuc et al., 2016 investigated how antibiotics are treated in wastewater treatment plants and how they behave in sewage network. They found that a major part of antibiotics is not treated and they flow out with effluents. Verlicchi et al., 2012 investigated distribution and concentration of pharmaceuticals in hospital effluents founding that municipal wastewater treatment plants sending out with tertiary effluents significant amounts of antibiotics. According to Kummerer, 2001, in wastewater treatment plant effluent the concentration of antibiotics is usually 50 µg per liter. In accordance with Galvin et al., 2010 studies hospital wastewater also contains a mixture of antibiotic resistant (AR) bacteria and multi-drug resistant (MDR) pathogens. Bengtsson-Palme and Larsson, 2015 reported that hospital wastewater also provide an environment for the exchange of antibiotic resistant genes (ARGs) between clinical pathogens and other bacteria. Standard methods for wastewater treatment are not able to fully remove pathogens from the treated liquids. Among available methods for hospital wastewater treatment, the most promising and suitable is membrane bioreactor

(MBR) technology especially if pathogens removal is considered. Membrane bioreactors steadily achieving efficient removal of suspended solids, protozoa and coliform bacteria. Moreover when MBR unit is perfectly operated also can significantly remove various viruses and phages (Faisal et al., 2014). Xagoraraki et al., 2014 reported that MBR operation proved a consistant removal of coliform bacteria and significant removal of human enteric viruses. MBR removes viruses due to their aggregation and adsorption to activated sludge followed by gel and cake layer formed over the membrane. Shang et al., 2005 reported significant removal of E. Coli and fecal coliform by MBR technique. There are the following factors affecting pathogens removal by MBR: membrane material, pore size, flux and membrane cleaning technique (Gander et al., 2000 and Hu et al.,2003).

2 MATERIALS AND METHODS

Before starting experiments two bioreactors of organic glass (plexi-glass) were constructed in KISR's workshop. To deliver oxygen for aeration process, the laboratory scale compressor was applied (model Condor MDR2/11 bars from PEAK SCIENTIFIC Company). For ensuring bubbling of air in mixed liquor special air stones were applied (fine bubble diffusers). Bioreactors were placed on special stands only to allow emptying them in an easy way. Samples were taken from wastewater outlet (manhole) from Maternity Hospital in Kuwait on a weekly basis. The sampling was carried out according to the standard operation procedure (SOP), which was in accordance with standard methods for water and wastewater examination (APHA, 2012). Sampling was carried out manually using a cylinder made of steel with volume of 6 liters which was hold by a rope (10 m long). Samples for laboratory analyses were collected into glass bottles.

Beside a manhole, the following field tests were carried out: temperature, conductivity, pH and dissolved oxygen. Moreover multi-gas detector delivered data for impurities of ambient air above wastewater as follow: hydrogen sulfide, methane, carbon dioxide and oxygen. Total volume of samples (20 l) were collected and divided to 2 l samples, which was taken for laboratory analysis to get characterization of tested wastewater and the remaining 18 l of sample was divided into two sets of samples which were placed in two bioreactors and were mixed with the same (9 liters) volume of activated sludge from Kabd Wastewater Treatment Plant. Obtained mixed liquors were aerated with two different levels of dissolved oxygen (DO); the first reactor was tested for DO level as 2 mg/l while the second one, the DO was 4 mg/l.

Aeration was done in two steps for 12 h and 24 h, so the results were obtained for two periods of aeration to determinate which HRT (hydraulic retention time) is better for a discussed process. For fresh samples of wastewater and for samples of effluent after 12 and 24 hours of aeration, analyses were carried out for COD and sulfides. All analyses were carried out in accordance with standard methods for water and wastewater examination (APHA, 2012).

3 RESULTS AND DISCUSSION

The concentrations of sulfides in an effluent after activated sludge process were very low, and thus it can be considered that they are efficiently removed. The changes of sulfides concentration were presented in Fig. 1 and Fig. 2, which show a low concentration of sulfides in both the cases when DO was at 2 and 4 mg/l. The mean, maximum and minimum values for the sulfides concentration in raw wastewater was found as 0.105 mg/l, 0.796 mg/l and 0.015 mg/l respectively. There were little differences between sulfides concentration in effluents for HRT 12 h, (0.016 mg/l) and HRT 24 h (0.009 mg/l). For the first option of parameters (HRT 12h at DO 2 mg/l), the sulfides concentration ranged between 0.000 mg/l and 0.070 mg/l, with a mean value of 0.016 mg/l (Fig. 1). The removal efficiency for this option ranged from 32.04 % to 100 %, with the mean value of 76.76 % (Table 1).

For the second option of process parameters (HRT 24h at DO 2 mg/l), the concentration of sulfides ranged from 0.000 mg/l to 0.058 mg/l, with mean value 0.009 mg/l and removal efficiency was from 40.78 % to 100 %, with mean value of 83.64% (Table 1).

In third options of parameters (HRT 12 h at DO 4 mg/l), the sulfides concentrations were ranged from 0.000 mg/l to 0.061 mg/l, with a mean value of 0,011 mg/l. The removal efficiency ranged from 43.69 % to 100 %, while the mean value was 82.54 %. The smaller values of removal efficiency in January and February were observed due to lower activity of bacteria in activated sludge which usually appears during season changes. The improvement in the sulfide concentrations in discussed effluents was due to the oxidation of sulfides to sulfates (equation 3).

For fourth option (HRT 24 h at DO 4 mg/l), sulfides concentration were ranged from 0.000 mg/l to 0.057 mg/l, with mean value was 0.006 mg/l. The removal efficiency ranged from 72.73 % to 100 %, while mean value of 93.85 %. It was found that an increment of HRT from 12 to 24 h improved removal efficiency by 10 % (Table 1).

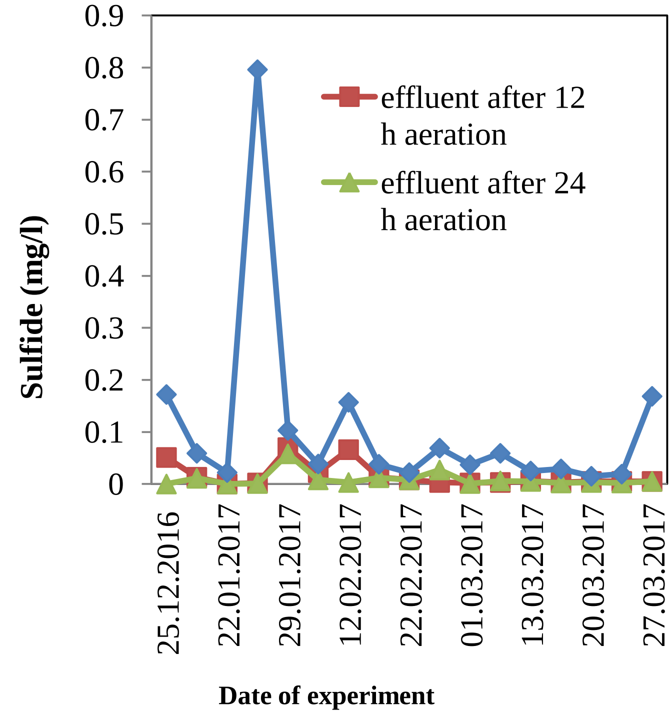

Figure1. Sulfides in wastewater and effluents after 12 and 24 h of aeration at DO 2 mg/l.

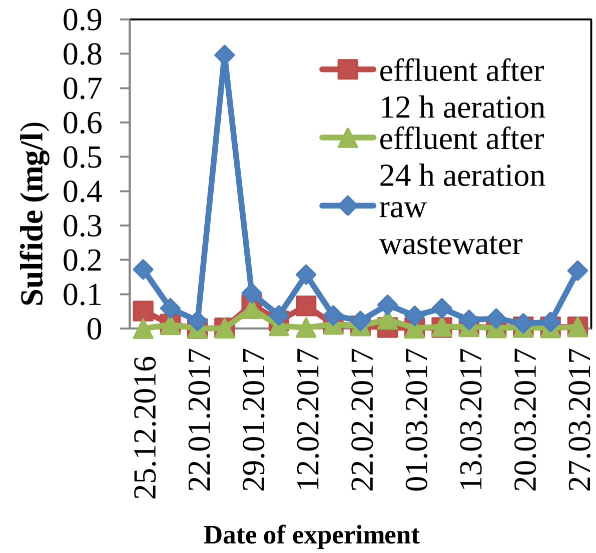

Figure 2. Sulfides in wastewater and effluents after 12 and 24 h of aeration at DO 4 mg/l.

Table 1. Results of Sulfides Removal Efficiency for Effluents after 12 and 24 h of Aeration at DO 2 and 4 mg/l

Number Experiments	Date of Experiments	Removal Efficiency (%)			
		12 h Aeration		24 h Aeration	
		DO (2 mg/l)	DO (4 mg/l)	DO (2 mg/l)	DO (4 mg/l)
1.	25.12.2016	ND	ND	ND	ND
2.	15.01.2017	77.97	79.66	81.36	89.83
3.	22.01.2017	100	100	100	100
4.	24.01.2017	99.75	99.87	99.87	99.87
5.	29.01.2017	32.04	40.78	43.69	94.47
6.	05.02.2017	42.86	63.64	77.92	87.01
7.	12.02.2017	57.96	63.06	98.09	98.73
8.	20.02.2017	65.79	68.42	68.42	84.21
9.	22.02.2017	63.64	95.45	63.64	72.73
10.	27.02.2017	95.65	100	60.87	100
11.	01.03.2017	94.59	97.30	97.30	100
12.	12.03.2017	94.92	96.61	89.83	96.61
13.	13.03.2017	76.00	84.00	80.00	88.00
14.	19.03.2017	89.66	93.10	93.10	96.55
15.	20.03.2017	66.67	73.33	80.00	100
16.	26.03.2017	73.68	84.21	89.47	94.74
17.	27.03.2017	97.03	98.81	97.03	98.81
MIN.		32.04	40.78	43.69	72.73
AVG.		76.76	83.64	82.54	93.85
MAX.		100	100	100	100

ND = not determined parameter; DO = dissolved oxygen; MIN. = minimum; AVG. = average; MAX. = maximum.

Above in Fig. 1, a peak of sulfide concentration appeared probably due to chock of drainage pipe in hospital, so wastewater was digested in the period of few hours delivering excessive amount of sulfide.

The COD values for raw wastewater ranged from 400 to 750 mg/l with a mean value of 633.28 mg/l .As shown in Fig. 3 and 4, the COD was reduced in significant way. For an effluent after 12 h aeration at DO 2 mg/l, the mean value was found to be 59.06 mg/l . The removal efficiency for this option of parameters ranged from 76.41% to 97.47 %, while mean value of 93.03 % (Table 2). For the second option (DO 2 mg/l, HRT 24 h), the COD mean value ranged from 15 mg/l to 139 mg/l, with the mean value of 30.7 mg/l. The removal efficiency for this case ranged from 72.89% to 97.87%, with a mean value of 93.97%.

At the third set of conditions (DO 4 mg/l at HRT 12 h) presented at Fig.4, the mean value was 51.93 mg/l. Removal efficiency for the same parameters ranged from 75.53% and

97.73%, with a mean value of 94.67% (Table 2).

For the fourth option of process conditions (HRT 24 h at DO 4 mg/l), the mean COD value was 29.31 mg/l (Fig.4), while the minimum and maximum values were between 11 and 174 mg/l respectively.. The removal efficiency for the last group of parameters ranged from 69.37% to 98.13%, with a mean value of 95.02% (Table 2). The obtained results for DO at 4 mg/l and HRT 24 h were even much lower (29.31 mg/l) than the KEPA requirements (100 mg/l) for irrigation water . These results indicated that the effluent can be used safely for irrigation purposes.

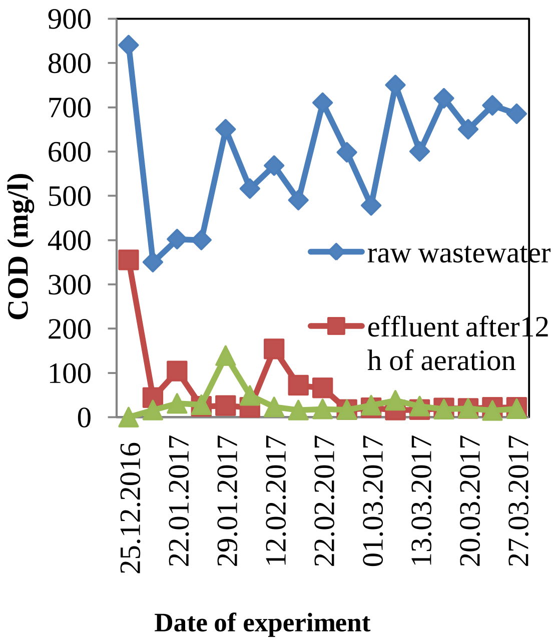

Figure 3. COD in wastewater and effluents after 12 and 24 h of aeration at DO 2 mg/l.

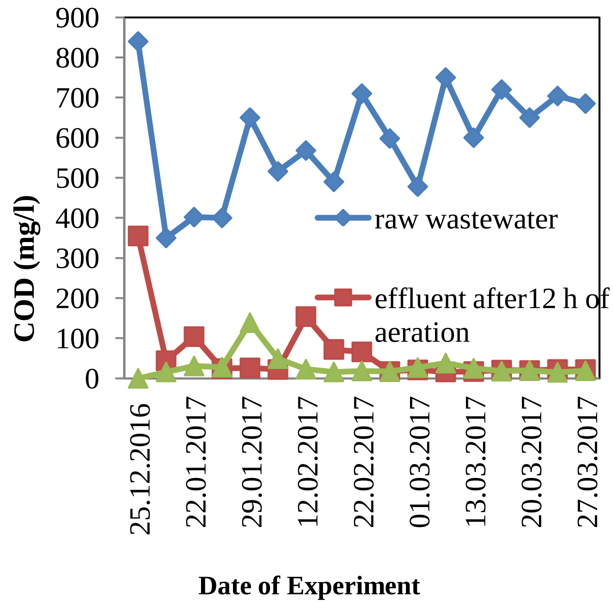

Figure 4. COD in wastewater and effluents after 12 and 24 h of aeration at DO 4 mg/l.

Table 2. Results of COD Removal Efficiency for Effluents after 12 and 24 h of Aeration at DO 2 and 4 mg/l

Number Experiments	Date of Experiments	Removal Efficiency (%)			
		12 h Aeration		24 h Aeration	
		DO (2 mg/l)	DO (4 mg/l)	DO (2mg/l)	DO (4 mg/l)
1.	25.12.2016	ND	ND	ND	ND
2.	15.01.2017	91.50	93.925	96.00	97.25
3.	22.01.2017	95.54	96.00	95.23	95.85
4.	24.01.2017	93.80	95.74	94.57	95.93
5.	29.01.2017	76.41	72.89	75.53	69.37
6.	05.02.2017	78.57	85.31	90.00	93.06

7.	12.02.2017	87.46	90.70	96.76	96.90
8.	20.02.2017	96.15	97.16	97.32	97.32
9.	22.02.2017	94.77	95.61	96.13	96.34
10.	27.02.2017	97.47	97.87	97.73	98.13
11.	01.03.2017	96.33	97.17	95.50	96.67
12.	12.03.2017	96.11	97.15	94.72	97.22
13.	13.03.2017	96.92	97.00	96.15	97.08
14.	19.03.2017	97.16	96.88	97.44	97.23
15.	20.03.2017	96.79	96.79	96.79	97.08
16.	26.03.2017	97.14	96.11	97.62	97.62
17.	27.03.2017	96.38	97.25	97.25	97.25
MIN.		76.41	72.89	75.53	69.37
AVG.		93.03	93.97	94.67	95.02
MAX.		97.47	97.87	97.73	98.13

CONCLUSIONS

The output results of this study can be summarized as follows:

- Extended aeration method is suitable for odorous compounds removal as well as for organic content significant reduction.
- The mean removal efficiency for sulfides exceeds 83% for 12 hours of aeration and 93% for 24 hours aeration if DO was fixed for 4 mg per liter.
- The mean removal efficiency for COD was above 97% (case with DO 4 mg/l and HRT 24 hrs), which proves satisfactory organic matter removal.

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