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Evaluation of nanobubble technology for the reduction of suspended solids and turbidity in Lake Amatitlán, Guatemala

Summary

Lake Amatitlán in Guatemala is in accelerated process of contamination and artificial eutrophication, having a high amount of suspended solids, these cause the appearance of the water to be turbulent. The purpose of the research was to evaluate the ability of oxygen nanobubble technology to minimize all particulate matter and reduce turbulence. The investigation consisted of taking a sample of 33 m^3 of water with a high organic load and cyanobacteria, Microcystis aeruginosa. Oxygen nanobubble was applied for eight days operating two hours and 45 minutes per day, making a total of 19 hours. Six samples were obtained, the first was the control sample. The results obtained were favorable with a recorded reduction of suspended solids from 73.39% to 64.05%. The final results were compared with quality standards of oligotrophic algos from Mexico and Peru.

Keywords: suspended solids, reduction, eutrophication, nanobubble, water turbidity

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Introduction

The effects of the accelerated contamination of the waters of Lake Amatitlán are numerous and visible. High levels of total suspended solids can affect turbidity, increase water temperature, and decrease dissolved oxygen (DO) levels. This can cause the water to heat up rapidly because the suspended particles absorb more heat and deplete oxygen, which can negatively affect aquatic organisms and aquatic life. The lake is located in the department of Guatemala. According to the latest study carried out, liquid discharges exceed 22 million cubic meters and more than 500,000 tons of solid sediments per year.

The urban and industrial growth of Guatemala City and the municipalities of Mixco, Villa Nueva, San Miguel Petapa, Villa Canales, Amatitlán and part of Santa Catarina Pinula, has caused the eutrophication of Lake Amatitlán and a high content of suspended solids, enriching this body of water with pollutants such as phosphorus, nitrogen and organic matter, mainly. These cities do not have the minimum treatment of wastewater or domestic solid waste. Therefore, domestic wastewater contributes 86% of the surface water that enters the lake, and industrial water, which constitutes 14%, is initially discharged into streams, rivers, streams, and the ground without any treatment.[1]

The three impacts that the lake suffers from constantly receiving discharges are: chemical contamination, the proliferation of pathogenic agents for humans and other species, the eutrophication of the waters,[2] and therefore the accumulation of solids in suspension.

The purpose of the research was to evaluate the capacity of the oxygen nanobubble technology to reduce percentages of suspended solids and turbidity parameters, which show the absence of treatment of ordinary industrial and residual water.

Materials and methods

Description of the problem

Lake Amatitlán must be considered within the national geographic framework since it is close to Guatemala City and exerts great influence on the María Linda river basin. This territory covers 384 km² where seven municipalities are located: Guatemala, Mixco, Villa Nueva, Amatitlán, Villa Canales, Santa Catarina Pinula and San Miguel Petapa. This zone represents 73% of the industry at the national level, where only 4% have an industrial wastewater and solid waste treatment system, many of which are toxic, such as: chrome, lead, zinc, oils and dyes. In addition, 18 coffee mills and four slaughterhouses that do not have an adequate system for waste disposal are identified. For its part, the Villa Lobos River, the main tributary of the lake, it drags around 500,000 tons of sediment, which means that an average of 0.70 meters of lake depth is lost annually. Wastewater treatment plants do not work permanently, due to lack of laws. Some treatment plants that were built are not in operation. Those that were put into operation have deteriorated due to lack of maintenance. Some were designed to serve a smaller population than the current one. Very few plants operate at regular capacity and all this contaminated water is received by the Amatitlán lake, having as an effect an accumulation of suspended solids and consequently a large amount of turbidity, this has caused an accelerated development of cyanobacteria, which can be observed below (Figure 1) which means that an average of 0.70 meters of lake depth is lost annually. Wastewater treatment plants do not work permanently, due to lack of laws. Some treatment plants that were built are not in operation. Those that were put into operation have deteriorated due to lack of maintenance. Some were designed to serve a smaller population than the current one. Very few plants operate at regular capacity and all this contaminated water is received by the Amatitlán Lake, having as an effect an accumulation of suspended solids and consequently a large amount of turbidity, this has caused an accelerated development of cyanobacteria, which can be observed below (Figure 1). Which means that an average of 0.70 meters of lake depth is lost annually. Wastewater treatment plants do not work permanently, due to lack of laws. Some treatment plants that were built are not in operation. Those that were put into operation have deteriorated due to lack of maintenance. Some were designed to serve a smaller population than the current one. Very few plants operate at regular capacity and all this contaminated water is received by the Amatitlán Lake, having as an effect an accumulation of suspended solids and consequently a large amount of turbidity, this has caused an accelerated development of cyanobacteria, which can be observed below (Figure 1). Wastewater treatment plants do not work permanently, due to lack of laws. Some treatment plants that were built are not in operation. Those that were put into operation have deteriorated due to lack of maintenance. Some were designed to serve a smaller population than the current one. Very few plants operate at regular capacity and all this contaminated water is received by the Amatitlán Lake, having as an effect an accumulation of suspended solids and consequently a large amount of turbidity, this has caused an accelerated development of cyanobacteria, which can be observed below (Figure 1). Wastewater treatment plants do not work permanently, due to lack of laws. Some treatment plants that were built are not in operation. Those that were put into operation have deteriorated due to lack of maintenance. Some were designed to serve a smaller population than the current one. Very few plants operate at regular capacity and all this contaminated water is received by the Amatitlán Lake, having as an effect an accumulation of suspended solids and consequently a large amount of turbidity, this has caused an accelerated development of cyanobacteria, which can be observed below (Figure 1). Those that were put into operation have deteriorated due to lack of maintenance. Some were designed to serve a smaller population than the current one. Very few plants operate at regular capacity and all this contaminated water is received by the Amatitlán Lake, having as an effect an accumulation of suspended solids and consequently a large amount of turbidity, this has caused an accelerated development of cyanobacteria, which can be observed below (Figure 1). Those that were put into operation have deteriorated due to lack of maintenance. Some were designed to serve a smaller population than the current one. Very few plants operate at regular capacity and all this contaminated water is received by the Amatitlán Lake, having as an effect an accumulation of suspended solids and consequently a large amount of turbidity, this has caused an accelerated development of cyanobacteria, which can be observed below (Figure 1).

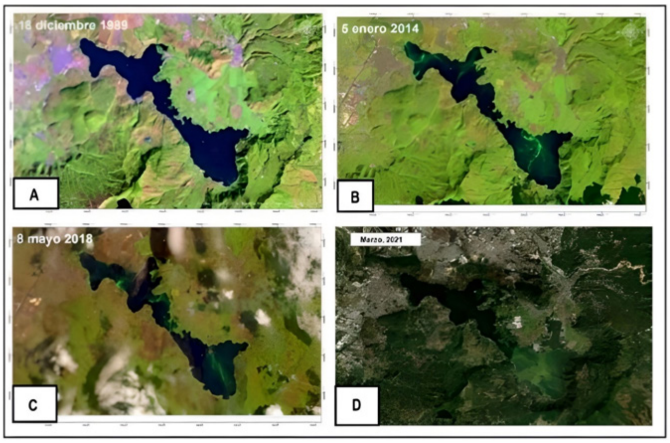

Figure 1 A) 1989, B) 2014, C) 2018 and D) 2021.

It can be seen that from 2014 in the southeast and northwest part of the lake an accumulation of organic matter began, contributing to the development of algae, by 2018, four years later, the accumulation of algae was more visible on the shores and northeast part. , finally by the year 2021, in the southeast part the accumulation of algae is notorious, covering more than 30% of the total lake.

Pollution tributaries

Lake Amatitlán has only one tributary: the Villalobos River. This in turn has several tributaries that come from San Lucas and México (to the Northwest) and from Puerta Parada and Carretera to El Salvador (East) (Figure 2).

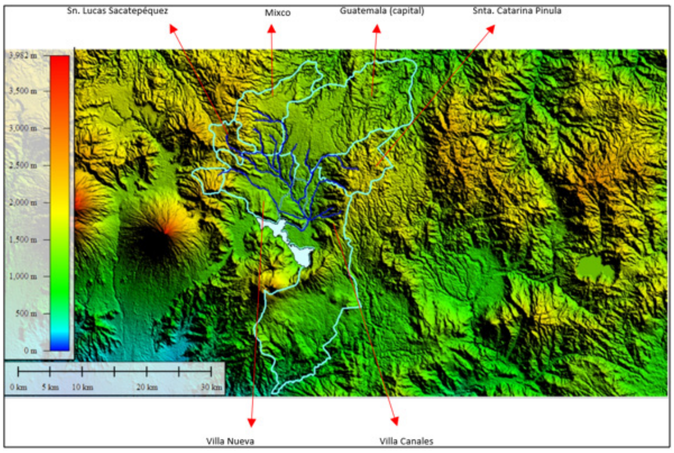

Figure 2 Rivers and municipalities that connect with the Villalobos river.

According to the previous image generated by the global mapper software, all these tributaries flow into the lake. The image above shows all the solid waste carried by the rivers of each municipality, not only plastics and cans, but wastewater with a large amount of solids in suspension, as well as liquid waste responsible for the great turbidity of the lake. Amatitlán. According to the National Life Survey,[3] only 70% of urban households and 30% of rural households have a solid waste collection service. And only 4% of the municipalities treat their water. This means that despite the fact that they have a drainage network, the municipalities discharge raw and untreated wastewater into the ecosystem.

Research description

Nanobubbles are one of the smallest bubbles known, approximately 2,500 times smaller than a grain of salt, that is, less than 200 nanometers (nm) in diameter, which means they remain in water for a long time, just as well. In this way, the size increases the internal pressure of the nanobubble, causing an electrostatic field to be generated around the periphery, attracting all polluting material found in the body of water, causing it to release free radicals when it collapses, having as a result a process of oxidation and degradation.

The present investigation was based on an experimental approach, that is, on a laboratory scale. Statistical data were used to observe and determine the behavior trend of each of the parameters evaluated.[4] The technique of data collection with censuses and continuous data recording statistics was used. Based on the results obtained, the correlation coefficient formula was applied to quantify the intensity of the linear relationship between each variable with the sample taken and processed in the laboratory. Finally, the trend analysis graph was developed, where the samples can be seen in comparison with time and the propensity of each parameter analyzed.

For the generation of nanobubbles, equipment from the company Kran, model K200, was used with a flow rate of 200L/m. The water samples were analyzed in the laboratory of the government entity in charge of the management and recovery of Lake Amatitlán. The results were compared with the Latin American quality standards (Mexico and Peru) for rivers and lakes.

The evaluation of the nanobubble technology was carried out in a 33 m^3 pool, which was filled with a water sample with a high organic load that included cyanobacteria (Microcystis aeruginosa).

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Results and discussion

Initial parameters of the water sample

The results obtained from the control sample obtained are reflected in Table 1.

Table 1 Results of the control sample

Parameters	Unit	Results
Suspended Solids	mg/L	203
Turbidity	mg/L	306

On the other hand, there are parameters that influence and indicate the level of water quality, of which three were analyzed: pH, dissolved oxygen and temperature. These parameters were not studied directly, but they play a very important role so that life develops in oligotrophic lakes (Table 2).

Table 2 Total treatment results

Parameters	Unit	Results
pH	---	9.48
Dissolved oxygen	mg/L	10.4
Temperature	----	27.5

Application of oxygen nanobubbles

The treatment lasted eight days operating two hours and 45 minutes per day, making a total of 19 hours, six samples were taken to carry out the respective laboratory analysis, the parameters to be analyzed, solid suspension and turbidity. Obtaining the following results in Table 3.

Table 3 Control of results obtained during the treatment with oxygen nanobubbles

Parameters	Unit	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Suspended solids	mg/L	203	82	66	82	72	54
Turbidity	mg/L	306	133	122	169	136	110
pH	----	9.48	9.81	9.62	9.33	9.47	8.39
Temperature	Centigrade	27.5	27	26.8	26.2	26.9	25.5
Dissolved Oxygen	mg/L	10.4	27.2	23.5	27.3	17.14	16.1

Sample one has no intervention (control sample). Sample number two represents the first laboratory result, it was obtained after 24 hours of activation of the advanced treatment system with two hours and 45 minutes of continuous application of oxygen nanobubbles, the rest of the day that nanobubble was not applied, which is 21 hours and 55 minutes, the oxygen nanobubble that was applied during the activation time of the equipment, the nanobubble concentrates on carrying out the oxidation and degradation process of the analyzed sample. This same process was carried out in the other samples.

As can be seen in the previous table, Table 3, the suspended solids and turbidity decrease significantly. The suspended solids, which have a starting point of 203mg/L, are reduced to 54mg/L, losing a total of 149mg/L in six days, equivalent to 14 hours of injection of nanobubbles. On the other hand, turbidity loses a total of 196mg/L. This shows that the nanobubble decreases the analyzed parameters.

In relation to the influential and indicative parameters (pH, temperature and dissolved oxygen) there was a reduction in pH of 11.49%, while for temperature this parameter is not measured because its behavior depends on atmospheric conditions. However, this parameter must be monitored because if it increases, the oxygen applied from the nanobubble will volatilize, thus decreasing the amount and availability of oxygen (Figure 3).

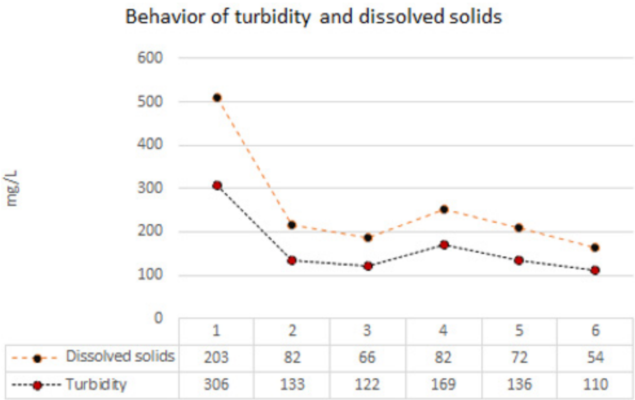

Figure 3 Behavior of the main parameters analyzed.

Turbidity was reduced by 64.05%, presenting a reduction of more than 50% with respect to the control sample. It can be seen how the nanobubble managed to reduce this parameter in just 24 hours. This phenomenon occurs due to the ability of the nanobubble to concentrate a large amount of electrical charge throughout its periphery. When the nanobubble collapses, it releases free radicals that solidify everything that is attached to it (electrostatic process), it is completely removed. The residence of the nanobubble in the water depends on the atmospheric climatic conditions, that is, if there are high temperatures, the nanobubble collapses quickly due to the volatilization process, while if the temperature is low, the residence of the nanobubble will be greater (Figure 4).

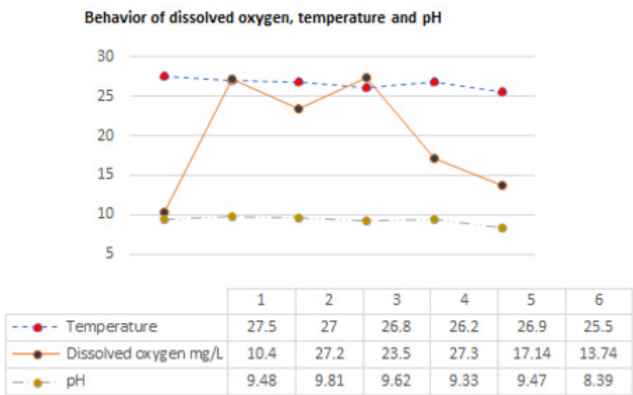

Figure 4 Behavior of dissolved oxygen, temperature and pH.

In relation to the dissolved oxygen, it started with 10.4mg/L with a maximum peak of 27.3 g/L, with respect to the samples where it decreases, it is because a large amount of oxygen was applied, having a large amount both in percentage and in mg/L of this bacterium takes advantage of the availability of oxygen to feed and then degrade itself. This process can be observed in the decreasing peaks. Finally, in the last two samples there is a decomposition, this is the optimal point of application of the nanobubble, that is, if more oxygen is applied, the bacteria that help the decomposition process, on the other hand, the relationship with the temperature, at the moment that there is an

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increase in temperature, the oxygen decays, this principle is due to volatilization.

Regarding the pH, it started at 9.48 and ended at 8.39, in the case of a liquid like water, the pH is a measure of the activity of the potential of hydrogen ions, that is, positive electrical charges, while the nanobubble has cations. In its periphery, negative charge, this generates an electrostatic process causing this parameter to gradually decrease. Maintaining an alkalinity that supports aquatic life.

Finally, in relation to temperature, it is a parameter that cannot be controlled, but it does affect the reproduction process of cyanobacteria (the higher the temperature, the greater the reproduction), therefore it is also very important. Depending on the stability of the nanobubble in the water, at higher temperatures, the internal pressure drops and causes it to collapse much faster; at lower temperatures, the nanobubble resides much longer.

Reduction percentage

According to the results obtained, Table 4 is presented, where the percentage reduction of each of the parameters analyzed is reflected.

Table 4 Percentages of reduction of each of the parameters analyzed

Parameters	Unit	Percentage reduction
Suspended solids	mg/L	73.39%
Turbidity	mg/L	64.05%
pH	----	11.49%

Considering the operating time of the system, the reduction of each of the analyzed parameters is notorious and efficient. Regarding the solids in suspension, 73.39% and turbidity were reduced by 64.05%, which confirms that the technology used is effective in reducing suspended solids and reducing the turbidity of the water, with the consequence of improving the water quality with the increase in flora development inside the lake from the capture of natural light so that photosynthesis can be generated, at the same time maintaining the oxygen balance in the aquatic environment.

Comparison of results obtained

The data obtained in the research work were compared with the official Mexican standards[5] and Peruvian national protocol.[6] This is because in Guatemala there is no legislation that stipulates the parameters for the protection of aquatic life or oligotrophic lakes (Table 5).

Table 5 Comparison of results

Referent parameters			Results obtained			
Parameters	Unit	Monthly average permissible maximum limit	Parameters	Unit	Initial registration	Final record
Suspended solids	mg/L	40	suspended solids	mg/L	203	54
pH	---	6.5 – 8.5	pH	---	9.48	8.39

As can be seen in the table above, the nanobubble manages to reduce most of the parameters, both the main ones and the indicative ones; compared to the maximum allowed according to the standards consulted. In one parameter it is more evident than in another, however, when considering the time and the amount of suspended solids, the objective of reducing the parameters analyzed is achieved, in the case of turbidity, there is no parameter referring to the Latin American level, this is due to because the conditions of Lake Amatitlán are particular, especially in its depth. This makes nanobubble technology a plausible tool for the recovery of oligotrophic lakes.

Behavior trend

The behavior trend of the main parameters reflects the following dispersion diagram (Figure 5).

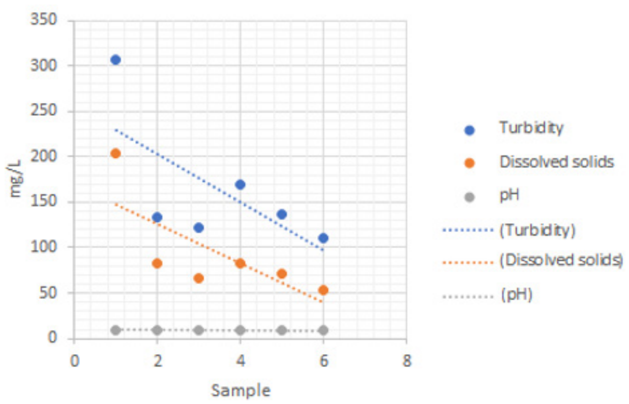

Figure 5 Behavior trend of analyzed parameters.

As can be seen, for solids in suspension as for turbidity the tendency is to decrease, these parameters are closely related, the correlation coefficient for turbidity is -0.9868611, and for solids in suspension it is -0.9868611. The pH has an insignificant tendency to decrease, in the parameter comparison table it was reduced until reaching an acceptable value according to the reference, the correlation coefficient of this is -0.6119881.

Conclusion

The nanobubble technology reduced the suspended solids and turbidity parameter by more than 50% in a short time. According to the regulations of the Latin American countries (Mexico and Peru) the maximum permissible limits, monthly average, for oligotrophic rivers and lakes are: Suspended solids must be 40mg/L and there is no reference for Turbidity, the results obtained were 54mg/L, respectively. This demonstrates nanobubble technology can be effective in reducing pollutant load of water bodies. On the other hand, the pH was lowered to an acceptable level at which aquatic life is allowed.

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None.

Conflicts of interest

The author declared that there is no conflict of interest.

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