Desalination and Water Treatment
www.deswater.com
doi:10.5004/dwt.2019.24389

164 (2019) 98–101
October

Generation and characterization of nanobubbles by ionization method for wastewater treatment

C. Rameshkumar[a], G. Senthilkumar[b,*], R. Subalakshmi[c], Risa Gogoi[d]

[a]*Department of Physics, Sathyabama Institute of Science and Technology, Chennai-600119, Tamilnadu, India, email: cramkum@gmail.com (C. Rameshkumar)*
[b]*Department of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai-600119, Tamilnadu, India, email: tosenthilgs79@gmail.com (G. Senthilkumar)*
[c]*Department of Physics, University of Madras, Chennai-600005, Tamilnadu, India, email: ramsubbu19@gmail.com (R. Subalakshmi)*
[d]*Department of Chemical Engineering, Sathyabama Institute of Science and Technology, Chennai-600119, Tamilnadu, India, email: risa.gogoi39@gmail.com (R. Gogoi)*

Received 12 October 2018; Accepted 13 May 2019

ABSTRACT

The water quality improvement is a great concern with the available quality of contaminated water at various places. On the off chance that letting out the utilized low quality water on the ground without appropriate treatment, will ruin the ground and it will have strong impact in ground water quality. Once the groundwater will be spoiled in due course of time and there is no possibility to bring back the original quality of the land. The presently available water treatment methods involve huge cost as the complexity in mechanism followed to treat the water is multifaceted. There is always a new technology is required to treat the water completely or in a partial way. The little quantity of water treated in laboratory way which is to be brought into proper system and clean the water in huge amount. The cost of this system is very low compare with the other available system and it is very easy to handle. This present experimental investigation is indented to examine the influence of nanobubbles (NBs) in wastewater or treatment. The generation of NBs is made by ionization method. The size of NBs has been measured by atomic force microscopy (AFM). The NBs are generated inside the tap water, pond water, domestic wastewater and industrial wastewater individually for testing of the improvement in water quality is the innovative concept attempted in the research. In this paper the average decrease in total suspended solids (TSS) of about 30% and 50 % increase in dissolved oxygen (DO) further 90% decrease in total dissolved solids (TDS) with the influence of NBs in the chosen samples are discussed with the test results.

Keywords: Nanobubbles; Water treatment; Atomic force microscopy; Ionization

1. Introduction

Nanobubbles (NBs) are gas filled cavities in the order of 100–800 nm in diameter [1]. The water nanobubbles have attracted increasing attention in recent years due to their smaller size and the associated stability [2]. From the different latest literatures it was depicted that compared with micro bubbles, nanobubbles retain their existence for months together without bursting out [3,7]. Nanobubbles are also called as surface nanobubbles because they were able to be stable on the surface [4,5]. Nanobubbles are the only bubbles which are stable for significant periods in suspension, in which larger or smaller bubbles continuously disappearing rapidly from aqueous suspensions unless stabilized with surface-active agents [6,9]. Nanobubbles have slow dissolution rate, whereas micro bubbles (MBs) gradually decrease in size and collapse due to long stagnation and dissolution of interior gases into the surrounding water [10,11]. Nanobubbles are dynamically stable at surface which was revealed by atomic force microscopy (AFM) investigation [10,12].

*Corresponding author.

Nanobubbles have large contact angle and high surface tension [13]. The existence of nanobubbles at the interface between hydrophobic solids and water has been revealed, it has been found that the interface of NBs consist of hydrogen bonds which cannot be broken easily which helps NBs to reduce diffusivity that helps to maintain adequate kinetic balance against high pressure. In a bubble, the diameter is 1 μm at 298 K temperature. The internal pressure is measured and it is be 390 kPa which is almost four times more than that of atmospheric pressure. This high pressure leads at the final stage of the MBs collapse. The four case studies have been investigated in this paper, which verify the efficiency of nanobubbles/micro bubbles in treating wastewater namely (1) treatment of tap water, (2) treatment of pond water, (3) treatment of domestic wastewater, and (4) treatment of industrial wastewater. The results show that NBs/MBs wastewater treatments achieved large reduction in total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD) etc in the tested sample.

2. Generation of NBs by ionization method

Nanobubbles have been generated by ionization method by the introduction of gas into water at a high shear rate. When an electric current is passed through water, electrolytic decomposition of the water molecules result in the production of oxygen and hydrogen gas. The process occurs rapidly in salt water and noticed to be very slow in pure water because of poor conductivity. This is due to the fact that water has a very limited ability to self-ionize or in other words for two H_2O molecules to become hydronium H_3O+ and hydroxide OH-. The upshot of all of this is that when a small voltage has been applied between a conductive component and a second electrode in a water bath, bubbles of gas instigate to form. If the component is used as the cathode, hydrogen gas is formed on its surface. But if the water is pure, the conductivity is very low and the quantity of gas is mini scule. This means that the bubbles form are only a few nanometers across and in a way too small to see even with a microscope. However, even supposing the bubbles may be invisible, their effects are not in a perfect way. The gas forms directly on to the surface, underneath the contaminants. As the bubble grows, it lifts the surface film and carries the contaminants off into the water when the bubble leaves the surface. If the process is repeated for a few times and it is possible to clean the water in a matter of seconds without the use of chemicals. In survey against other methods, sizes of NBs generated by ionization method are much smaller. These smaller bubbles are harder and withstand against destroying and stay firm for longer interval into the water in an effective way. Nanobubbles, with diameters of 0.1–0.8 μm are observed to appear spontaneously at the interface between a polar solvent (e.g. water) saturated with air and hydrophobic surfaces.

3. Results and discussion

3.1. Measurement of size of NBs

The most appropriate technique for the measurement of size of nanobubbles is AFM. The surface topography

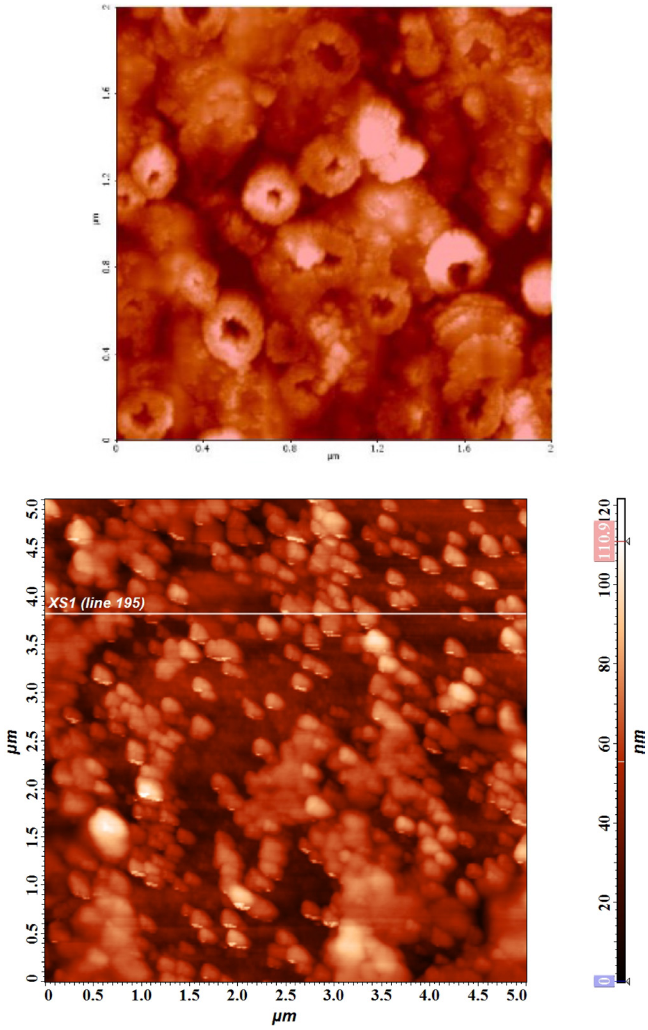

Fig. 1. Surface topography with AFM without and with NBs.

image of NBs revealed from AFM is shown in Fig. 1. AFM results obtained in tapping mode as one of the appropriate imaging modes bear the cost of a topographic guide that takes after a spherical cap in three measurements (3D). As per AFM pictures, for example, demonstrated in Fig. 2, typical surface nanobubbles were of diameters in the range of 100–800 nm.

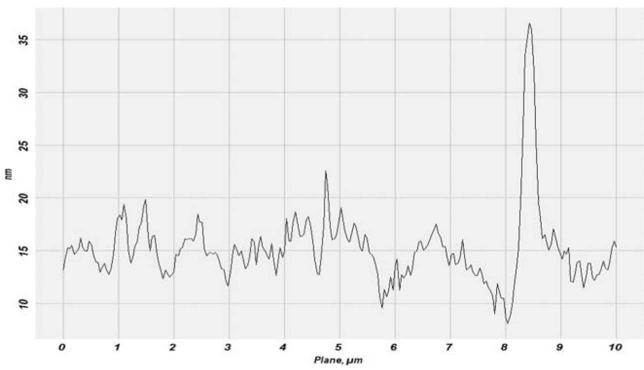

Fig. 2. Contact angle of NBs with the plane of shear.

3.2. NBs for wastewater treatment

Water containing nanobubbles can be utilized as a part of water treatment and as a surface cleaning materials. In recent years, more consideration has been given to the potential uses of the MBs/NBs for water treatment because of their capacity to produce exceptionally receptive free radicals. This broad utilization of reused wastewater requires the improvement of new innovations that are both cost effective and energy efficient. So energy efficient pre-treatment is to lessen the running expense of further treating and increment in quality nature of water to feed further. Wastewater is a forthcoming water source if its quality can be enhanced with the goal that it fulfills the criteria for reuse or transfer into the environment.

3.3 Treatment of tap water

Tap water has been taken directly from the tank in a capacity of two liters for the testing process. The nanobubbles generating system has been embedded in to the tank, which is kept in operation for 2–3 h constantly. After 3 h the operation is stopped, the unwanted sludge, dissolved solids and suspended solids get settled down on the bottom of the tanks. The testing sample has been taken from the top, which is further taken to the lab, for testing the water quality. The tested water parameters, measured are shown for before and after treatment in Table 1. The testing results shows the effect of nanobubbles in water in an excellent positive results. Initially, that is before treatment the BOD, COD, TSS, TDS, nitrate and phosphates composed were more and after treatment the quality of water had improved from the level of bad to good. Before treatment of water, the COD level was 11 mg/l which has shown a decrease to BDL (Below detection limit)/DL (detection limit) of 4 mg/l. In the same process the BOD level to 2 mg/l leads to increasing the oxygen level twice in the tap water after treatment. The complete explanation of this technique has been well explained by comparing before and the after treatment of water by nanobubbles.

3.4. Treatment of pool water

This second case study demonstrates the efficacy of nanobubbles in cleaning and treating pond water. The results are shown in Table 2. Before the treatment of water by nanobubbles, COD level was 121mg/l which has decreased to BDL (below detection limit)/ DL (detection limit) 4 mg/l after the treatment of water by nanobubble. Also the same can be taken for BOD, the decreasing level of BOD level is shows it significantly increases the oxygen level in the pond water after treatment. The accepted clean and safe water quality have been achieved by the nanobubble treatment. From Table 2 it is clear that all the parameters of the raw pond water met and 0.01 mg/l of phosphate. Therefore, the prime objective of this case study is to reduce the content of phosphate level in the pond water. Clean and without any odors are realized in the treatment process.

3.5. Treatment of domestic wastewater

A comparison has been shown with and without NBs for domestic wastewater in Table 3 for different parameters. Before treatment COD level was noticed to be 399 mg/l, has decreased to BDL (below detection limit)/DL (detection limit) (4 mg/l). After treatment of water the BOD value has been decreased and it leads to increase in the oxygen level in the pond water. It is clear that all the parameters of the domestic wastewater met the specifications required for

Table 1
Test report for before and after the presence of nanobubbles in sample no 1 (tap water)

Test parameters	Before (mg/L)	After (mg/L)
Chemical oxygen demand (COD)	11	BDL: (4)
Biochemical oxygen demand (BOD)	3	BDL: (2)
Dissolved oxygen (DO)	3.2	6.4
Total suspended solids (TSS)	13	9
Total dissolved solids	1550	263
Nitrate	25	1.3
Phosphate	4.86	BDL: (0.9)

Table 2
Test report for before and after the presence of nanobubbles in sample no 2 (pond water)

Parameters	Before (mg/L)	After (mg/L)
Chemical oxygen demand (COD)	121	BDL: (4)
Biochemical oxygen demand (BOD)	18	BDL: (2)
Dissolved oxygen (DO)	4.2	6.07
Total suspended solids (TSS)	38	8
Total dissolved solids	1537	242
Nitrate	7	1.4
Phosphate	0.04	BDL: (0.01)

Table 3
Test report for before and after the presence of nanobubbles in sample no 3 (domestic wastewater)

Test parameters	Before (mg/L)	After (mg/L)
Chemical oxygen demand (COD)	399	BDL: (4)
Biochemical oxygen demand (BOD)	105	BDL: (2)
Dissolved oxygen (DO)	BDL: (0.2)	7.4
Total suspended solids (TSS)	300	BDL: (1)
Total dissolved solids	1742	181
Nitrate	4.6	2.2
Phosphate	1.46	BDL: (0.01)

Table 4
Test report for before and after the presence of nanobubbles in sample no 4 (industrial wastewater)

Test parameters	Before (mg/L)	After (mg/L)
Chemical oxygen demand (COD)	4520	124
Biochemical oxygen demand (BOD)	2620	0.17
Total suspended solids (TSS)	1688	16
Total dissolved solids (TDS)	10556	242
Sulphite	264	BDL: (0.01)
Chromium	72.6	BDL: (0.005)
Total suspended solids (TSS)	12244	258

clean and safe water (targeted at 2.2 mg/L of nitrate and 0.01 mg/l of phosphate). Therefore, the prime objective of the case study, to reduce nitrate and phosphate levels in the domestic wastewater, for making it to use level, has been successfully done with decolored and with no odor.

3.6. Treatment of Industrial wastewater

Before treating the water by nanobubble, the BOD, COD, TSS, TDS, Sulphide, chromium and total solids contain was higher. After the treatment water, one can see that the quality of water has been improved from bad to good intensity in quality. By analyzing Table 4, the values of different parameters has been compared before and after the treatment. The TSS value has to be reduced by 97.82% and the decrease in TDS value was 97.71%. From Table 4 it is clear that all the parameters of the Industrial wastewater met the specifications required for a clean and safe water (targeted at 0.005 mg/L of total chromium) and (0.01 mg/l of sulphide) which was (264 mg/l and 72.6 mg/l) before treatment. Therefore, the prime objective of this case study is to decolorize and remove any residual odors has been met, proving the effectiveness of the technique adopted.

4. Conclusions

The application of NBs for wastewater treatment was elaborated in section 4 in detail. It was evident that there was drastic increase in dissolved oxygen in water after treatment in all the case studies. Though the techniques for wastewater treatment were numerous, the NBs were found to be unique, dependable and highly accurate. From the experimental evidence, the following conclusions were made. The DO has increased by 2 times and 1.5 times after treatment of tap water and pond water respectively with NBS. The TSS has reduced by 97.82% and 100 % in industrial wastewater and domestic wastewater with the influence of NBs. The 84.2% decrease in TDS was observed in pond water after NBs treatment.

References

[1] A. Gurung, O. Dahl, K. Jansson, The fundamental phenomena of nanobubbles and their behaviour in wastewater treatment technologies, Geosyst. Eng., 19(3) (2016) 1–10.
[2] C.-W. Yang, Y.-H. Lu, I.-S. Hwang, Imaging surface nanobubbles at graphite–water interfaces with different atomic force microscopy modes, J. Phys.: Condensed Matter, 25(18) (2013).
[3] P. Nasr, H. Sewilam, Investigating fertilizer drawn forward osmosis process for groundwater desalination for irrigation in Egypt, Desal. Water Treat., 57(56) (2016) 26932–26942.
[4] G. Senthilkumar, C. Rameshkumar, M.N.V.S. Nikhil, J.N.R. Kumar, An investigation of nanobubbles in aqueous solutions for various applications, Appl. Nanosci., 8(6) (2018) 1557–1567.
[5] S. Mozaffar, P. Tchoukov, A. Mozaffar, J. Atias, J. Czarnecki, N. Nazemifar, Capillary driven flow in nanochannels - Application to heavy oil rheology studies, Colloids Surfaces A: Physiochem. Eng. Asp., 513 (5) (2017) 178–187.
[6] S. Mozaffari, P. Tchoukov, J. Atias, J. Czarnecki, N. Nazemifard, Effect of asphaltene aggregation on rheological properties of diluted athabasca bitumen, Energy Fuels, 29(9) (2015) 5595–5599.
[7] Z. Zheng, X. Zhang, D. Carbo, C. Clark, C.-A. Nathan, Y. Lvov, Sonication-assisted synthesis of polyelectrolyte-coated curcumin nanoparticles Langmuir, 26(11) (2010) 7679–7681.
[8] Y.M. Lvov, P. Pattekari, X. Zhang, V. Torchilin, Converting poorly soluble materials into stable aqueous nanocolloids, Langmuir, 27(3) (2011) 1212–1217.
[9] P. Pattekari, Z. Zheng, X. Zhang, T. Levchenko, V. Torchilin, Y. Lvov, Top-down and bottom-up approaches in production of aqueous nanocolloids of low solubility drug paclitaxel, Phys. Chem. Chem. Phys., 13(19) (2011) 9014–9019.
[10] A.F. Alghannam Metabolic limitations of performance and fatigue in football, J. Can. Res Updates, 4(2) 65–73.
[11] D. Vergara, C. Bellomo, X. Zhang, V. Vergaro, A. Tinelli, V. Lorusso, R. Rinaldi, Y.M. Lvov, S. Leporatti, M. Maffia, Lapatinib/Paclitaxel polyelectrolyte nanocapsules for overcoming multi drug resistance in ovarian cancer, Nanomedicine, 8(6) 891–899.
[12] V. Vergaro, F. Scarlino, C. Bellomo, R. Rinaldi, D. Vergara, M. Maffia, F. Baldassarre, G. Giannelli, X. Zhang, Y.M. Lvov, S. Leporatti, Drug-loaded polyelectrolyte micro capsules for sustained targeting of cancer cells, Adv Drug Delivery Rev., 63(9) (2011) 847–864.
[13] A.E. Khalifa, D.U. Lawal, Application of response surface and Taguchi optimization techniques to air gap membrane distillation for water desalination—A comparative study, Desal. Water Treat., 57(59) (2016) 28513–28530.