

Reduction of Chemical Demand of Oxygen and Organic Material from water contaminated with Amoxicillin through application of Air Micro-Nanobubbles

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Resumen

La amoxicilina es usada para tratar ciertas infecciones causadas por bacteria, como neumonía, bronquitis, gonorrea y infecciones de oído, nariz, garganta, tracto urinario y piel. El propósito de esta investigación fue reducir la concentración de demanda química de oxígeno y materia orgánica de agua contaminada con amoxicilina a nivel laboratorio mediante la aplicación de micro-nano burbujas de aire. El método que se utilizó fue pre-experimental. Se elaboraron muestras con tres concentraciones diferentes de amoxicilina por litro en agua desionizada. Las concentraciones de amoxicilina fueron de 0.5g/L, 1 g/L y 2.5 g/L. Tres tratamientos se realizaron en los periodos de 15 minutos (T1), 30 minutos (T2) y 45 minutos (T3).

Las muestras elaboradas tuvieron concentraciones iniciales de Demanda Química de Oxígeno (DQO) de 508.6 mg/L (M1), 711.8 mg/L (M2) y 1582.6 mg/L (M3) y concentraciones iniciales de materia orgánica (MO) de 531.7 mg/L O₂ (M1), 703.4 mg/L O₂ (M2) y 752.6 mg/L O₂ (M3), lo cual se considera por sus concentraciones como muestras contaminadas. Los resultados de reducción para DQO fue de 76.9% (M1), 56.3% (M2), 68.6% (M3) y para materia orgánica fue de 65.8% (M1), 55.7% (M2), 40.9% (M3) después de los tratamientos. Por tanto se demostró que las micro-nano burbujas lograron reducir la DQO y materia orgánica.

Palabras clave: Amoxicilina, Demanda Química de Oxígeno, materia orgánica, micro-nano burbujas, aire.

Abstract

Amoxicillin is used to treat certain infections caused by bacteria, such as pneumonia; bronchitis; gonorrhoea; and infections of the ears, nose, throat, urinary tract and skin. The purpose of this research was to reduce the concentration of chemical demand of oxygen and organic material from water contaminated with amoxicillin at the laboratory level through the application of air micro-nanobubbles. The method used was pre-experimental. Three samples were elaborated with 3 different concentrations of amoxicillin per liter within deionized water. Amoxicillin concentrations were 0.5 g/L, 1 g/L and 2.5 g/L. Three treatments were done in the periods of 15 minutes (T1), 30 minutes (T2) and 45 minutes (T3).

The elaborated samples had COD initial concentrations of 508.6 mg/L (S1), 711.8 mg/L (S2) y 1582.6 mg/L (S3) and organic matter initial concentrations of 531.7 mg/L O₂ (S1), 703.4 mg/L O₂ (S2) y 752.6 mg/L O₂ (S3), which are considered by their concentrations as contaminated samples. Results of reduction were obtained to COD 6.9% (S1), 56.3% (S2), 68.6% (S3) and to organic matter 65.8% (S1), 55.7% (S2), 40.9% (S3) after the treatments. Therefore it was demonstrated that the micro-nano bubbles reduce the COD and organic matter in water.

Keywords: Amoxicillin, Chemical Oxygen Demand, Organic matter, Micro-nanobubbles, air.

1. Introduction

The greatest concern in society is the impact generated by the growing industrialization, since its waste is increasingly difficult to treat or eliminate. The water resource is of the most importance in natural ecosystems due to its capacity to house life and be a vital resource for humanity, which is why this vital resource should not be affected. In recent years, as part of the lifestyle of people, a considerable variety of drugs has been developed, although these drugs have been created for the benefit of people's health. This technological advance has had an impact on the environment, since they are discarded without any type of treatment. The contamination caused by the use of medicines is one of the biggest problems at present, since these compounds are resistant to the attack of microorganisms as well as to degradation mechanisms (anaerobic processes, filtration, activated sludge, etc.). On the other hand, pharmaceutical laboratories mostly pour their effluents into the sewerage network, without prior treatment, so their effluents discharged contain chemical substances that are used as raw material in the preparation of medicines; substances such as: acetone, ethyl alcohol, chlorine, etc. As well as, organic compounds are present; such as: acetaminophen, amoxicillin, ibuprofen, etc., which are used for the extraction of the active ingredients used in the preparation of medicines. There are also residues of medicines, expired medicines, which are discarded. While taking into account that, humans excrete up to 90 percent of the drugs ingested. These effluents in the receiving body present a great threat, since they directly and continuously affect aquatic species, both flora and fauna. Also, these contaminants present in the effluents alter the sewer infrastructure. Due to the aforementioned, there is a concern about the presence of pharmaceutical products in wastewater, since the existing purification technologies do not manage to eliminate these toxic substances.

Wastewater contaminated with pharmaceutical products is characterized by having large compositions of organic matter (acetones), organic compounds (acetaminophen, amoxicillin, etc.) and toxic compounds (antibiotics). All this interferes with the quality of the effluent, since having this characterization and not having the proper removal treatment produces major alterations in the sewerage network and in the receiving body, thus contaminating the environment (Carlsson et al, 2006).

As a result of the use of antibiotics, analgesics, antivirals, among others, high concentrations of water contaminated with these pharmaceutical products are generated, which results in the loss of marine biodiversity, both of fauna and flora. In turn, solid waste is generated, which occurs after the use of glass jars, damaged labels, empty containers of disinfectants, damaged blisters, bottles of injectable solutions.

Antipyretics and analgesics such as: amoxicillin, acetaminophen, aspirin 500mg, ibuprofen, naproxen and diclofenac, which are products used in large quantities worldwide, exert that decreases the mobility- and growth activity on certain functions in vertebrate- and invertebrate animals. (Cleuvers, 2004).

The environmental nanotechnology is a technological discipline which study properties of natural and manmade nanomaterials, applications, techniques for their characterization, integration processes and transformation into ecosystems. The Microbubbles (MBs) have diameter more

than 100 μm , the micro-nanobubbles (MNBs) have diameter between 1 to 100 μm and the nanobubbles (NBs) have diameter less than 1 μm within the fluid field (Valverde, 2016).

The micro-nanobubbles generation technology in water is applied in: sea water, water bodies, groundwater, domestic wastewater and industrial wastewater (Valverde, 2017).

The best treatment reduction Efficiency of BOD in river's water was applying ozone micro-nanobubbles (Salguero and Valverde, 2017).

2. Materials and Methods

The research design was Pre-experimental. The population was water contaminated by amoxicillin.

Preparation of laboratory samples

The sample was 75 liters of deionized water with amoxicillin's capsules of 500 mg. Prepare concentrations of 0.5 g of amoxicillin/L, 1 g of amoxicillin/L and 2.5 g of amoxicillin/L. The total of laboratory samples was 60 liters (20 liters per concentration) used for treatment with air micro-nanobubbles in three different times (15, 30 and 45 minutes) and 15 liters was used as a blank sample.

Initial Analysis from parameters of the prepared samples

The parameters for initial analysis of the prepared samples are: COD (mg/L), pH (unit pH), Temperature ($^{\circ}\text{C}$), Turbidity (NTU), Organic Matter (mg/L O₂)

Treatment with air micro-nanobubbles

An air micro-nanobubble generating equipment was used.

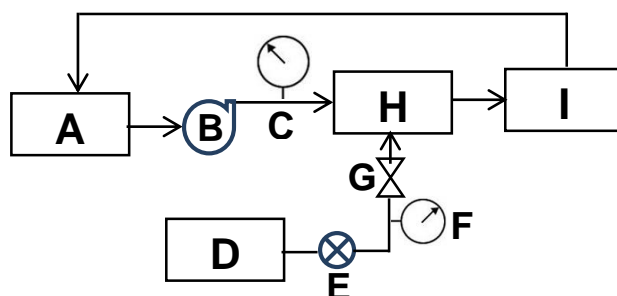


Figure 1. Presentation of the micro-nano bubble generating equipment. Where, A: water tank, B: pump, C: flowmeter, D: air generator, E: pressure valve, F: pressure manometer, G: valve (general), H: MNBs generator, I: wastewater with air MNBs.

To determine the size of the micro-nano bubbles, we used a Boeco's triocular microscope, from 5-megapixel camera.

To carry out the treatment and generate the micro-nano bubbles, a pressure of 85 to 90 psi was taken into account; with a flow rate of 1.05 L/s.

The minimum measurement of micro-nanobubble was 1 μm and the maximum measurement of micro-nanobubble was 2.53 μm . The average measurement of micro-nanobubble was 1,505 μm .

Final Analysis from parameters of the prepared samples

The parameters for final analysis are:

COD (mg/L), pH (unit pH), Temperature (°C), Turbidity (NTU), Organic Matter (mg/L O₂)

Treatment efficiency on COD and organic matter.

To measure the MNBs treatment's efficiency on COD was used the equation 1:

$$\% \text{ Remotion}(COD) = \frac{[COD]_{initial} - [COD]_{end}}{[COD]_{initial}} * 100 \quad (1)$$

To measure the MNBs treatment's efficiency on organic matter (OM) was used the equation 2:

$$\% \text{ Remotion}(OM) = \frac{[OM]_{initial} - [OM]_{end}}{[OM]_{initial}} * 100 \quad (2)$$

3. Results

3.1. Initial analysis of parameters

The average results of analysis before the treatment is shown in the following Table.

Table 1. Average results of the analysis before treatment.

Parameters	Samples		
	S1	S2	S3
COD (mg/L)	508.6	711.8	1582.6
Organic matter (mg/L)	531.7	703.4	752.6
pH	5.16	5.47	5.97
Turbidity (NTU)	7.44	7.32	11.7
Temperature (°C)	23.06	23.04	23.1

As shown in table 1, the values of initial parameters analyzed by three samples were obtained as: COD, Organic matter, pH, Turbidity and Temperature.

3.2. Ascent speed pf air micro-nanobubbles.

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

$$V = \frac{pgd^2}{18 \eta} \quad (3)$$

Where:

V: ascending speed = X

p: density of the liquid (1 g/ml) = 1000 g/L = 1000 kg/m³

g: gravitational acceleration = 9.8 m/s²

d: diameter of the bubble= 1.505 X 10⁻⁶ m

η: viscosity of the liquid = 1.0016 X 10⁻³ kg/ms

$$V = \frac{1000 \text{ kg/m}^3 (9.8 \text{ m/s}^2) (1.505 \times 10^{-6} \text{ m})^2}{18 (1.0016 \times 10^{-3} \text{ kg/ms})}$$

$$V = 1.23 \times 10^{-6} \text{ m/s}$$

Therefore, it is concluded that the ascent speed of the air micro-nanobubbles is 1.23 X 10⁻⁶ m/s.

Internal pressure of micro-nanobubble

The Internal pressure of the micro-nano bubble was obtained by equation (4).

$$\Delta P = 4\sigma/d \quad (4)$$

Where:

ΔP : bubble pressure

σ : Surface tension = 0.0728 N/m

d: diameter of the bubble = 1.505×10^{-6} m

$$\Delta P = \frac{4(0.0728 \text{ N/m})}{1.505 \times 10^{-6} \text{ m}}$$

$$\Delta P = 193488.37 \text{ N/m}^2 = 1.91 \text{ atm}$$

Therefore, it is concluded that the internal pressure of the micro-nanobubbles is 1.91 atm.

Final analysis of parameters

Table 2. Average results of the analysis after treatment

N° Sample	Time (min)	Temperature (°C)	pH	Turbidity (NTU)	COD (mg/L)	organic matter (mg/L)
Sample 1 (0.5 g/L)	15	22.7	7	6.2	389	381.4
	30	22.6	7.06	6.15	318.28	322.28
	45	22.8	7.14	6	117.3	181.72
Sample 2 (1 g/L)	15	22.6	6.99	5.26	653.3	658.94
	30	22.7	7.04	5.24	497.94	595.46
	45	22.8	7.03	3.36	310.86	311.3
Sample 3 (2.5 g/L)	15	22.6	7	3.76	1289.48	746.54
	30	22.8	7.06	2.67	804.74	555.2
	45	22.7	7.1	2.5	497.38	444.5

The results obtained from Sample 1 on 45 minutes were: temperature (22.8 °C), pH (7.22), Turbidity (6 NTU). COD (117.3 mg/L) and Organic matter (181.72 mg/L). The results obtained from Sample 2 on 45 minutes were: temperature (22.8 °C), pH (7.03), Turbidity (3.36 NTU). COD (310.86 mg/L) and Organic matter (311.3 mg/L). The results obtained from Sample 3 on 45 minutes were: temperature (22.7 °C), pH (7.1), Turbidity (2.5 NTU). COD (497.38 mg/L) and Organic matter (444.5 mg/L). See Table 2.

The following figures show parameters of three samples measured in different times.

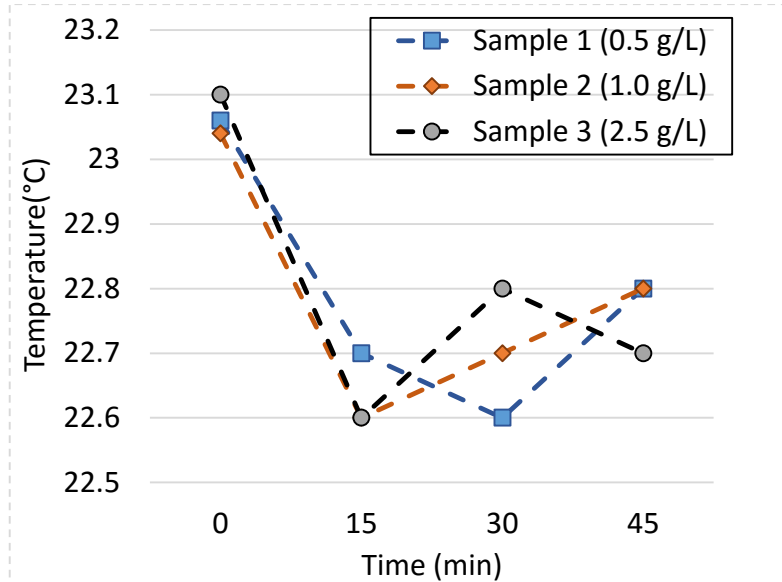


Figure 2. Temperature vs. Time of three samples with amoxicillin.

It is observed that the temperature has not variations during 45 minutes. Sample 1 achieved 22.8 °C, Sample 2 achieved 22.8 °C and Sample 3 achieved 22.7 °C.

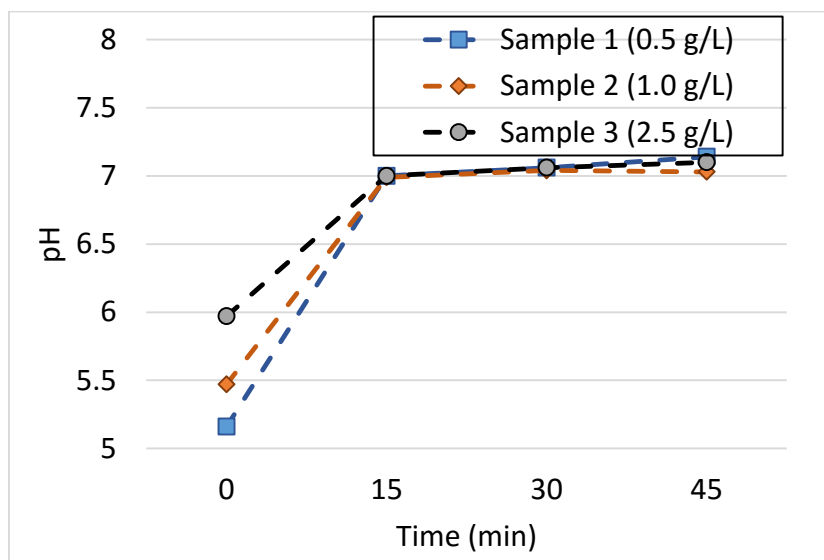


Figure 5. pH vs. Time of three samples with amoxicillin.

It is observed that pH was increasing with longer treatment time. pH until 45 minutes in sample 1 achieved 7.14, in sample 2 achieved 7.03 and in sample 3 achieved 7.01.

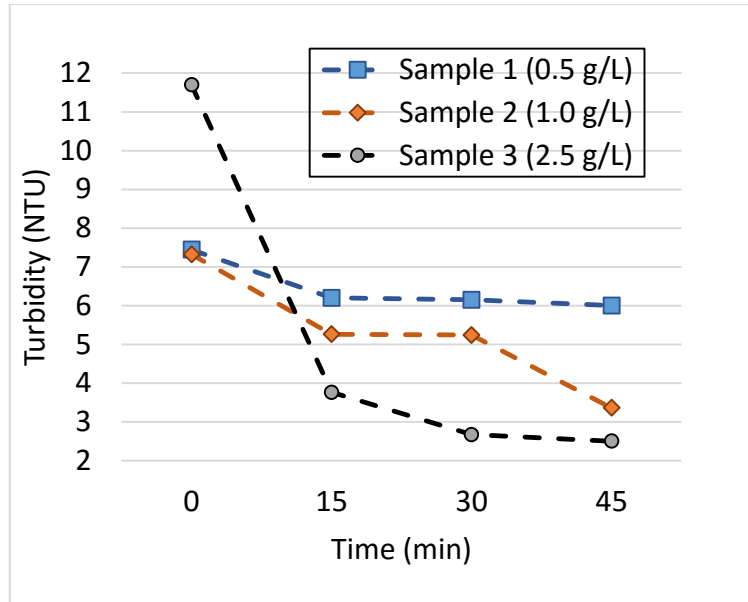


Figure 4. Turbidity vs. Time of three samples with amoxicillin.

It is observed that Turbidity was decreasing with longer treatment time. Turbidity until 45 minutes in sample 1 achieved 6 NTU, in sample 2 achieved 3.36 NTU and in sample 3 achieved 2.5 NTU.

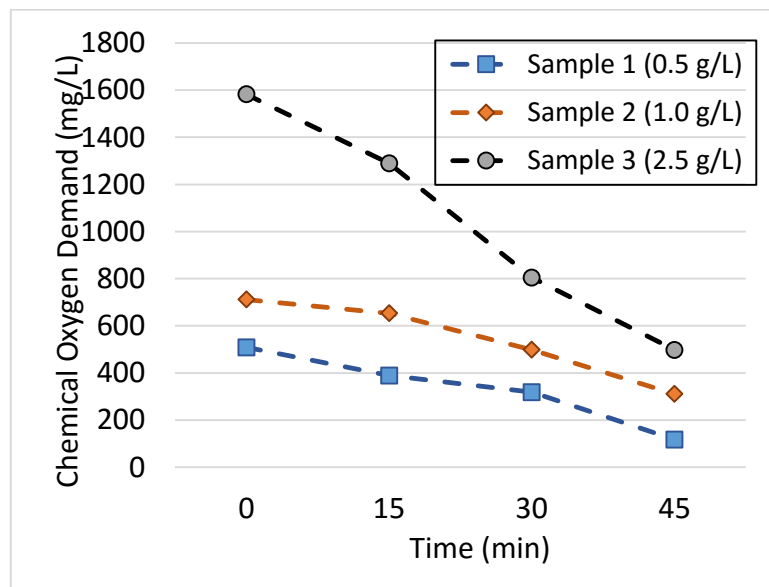


Figure 3. COD vs. Time of three samples with amoxicillin.

It is observed that the COD was decreasing with longer treatment time. COD until 45 minutes in sample 1 achieved 117.3 mg/L, in sample 2 achieved 310.86 mg/L and in sample 3 achieved 497.38 mg/L.

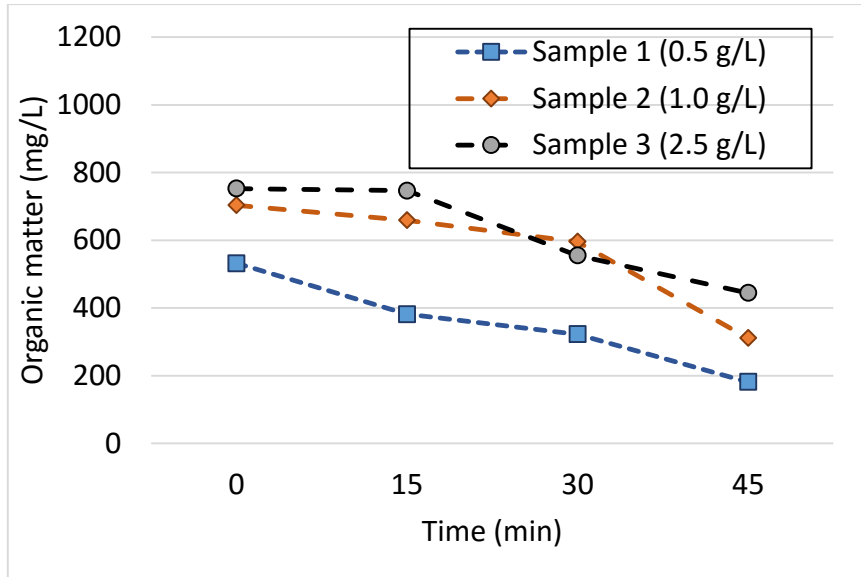


Figure 6. Organic matter vs. Time of three samples with amoxicillin.

It is observed that the organic matter was decreasing with a longer treatment time. Organic matter until 45 minutes reduced to sample 1 (181.72 mg/L), to sample 2 (311.3 mg/L) and to sample 3 (444.5 mg/L).

Treatment's efficiency

To calculate treatment's efficiency with air MNBs on COD in Sample 1 as % Remotion was used the equation1:

$$\% \text{ remotion (Sample1)} = (508.6 - 117.3) * 100 / 508.6 = 76.90 \%$$

Then was calculated to Sample 2 and Sample 3. As a resume the efficiency is seen in figure 7.

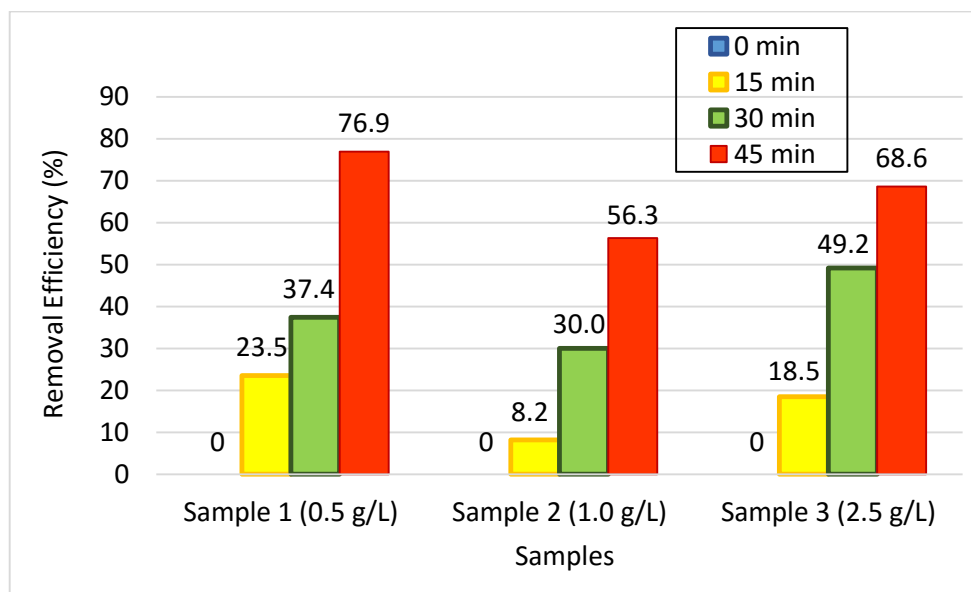


Figure 7. Removal efficiency of COD in water.

It is observed that removal efficiency for COD in water was increasing with longer treatment time. Efficiency until 45 minutes for sample 1 achieved 76.9%, for sample 2 achieved 56.3% and for sample 3 achieved 68.6%.

To calculate treatment's efficiency with air MNBs on Organic matter in Sample 1 as % Remotion was used the equation2:

$$\% \text{ remotion (Sample1)} = (531.7 - 181.72) * 100 / 531.7 = 65.80 \%$$

Then was calculated to Sample 2 and Sample 3. As a resume the efficiency is seen in figure 8.

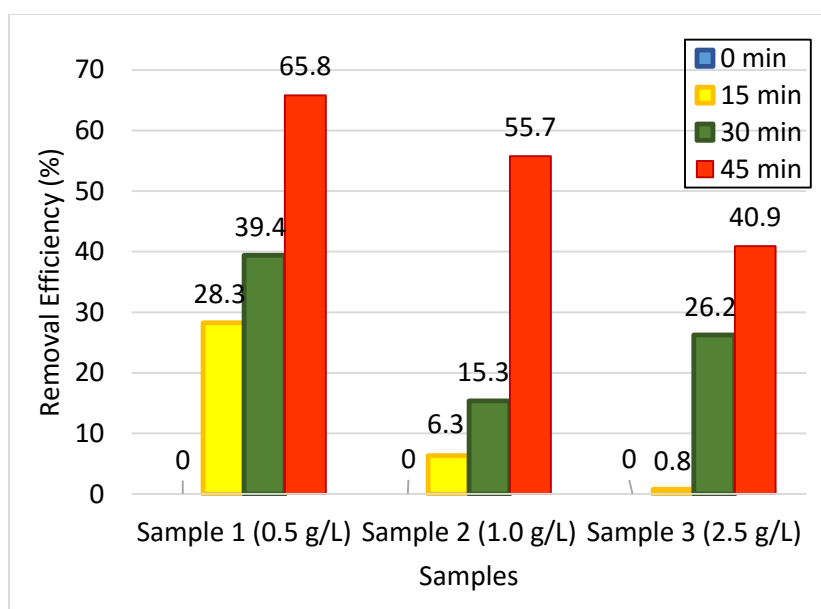


Figure 8. Removal efficiency of Organic matter in water.

It is observed that removal efficiency for organic matter in water was increasing with longer treatment time. Efficiency until 45 minutes for sample 1 achieved 65.8%, for sample 2 achieved 55.7% and for sample 3 achieved 40.9%.

4. Conclusions

- Regarding the chemical oxygen demand, in samples S1T3 (0.5 g/L, 45 minutes), S2T3 (1 g / L, 45 minutes) and M3T3 (2.5 g / L, 45 minutes) were reduced 76.9%, 56.3% and 68.6% respectively.
- Regarding organic material, in the samples S1T3 (0.5 g / L, 45 minutes), S2T3 (1 g / L, 45 minutes) and S3T3 (2.5 g / L, 45 minutes) were reduced 65.8%, 55.7% and 40.9% respectively.
- With regard to turbidity, in the sample S1T3 (0.5 g / L, 45 minutes) and S2T3 (1 g / L, 45 minutes), it was possible to reduce by 19.35% and 54.10% respectively.

- With respect to turbidity, a large increase in transparency was observed in the liquid after treatment with air micro-nanobubbles in sample S3T3 (2.5 g / L, 45 minutes) and it was possible to reduce it by 78.63%.
- After the treatment, the pH became neutral, since initial average values of 5.16, 5.47 and 5.97 were obtained, after treatment with air micro-nanobubbles the pH became neutral, obtaining pH values between 7 and 7.14.
- It is concluded that the use of air micro-nanobubbles is effective in the reduction of COD and organic material.

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