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Reduction of hospital wastewater through ozone-air micro-nanobubbles

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Resumen

La reducción de la concentración de materia orgánica de las aguas residuales hospitalarias es expresada en DBO_5 y DQO. El tratamiento se desarrolló empleando un equipo generador de micro-nano burbujas con sistema continuo. Se obtuvieron micro-nano burbujas de 0.024µm de diámetro promedio. Para el tratamiento se tomaron dos muestras; Muestra 1 (a las 8:00am) y muestra 2(a las 11:00am). Luego de aplicar el tratamiento con micro-nano burbujas de ozono-aire, se logró reducir las concentraciones iniciales de la muestra 1: DBO_5 de 132mg/L a 14mg/L, DQO de 374mg/L a 30mg/L y de la muestra 2: DBO_5 de 127mg/L a 21mg/L y DQO de 297mg/L a 36mg/L. La eficiencia obtenida a los 15 minutos de la muestra 1 de DBO_5 fue de 90.2% y de DQO fue de 92.51% y de la muestra 2 de DBO_5 fue de 83.5% y de DQO fue de 87.9%

Palabras clave: Aguas residuales hospitalarias, Demanda biológica de oxígeno, Demanda química de oxígeno, micro-nano burbujas de ozono-aire.

Abstract

The reduction of the organic matter concentration of hospital wastewater is expressed in BOD_5 and COD. The treatment was developed using a micro-nanobubble generator with continuous system. Micro-nanobubbles of 0.024µm average diameter were obtained. For the treatment, two samples were taken; Sample 1 (at 8:00 a.m.) and show 2 (at 11:00 a.m.). After applying the treatment with ozone-air micro-nanobubbles, it was possible to reduce the initial concentrations of sample 1: BOD_5 from 132mg/L to 14mg/L, COD from 374mg/L to 30mg/L and from sample 2: BOD_5 from 127mg/L to 21mg/L and COD from 297mg/L to 36mg/L. The efficiency obtained at 15 minutes of sample 1 of BOD_5 was 90.2% and of COD was 92.51% and of sample 2 of BOD_5 was 83.5% and of COD was 87.9%.

Keywords: Hospital wastewater, Biological oxygen demand, Chemical oxygen demand, ozone-air micro-nanobubbles.

1. Introduction

In Peru, only 32% of wastewater sent to the sewerage system receives some type of treatment, and several treatment plants are added, which are not adequate. (OEFA, 2014). The discharge of effluents without treatment is one of the main causes of the loss of water quality. Hospital effluents represent a particular problem, encompassing a mixture of medicines, detergents, antiseptics, solvents and organic matter, to which are added excreta and secretions from patients contaminated by different pathogens. It is also known that large quantities of disinfectant solutions

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are used in hospitals for the elimination of pathogens on surfaces (floors, walls, etc.), equipment and biomedical instruments and on the skin. Having alcohol, aldehydes and different chlorinated compounds as active ingredients of the solutions mentioned (Núñez, 2006).
The use of ozone (dose of 187mg O_3/h) in hospital wastewater at pH = 10, increases biodegradability by 70% and acute toxicity is reduced by 62% (Grisales et al., 2012).
The Micro-Nano bubbles are sub-micronic cavities containing gas in aqueous solution. The Microbubbles (MBs) have a diameter of more than 100 µm, the micro-nano bubbles (MNBs) have a diameter between 1 to 100 µm and the nano-bubbles (NBs) have a diameter less than 1 µm inside the fluid. The micro-nanobubbles generation technology in water is applied in: sea water, water bodies, groundwater, domestic wastewater and industrial wastewater (Valverde, 2017).
There are reductions of thermotolelant coliforms presents in marine water from 1400 CFU /100 mL, until 56 CFU/100 mL, (96%) after applying the air-ozone micro-nanobubbles (Abate and Valverde, 2017). The best treatment reduction Efficiency of BOD in river's water was applying ozone micro-nanobubbles (Salguero and Valverde, 2017). The chemical oxygen demand of 0.5 g Amoxicillin per Liter of water were reduced until 76.9%, organic matter until 65.8% and turbidity until 19.35% in 45 minutes applying air micro-nanobubbles (Mendez and Valverde, 2017). Total coliforms presents in domestic wastewater were reduced from 14500 CFU /100 mL, until 4900 CFU / 100 mL. applying air micro-nanobubbles (Reyes and Valverde, 2017). Sanguaza treated applying air micro-nanobubbles in 60 minutes achieved an average turbidity of 81.5 NTU (79.61%), average BOD5 of 134 mg/L (69.65%) and COD of 150.43 mg/L. (69.24%) (Ventura and Valverde, 2017).

2. Materials and Methods

A sample of 40 liters of hospital wastewater was used to develop the experimental process and 4L of residual water for the initial analysis. For the development of this research, four stages were considered:

Collection and initial analysis of the residual water sample
In this stage, 40 liters of hospital wastewater were collected. Sample 1 was taken at 8:00 a.m. when there was little activity and sample 2 was taken at 11:00 a.m. when the activities increased. Subsequently, the field parameters (temperature, pH, electrical conductivity and Turbidity) and physical-chemical parameters (TSS, BOD5, and COD) were determined.

Treatment with Ozone-air MNBs
In this stage, the continuous-system ozone-air micro-nanobubble generator was conditioned

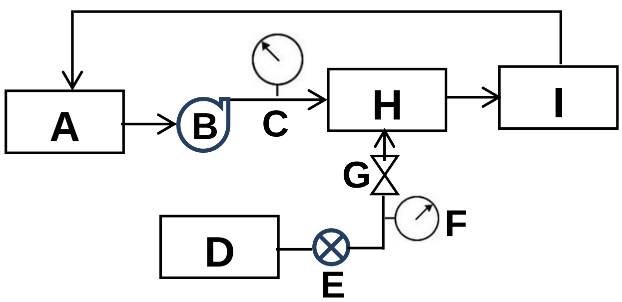

Figure 1. Presentation of the micro-nano bubble generating equipment. Where, A: water tank, B: pump, C: flowmeter, D: air generator, E: pressure valve, F: pressure manometer, G: valve (general), H: MNBs generator, I: wastewater with air MNBs.

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To treat both sample 1 and sample 2, time intervals of 5, 10 and 15 minutes were used.

Analysis after treatment
The field parameters (T, pH, electrical conductivity and Turbidity) and the physical-chemical parameters (BOD_5, COD and TSS) of the samples were analyzed.

Treatment efficiency on parameters.
To measure the MNBs treatment's efficiency on EC will be used the equation 1:

$$\% \, Remotion(EC) = \frac{[EC]_{initial} - [EC]_{end}}{[EC]_{initial}} * 100 \qquad (1)$$

Also this equation is used to measure treatment's efficiency on: Turbidity, TSS, BOD_5 and COD.

3. Results

3.1. Collection of the residual water sample
40 Liters of hospital wastewater were collected at the main drainage point, which were filled in plastic containers for later treatment. Initial samples required 1 L of wastewater for BOD_5, 0.5 L for TSS and 0.25 L for COD preserved with 10 drops of H_2SO_4.

3.2. Initial analysis of the sample
For the initial analysis of the field parameters, the HQ40d multiparameter and the OAKTON T-100 turbidimeter were used. The results are shown below.

Table 1. Results of the initial measurement of the field parameters.

Initial Samples	Parameter	Unit	Value
Sample 1 (8 am)	Temperature	C°	21.4
	pH	-	7.48
	Electrical conductivity	μS/cm	743
	Turbidity	NTU	44.9
Sample 2 (11 am)	Temperature	C°	21.5
	pH	-	7.65
	Electrical conductivity	μS/cm	775
	Turbidity	NTU	79.5

The initial analysis of the field parameters for sample 1 was carried out: temperature (21.4 °C), pH (7.48), electrical conductivity (743 μS/cm) and turbidity (44.9 NTU) of the wastewater. In addition, the initial analysis was carried out for sample 2: temperature (21.5 °C), pH (7.65), electrical conductivity (775 μS/cm) and turbidity (79.5 NTU) of waste water.

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Table 2. Results of the initial measurement of the physical-chemical parameters

	Parameter	Unit	Value
Sample 1 (8 am)	BOD_5	mg/L	132
	COD	mg/L	374
	TSS	mg/L	43
Sample 2 (11 am)	BOD_5	mg/L	127
	COD	mg/L	297
	TSS	mg/L	110

The initial analysis of the physical-chemical parameters for sample 1 was carried out: BOD_5 (132 mg/L), COD (374 mg/L) and TSS (43 mg/L). In addition, the initial analysis of the physical-chemical parameters for sample 2 was carried out: BOD_5 (127 mg/L), COD (297 mg/L) and TSS (110 mg/L) of waste water.

3.3. Treatment with Ozone-air MNBs

The micro-nano bubbles were generated at an air pressure of 30 PSI, water flow of 8L/min and 1000mg of O_3/h.

The micro-nanobubbles were characterized through a trinocular microscope MOD BM-120T-LED light with a 5 MP camera obtaining as a result micro-nano bubbles of 0.024 μm average diameter.

Internal pressure
The internal pressure was determined from the Young's equation - Laplace

$$\Delta P = 4\sigma/d \tag{2}$$

Where:
ΔP: bubble pressure
σ: Surface tension = 0.0728 N/m
d: diameter of the bubble = 0.024 X 10^{-6} m

$$P = 0.96\ atm + \frac{4(0.0728\frac{N}{m})}{0.024\text{x}10-6\text{ m}}$$

$$P=0.96atm + (2133333\ N/m^2)*\ 9.86923 \times 10^{-6}\ atm/\ N/m^2$$

P=0.96atm + 21.05atm= 22.01atm

Therefore, it is concluded that the internal pressure of the micro-nanobubbles is 22.01 atm.

Ascent speed pf air micro-nanobubbles.
Ascent speed of the micro-nanobubble was obtained by replacing equation (3).

$$V = pgd^2/18\ \eta \tag{3}$$

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Where:
V: ascending speed = X
p: density of the liquid = 998.2 g/L = 998.2 kg/m^3
g: gravitational acceleration = 9.8 m/s^2
d: diameter of the bubble= 0.024x10^{-6} m
n: viscosity of the liquid = 1.003 x 10^{-3} m^2 /s

$$U = \frac{998.2\ kg/m3(9.8\frac{m}{s^2})(0.024x10^{-6})^2}{18(\frac{1.003\text{x}10^{-3}kg}{ms})}$$

$$U = 3.12 \text{ x } 10^{-10}\ m/s$$

Therefore, it is concluded that the ascent speed of the air micro-nanobubbles is 3.12 x 10^{-10} m/s.

Table 3. Results of the characterization of the micro-nano bubbles

Description	Value
Contact Time (min)	5 min,10 min and 15 min
Diameter of MNB(µm)	0.024
Internal Pressure (atm)	22.01
Ascent Speed(m/s)	3.12x10^{-10}

Both for the treatment of sample 1 (8:00 a.m.) and sample 2 (11:00 a.m.), 12 L of residual water were used in a period of 5, 10 and 15 minutes.

Table 4. Results of the field parameters of Sample 1 and sample 2.

time (min)	Sample 1 (8:00 a. m.)				Sample 2 (11:00 a. m.)			
	T (°C)	pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	T (°C)	pH	Electrical conductivity (µS/cm)	Turbidity (NTU)
0	21.4	7.48	743	44.9	21.5	7.65	775	79.5
5	21.5	8.4	566	6.84	20.5	8.2	587	6.62
10	21	8.07	482	4.49	20.8	9.01	561	6.01
15	21.2	8.6	405	4	21.6	8.14	530	5.9

The results obtained from the analysis of the field parameters of sample 1 (8:00 a.m.) and sample 2 (11:00 a.m.) at 0, 5, 10 and 15 minutes with the ozone-air micro-nanobubbles are observed.

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Table 5. Results of the physical-chemical parameters of Sample 1 and sample 2.

time (min)	Sample 1 (8:00 a. m.)			Sample 2 (11:00 a. m.)		
	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)
0	43	132	374	110	127	297
5	13	27	44	12	28	49
10	8	14	30	10	23	44
15	9	13	28	13	21	36

The results obtained from the analysis of the physical-chemical parameters of sample 1 (8:00 a.m.) and sample 2 (11:00 a.m.) at 0, 5, 10 and 15 minutes with the ozone-air micro-nanobubbles are observed. The results obtained before and after the treatment of the field and physical-chemical parameters are detailed below.

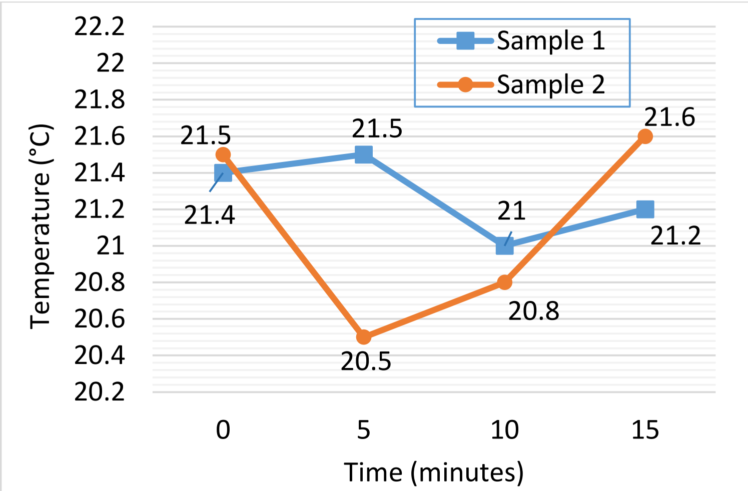

Figure 2. Temperature vs Time of Sample 1 and Sample 2.

It is observed that the temperature has not variations during 15 minutes. Sample 1 achieved 21.2 °C, and Sample 2 achieved 21.6 °C.

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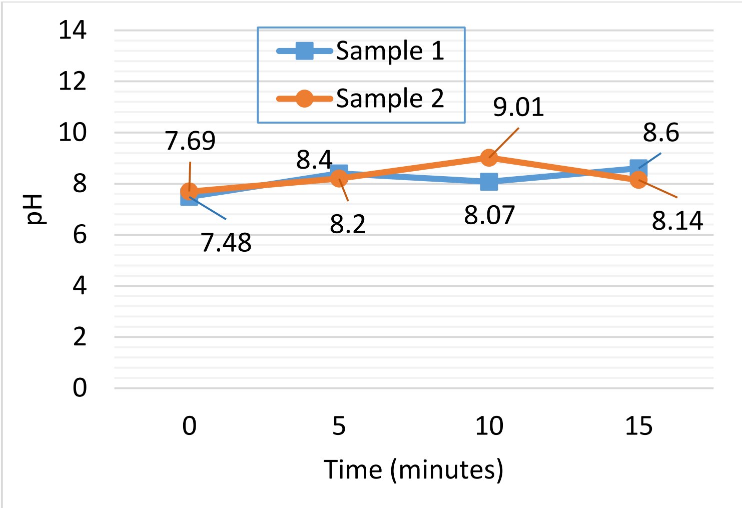

Figure 3. pH vs Time of Sample 1 and Sample 2.

It is observed that pH has not variations during 15 minutes. pH in sample 1 achieved 8.6, and in sample 2 achieved 8.14 in 15 minutes.

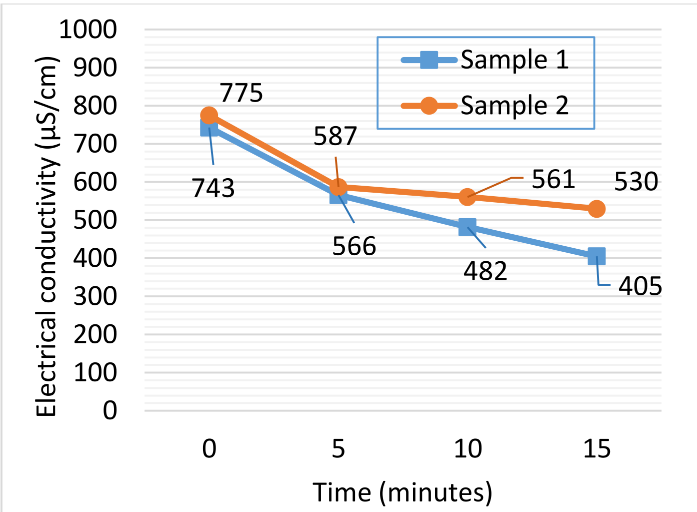

Figure 4. Electrical conductivity vs Time of Sample 1 and Sample 2.

It is observed that Electrical conductivity (EC) was decreasing with longer treatment time. EC in sample 1 achieved 405 µS/cm and in sample 2 achieved 530 µS/cm in 15 minutes.

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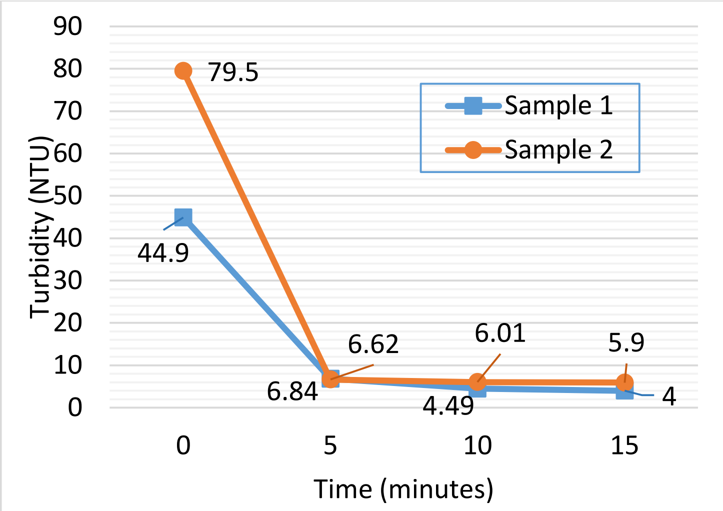

Figure 5. Turbidity vs Time of Sample 1 and Sample 2.

It is observed that Turbidity was decreasing with longer treatment time. Turbidity in sample 1 achieved 4 NTU, and in sample 2 achieved 5.9 NTU in 15 minutes.

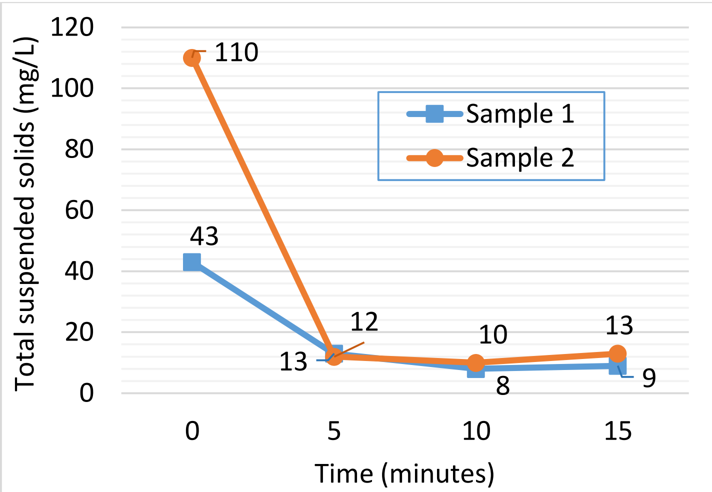

Figure 6. Total Suspended Solids vs Time of Sample 1 and Sample 2.

It is observed that Total Suspended Solids (TSS) was decreasing with longer treatment time. Turbidity in sample 1 achieved 9 mg/L, and in sample 2 achieved 13 mg/L in 15 minutes.

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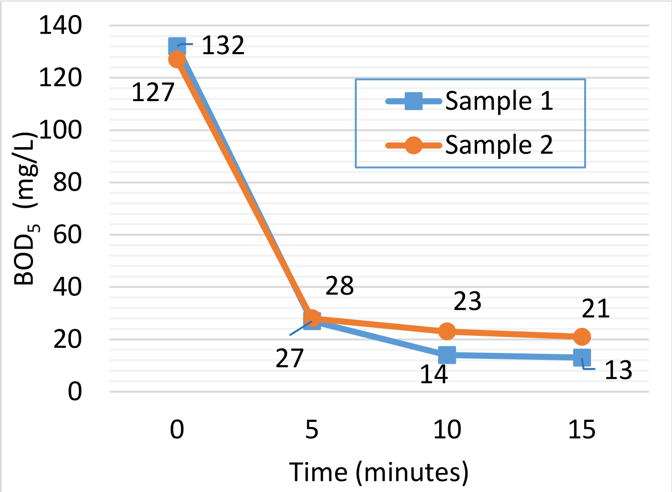

Figure 7. BOD_5 vs Time of Sample 1 and Sample 2.

It is observed that BOD_5 was decreasing with longer treatment time. BOD_5 in sample 1 achieved 13 mg/L, and in sample 2 achieved 21 mg/L in 15 minutes.

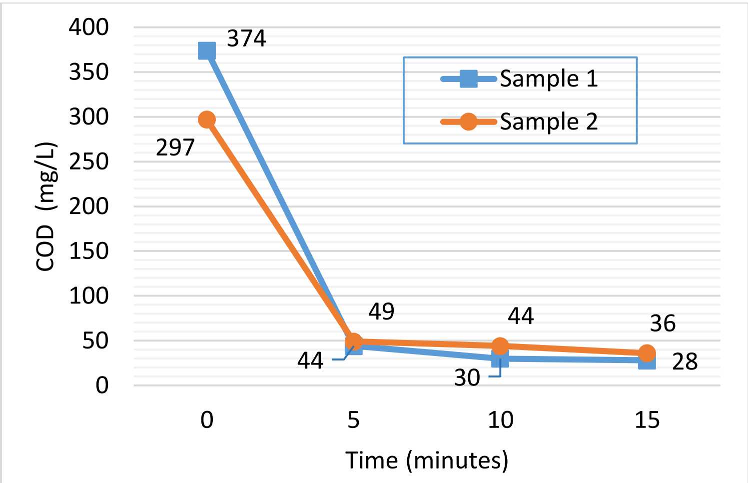

Figure 8. COD vs Time of Sample 1 and Sample 2.

It is observed that COD was decreasing with longer treatment time. COD in sample 1 achieved 28 mg/L, and in sample 2 achieved 36 mg/L in 15 minutes.

3.4. Treatment's efficiency

To calculate treatment's efficiency with ozone-air MNBs on Electrical conductivity in Sample 1 as % Remotion was used the equation 3:

% remotion $(Sample1)_{15}$ = (743 – 405)*100/ 743 = 45.5 %

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Then was calculated to the rest of Sample 1 and Sample 2. As a resume the efficiency is seen in figure 9.

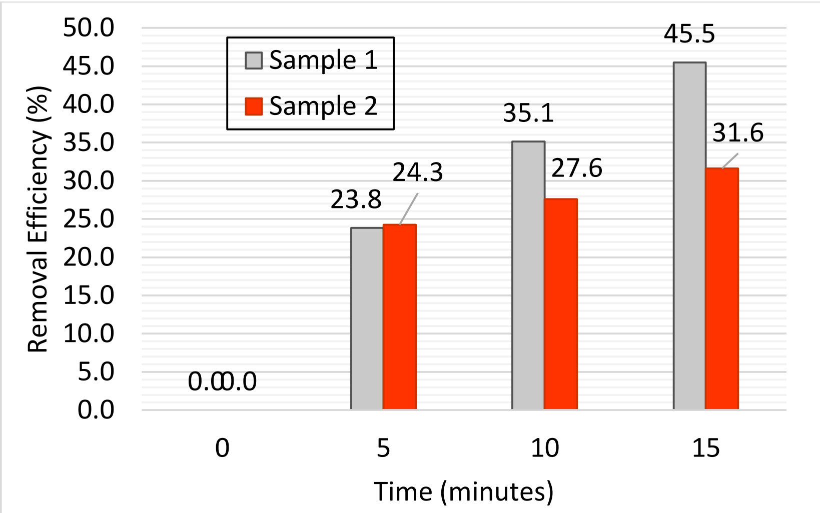

Figure 9. Efficiency of removal of the electrical conductivity of sample 1 and sample 2

To calculate treatment's efficiency with ozone-air MNBs on Turbidity in Sample 1 as % Remotion was used the equation 1:

% remotion $(Sample1)_{15}$ = (44.9 – 4)*100/ 44.9 = 91.1 %

Then was calculated to the rest of Sample 1 and Sample 2. As a resume the efficiency is seen in figure 10.

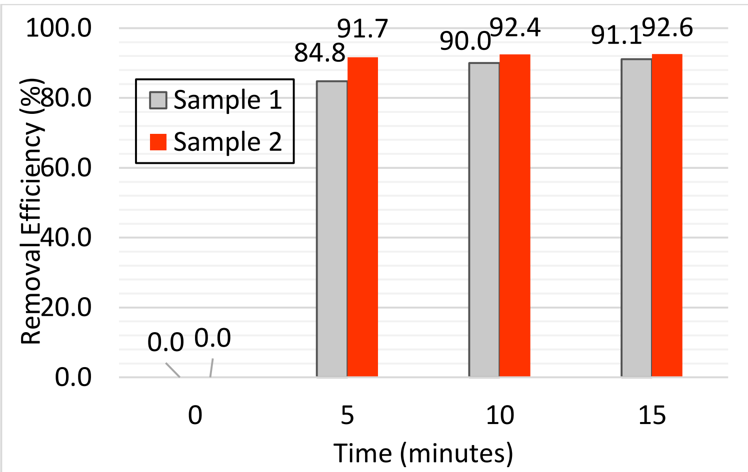

Figure 10. Efficiency of turbidity removal of sample 1 and sample 2

To calculate treatment's efficiency with ozone-air MNBs on Total Suspended Solids (TSS) in Sample 1 as % Remotion was used the equation 1:

% remotion $(Sample1)_{15}$ = (43 – 9)*100/ 43 = 79.1 %

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Then was calculated to the rest of Sample 1 and Sample 2. As a resume the efficiency is seen in figure 11.

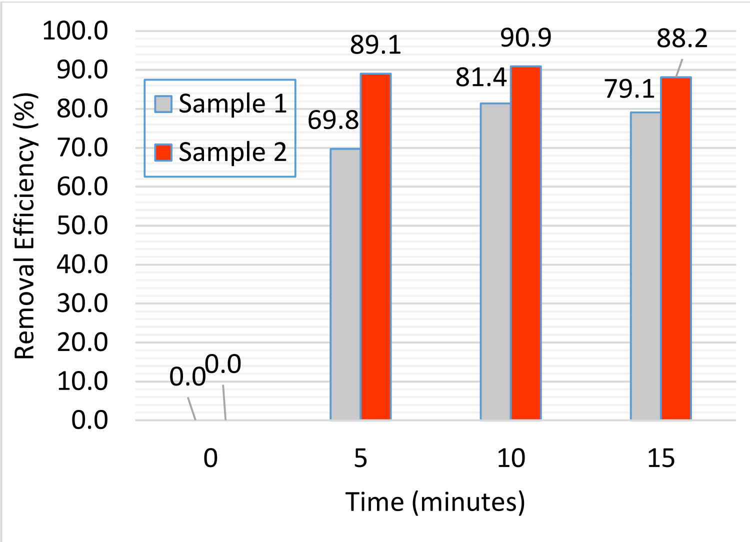

Figure 11. TSS removal efficiency of sample 1 and sample 2.

To calculate treatment's efficiency with ozone-air MNBs on BOD_5 in Sample 1 as % Remotion was used the equation 1:
% remotion $(Sample1)_{15}$ = (132 – 13)*100/ 132 = 90.2 %

Then was calculated to the rest of Sample 1 and Sample 2. As a resume the efficiency is seen in figure 12.

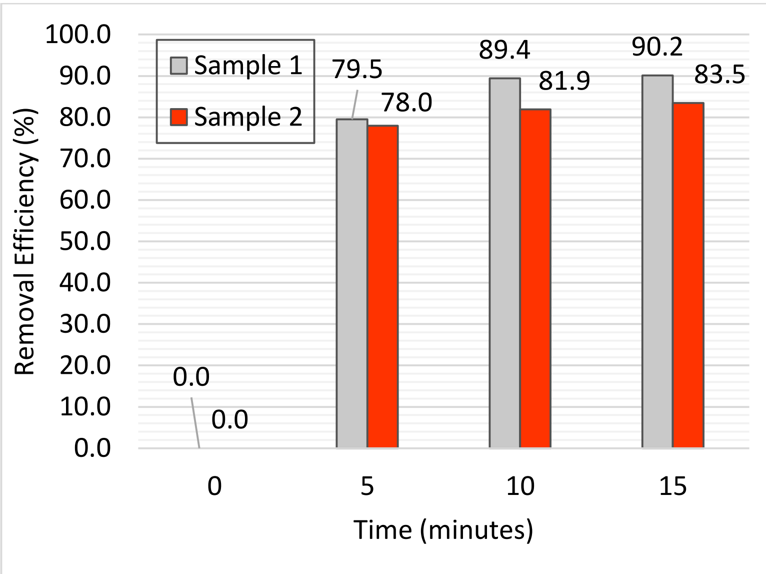

Figure 12. Efficiency of removal of BOD_5 from sample 1 and sample 2

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To calculate treatment's efficiency with ozone-air MNBs on COD in Sample 1 as % Remotion was used the equation 1:
% remotion $(Sample1)_{15} = (374 - 28)*100/ 374 = 92.51$ %

Then was calculated to the rest of Sample 1 and Sample 2. As a resume the efficiency is seen in figure 13.

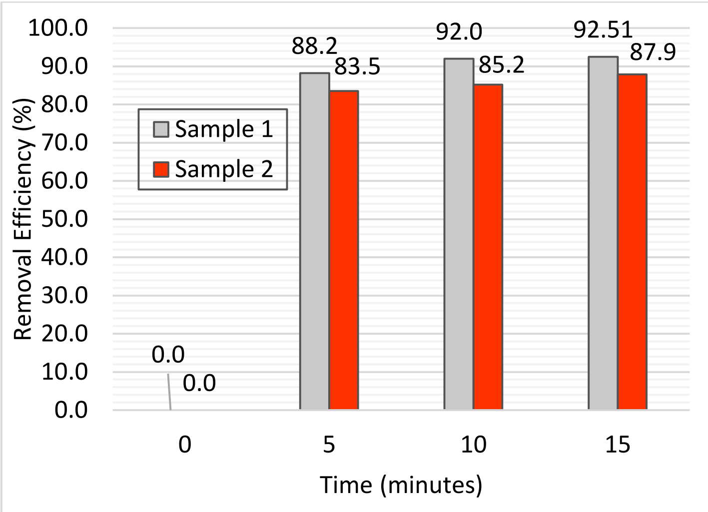

Figure 13. Efficiency of COD removal from sample 1 and sample 2

4. Conclusions

- It is concluded that the initial concentrations of the field parameters of the wastewater in sample 1 as: EC (743 µS/cm), and Turbidity (44.9 NTU) applying ozone-air micro-nanobubbles in 15 minutes decreased their concentrations at 405 µS/cm EC, and 4 NTU Turbidity. In addition, the initial concentrations of the field parameters of the wastewater in sample 2 as: EC (775 µS/cm), and Turbidity (79.5 NTU) applying ozone-air micro-nanobubbles in 15 minutes decreased their concentrations to 530 µS/cm of EC, and 5.9 NTU of Turbidity.

- It is concluded that the initial concentrations of the physical-chemical parameters of the wastewater in sample 1 such as: BOD_5 (132mg/L), COD (374mg/L) and TSS (43mg/L) applying ozone-air micro-nanobubbles in 15 minutes decreased their concentrations to 13mg/L of BOD_5, 28mg/L of COD and 9 mg/L of TSS. In addition, the initial concentrations of the parameters of wastewater in sample 2 such as: BOD_5 (127mg/L), COD (297mg/L) and TSS (110mg/L) applying ozone-air micro-nanobubbles in 15 minutes decreased its concentrations at 21mg/L of BOD_5, 36mg/L of COD and 13 mg/L of TSS.

- According to the results obtained, the percentage of the removal efficiency of the electrical conductivity was 45.5% for sample 1, turbidity was 92.6 for sample 2, Total Suspended Solids (TSS) was 88.2% for sample 2, BOD_5 was 90.2% for sample 1 and COD was 92.51% for sample 1.

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