

Application of air nanobubbles in washing sewage of a Soft drink bottling plant

[Aplicación de nanoburbujas de aire en aguas residuales de lavado de una Embotelladora de Bebidas Carbonatadas]

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Resumen

El presente trabajo tuvo como objetivo general aplicar nanoburbujas de aire en aguas residuales de lavado de una Embotelladora de Bebidas Carbonatadas. La metodología utilizada fue pre experimental y de tipo aplicada. Se aplicaron las nanoburbujas de aire en las 3 muestras de 20 litros de agua residual de lavado de una Embotelladora de Bebidas Gaseosas, de las cuales se extrajeron 2 muestras: una a los 45 minutos y otra a los 90 minutos después de haber comenzado el tratamiento. Los resultados demostraron que las nanoburbujas redujeron la concentración de: conductividad en un 8.4% (de 2500 mS/cm a 2290 mS/cm), turbidez en un 71,97% (de 152 NTU a 42.6 NTU), DBO₅ en un 99.89% (de 1892.7 mg/L a 1.9 mg/L) y DQO en un 99.13% (de 3681 mg/L a 32 mg/L).

Palabras clave: Nanoburbujas, DBO₅, DQO, agua residual de lavado

Abstract

The research's purpose was to apply air nanobubbles in washing sewage of a soft drink bottling plant. The methodology used was pre-experimental and applied. The air nanobubbles were applied in the 3 samples of 20 liters of washing sewage of a Soft drink bottling plant, from which 2 samples were extracted: one at 45 minutes and another at 90 minutes after starting treatment. The results showed that air nanobubbles reduced the concentration of: conductivity by 8.4% (from 2500 mS/cm to 2290 mS/cm), turbidity by 71.97% (from 152 NTU to 42.6 NTU), BOD₅ by 99.89% (from 1892.7 mg/L to 1.9 mg/L) and COD in 99.13% (from 3681 mg/L to 32 mg/L).

Keywords: Nanobubbles, BOD₅, COD, washing sewage

1. Introduction

Water is a vital and fundamental element for the life development and is intended for all types of activity (consumption, domestic use or industrial use). This element allows the creation of new products that give us satisfaction and pleasure on the palate, such as soft drinks.

The beverage industry Wastewater may include wastes of wasted syrup and drink, bottle wash water, detergents and caustic products. These pollutants contain organic and inorganic substances described by the biochemical oxygen demand (BOD₅) and the chemical oxygen demand (COD) (Boguniewicz-Zabłocka et al, 2017).

According to OEFA (2014) in Peru, about 2,127,946 m³ per day of wastewater is generated, which is discharged to the sewerage network of the Entities that provide Sanitation services, where only 32% receive treatment. While in Lima discharged wastewater generates a volume of 1 202 286 m³ per day and only 20.5% are treated.

The research found shows the application of various wastewater treatment techniques in: activated sewage sludge (Alvarado y Gonzalez, 2016), marine waters (Abate and Valverde, 2017), river waters (Reyes and Valverde, 2017; Salguero and Valverde, 2017), hospital wastewater (Menéndez and Valverde, 2017), sanguaza (Ventura and Valverde, 2017), pharmaceutical wastewater (Mendez and Valverde, 2017), mining effluent (Vicente and Valverde, 2017), industrial wastewater (Leyva and Valverde, 2018; Valenzuela and Valverde, 2018).

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).

2. Materials and Methods

The residual water contained in the collecting tank of the Soft drink bottling plant has a volume of 280 m^3 . The sample used for the treatment with air nanobubbles was 0.02 m^3 (equivalent to 20 liters). The following stages were followed:

Stage 1. Analysis of the initial sample

For the analysis of the initial effluent sample, 1600 mL was extracted. of the wastewater collection tank before applying the nanobubble treatment to analyze the initial concentrations of the parameters of Electrical Conductivity, Turbidity, BOD_5 and COD, temperature and pH. The treatment was evaluated in two stages (45 min and 90 min) in each water sample to determine the reduction of the parameters. See figure 1.



Figure 1. Initial simple in collecting tank of the Soft drink bottling plant

Stage 2. Treatment with air nanobubbles

The sample previously extracted from the sewage collection tank of the Soft drink bottling plant was entered into the nanobubble generator, as shown in Figure 2.



Figure 2. Entering wastewater to the nanobubble generator

The nanobubble generating equipment was used with the authorization of Dr. Jhonny Valverde's patent. Using in the treatment an air compressor at a pressure of approximately 80 PSI (Pound Squared Inch) for the generation of micro-nanobubbles.

In addition, the amount of nanobubbles and their average diameter was determined with the DigitalCam software. See table 1.

Table 1. Number of nanobubbles and average sample diameter

Sample	Amount	Average Diameter (nm)
M1-45	46	162.61
M2-45	76	171.32
M3-45	63	166.35
M1-90	74	321.35
M2-90	93	295.70
M3-90	84	339.05

Stage 3. Analysis of the final sample

The final concentrations of the parameters of Electrical Conductivity, Turbidity, BOD₅ and COD, temperature and pH after treatment with air nanobubbles were analyzed

3. Results

The results obtained from the initial samples and the final water samples at 45 minutes and 90 minutes are shown in Table 2.

Table 2. Results of initial samples and final samples of wastewater from Soft drink bottling plant

Sample	Code	Time (min)	pH	Temperature (°C)	Turbidity (NTU)	Conductivity (mS/cm)	BOD ₅ (mg/L)	COD (mg/L)
M1	M1-0	Initial	8.5	26	216	2410	2133	3514
	M1-45	45	8	25	87.3	2270	1042	1821
	M1-90	90	7.5	26	64	2320	6.3	102
M2	M2-0	Initial	8.5	25	180.7	2500	2136	3681
	M2-45	45	8	25	90	2360	1061.4	1803
	M2-90	90	7	26	51	2290	4.4	32
M3	M3-0	Initial	9	24	152	2370	1593	3296
	M3-45	45	8.5	24	85	2240	784	1618
	M3-90	90	7.5	25	42.6	2180	1.9	48.2

As can be seen in Table 2, the pH of initial sample 1 was 8.5 (M1-0) and decreased to 7.5 (M1-90), the pH of initial sample 2 was 8.5 (M2-0) and decreased to 7.0 (M2-90) and with pH of initial sample 3 was 9.0 (M3-0) and decreased to 7.5 (M3-90).

The turbidity of initial sample 1 was 216 NTU (M1-0) and decreased to 64 NTU (M1-90), the turbidity of initial sample 2 was 180.7 NTU (M2-0) and decreased to 51 (M2-90) and the Turbidity of initial sample 3 was 152 NTU (M3-0) decreased to 42.6 NTU (M3-90).

The electrical conductivity of initial sample 1 was 2410 uS/cm (M1-0) and decreased to 2320 uS/cm (M1-90), the electrical conductivity of initial simple 2 was 2500 uS/cm (M2-0) and decreased to 2290 (M2-90) and the electrical conductivity of initial sample 3 was 2370 uS/cm (M3-0) and decreased to 2180 uS/cm (M3-90).

The BOD₅ of initial sample 1 was 2133 mg/L (M1-0) and decreased to 6.3 mg/L (M1-90), the BOD₅ of initial sample 2 was 1892.7 mg/L (M2-0) and decreased to <2.0 mg/L (M2-90) and the BOD₅ of initial sample 3 was 2276 mg/L (M3-0) and decreased to 4.4 mg/L (M3-90).

The COD of initial sample 1 was 3514 mg O₂/L (M1-0) and decreased to 102 mg O₂/L (M1-90), the COD of initial sample 2 was 3681 mg O₂/L (M2-0) and decreased to 32 mg O₂/L (M2-90) and the COD of initial sample 3 was 3296 mg O₂/L (M3-0) and decreased to 48.2 mg O₂/L (M3-90).

In addition, the efficiency of electrical conductivity (EC), turbidity, BOD₅ and COD of samples at 90 minutes were determined.

- Efficiency of electrical conductivity (EC)

$$Efficiency = \left(1 - \frac{EC. \text{ mS/cm (treatment)}}{EC. \text{ mS/cm (without treatment)}}\right) \times 100$$

$$Effic. M1 = \left(1 - \frac{2320}{2410}\right) \times 100 = 3.73\%$$

$$Effic. M2 = \left(1 - \frac{2290}{2500}\right) \times 100 = 8.4\%$$

$$Effic.M3 = \left(1 - \frac{2180}{2370}\right) \times 100 = 8.01\%$$

- Efficiency of turbidity

$$Efficiency = \left(1 - \frac{\text{Turbidity (treatment)}}{\text{Turbidity (without treatment)}}\right) \times 100$$

$$Effic.M1 = \left(1 - \frac{64}{216}\right) \times 100 = 70.37\%$$

$$Effic.M2 = \left(1 - \frac{51}{180.7}\right) \times 100 = 71.77\%$$

$$Effic.M3 = \left(1 - \frac{42.6}{152}\right) \times 100 = 71.97\%$$

- Efficiency of BOD₅

$$Efficiency = \left(1 - \frac{BOD_5 \text{ mg/L (treatment)}}{BOD_5 \text{ mg/L (without treatment)}}\right) \times 100$$

$$Effic.M1 = \left(1 - \frac{6.3}{2133}\right) \times 100 = 99.7\%$$

$$Effic.M2 = \left(1 - \frac{1.9}{1892.7}\right) \times 100 = 99.89\%$$

$$Effic.M3 = \left(1 - \frac{4.4}{2276}\right) \times 100 = 99.8\%$$

- Efficiency of COD

$$Efficiency = \left(1 - \frac{COD \text{ mg/L (treatment)}}{COD \text{ mg/L (without treatment)}}\right) \times 100$$

$$Effic.M1 = \left(1 - \frac{102}{3514}\right) \times 100 = 97.09\%$$

$$Effic.M2 = \left(1 - \frac{32}{3681}\right) \times 100 = 99.13\%$$

$$Effic.M3 = \left(1 - \frac{48.2}{3296}\right) \times 100 = 98.53\%$$

In summary, the parameter efficiencies of samples treated with air nanobubbles are shown in the following table.

Table 3. Parameter efficiencies of samples treated with air nanobubbles

Sample	Efficiency (%)			
	EC	Turbidity	BOD ₅	COD
M1-90	3.73	70.37	99.7	97.09
M2-90	8.4	71.77	99.89	99.13
M3-90	8.01	71.97	99.8	98.53

Sample M1 indicates a reduction of 99.7% BOD₅, sample M2 indicates a reduction of 99.89% BOD₅; and the sample M3 indicates a 99.8% reduction BOD₅. Therefore, the one with the highest percentage reduction in BOD₅ concentration was M2-90 with 99.89%.

Sample M1 indicates a 97.09% COD reduction, sample M2 indicates a 99.13% COD reduction; and the M3 sample indicates a 98.53% COD reduction. From the results observed, it was determined that M2-90 had the greatest reduction in COD concentration of 99.13%.

4. Conclusions

From the results obtained in the present investigation, the following conclusion was reached:

- The application of air nanobubbles allows the reduction of the parameters of pH, conductivity, turbidity, BOD₅ and COD, of which the highest removal percentages are shown in the chemical parameters, BOD₅ and COD. In addition, it should be noted that the pH, temperature, BOD₅ and COD parameters manage to comply with the Maximum Admissible Values, which allow reuse of treated water in sanitary sewer systems.
- The physical parameters of the wastewater reduced their percentage of electrical conductivity in the M2-90 sample by 8.4% (from 2500 mS/cm to 2290 mS/cm), while the turbidity was reduced in the M3-90 sample by 71.97% (from 152 NTU to 42.6 NTU).
- Chemical parameters significantly reduced at 90 minutes, BOD₅ in sample M2-90 reduced 99.89% (from 1892.7 mg/L to 1.9 mg/L), while COD reduced 99.13% (from 3681 mg/L at 32 mg/L).

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