Nano bubble technology in environmental engineering; revolutionization potential and challenges

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Abstract

Global environmental challenges such as depletion and degradation of water resources have increased the demand for water treatment technologies in the present time. Nanobubbles and their applications are widely accepted as a solution to address these challenges. In this study, various fields such as agriculture, aquaculture, drug delivery, and industrial energy systems where the nanobubbles can be used have been discussed. Bubble stability, generation methods as well as various physical and chemical features of nanobubbles have been discussed in the study. The current status of the nanobubble application in the water treatment process has been discussed in the study. From the study, it can be concluded that nanobubble technology has a promising future in water-related applications. The progress in nanobubble technologies needs to be enhanced to take the full benefits of nanobubble technology.

Keywords: Global environmental challenge, nano bubbles, water treatment applciaiton, nano bubble technologies and aquaculture.

1. Introduction

Nanobubbles are found as cavities in the aqueous solution whose diameter is less than 1000 nm. The presence of charge gas or liquid interface in the aqueous solution reduces the internal pressure and surface tension of the nanobubbles defining their unique properties. Over the last two years significant advancement has been seen in nanobubble (NB) technology (Lyu et al. 2019). Novel devices for NB generation are one of the theoretical and technological developments that took place in the field of NB technology. In the year 1994, the concept of Nanobubbles was first proposed to analyze the under-predicted attractive forces found between hydrophobic surfaces present in the water. Nanobubbles are found in the shape of bubbles whose diameter is less than 1000 nm.

For several years the existence of NB has become one of the most common topics for the researchers as classic Laplace Pressure Bubble Catastrophe theory has failed to explain its existence. In the year 2000, the first image of nanobubbles came into existence

with the help of atomic force microscopy. Various studies have been done to understand the generation process and physicochemical surface properties of the Nanobubbles. Nanobubbles are used for biomedical research as well as for drug delivery.

2. Significant/Purpose of the study

Water scarcity, irregular distribution of water as well as production models are some of the common challenges faced by the world related to water resources. Rapid urbanization and industrialization are two major causes of increasing the amount of wastewater. To ensure the sufficient availability of water it is important to recycle the wastewater as well as have a recycling method. Activated sludge is the biological method that is used for the treatment of industrial and domestic water (Lyu wt al. 2019). The cost of energy used in this method is high and produces solid wastes as the consequence therefore nanobubbles technology has become an important topic for the development of water treatment technology to address water scarcity. The purpose of the study is to understand the benefits of nanobubble technology in various fields including medical and others. Nanobubbles technology offers various benefits due to its small size and structure as it effectively improves the quality of the water by enhancing water treatment (Tang et al. 2021).

The productivity in industrial and agricultural applications gets improved due to the presence of nanobubbles in the water. The study helps to understand various methods through which nanobubbles are injected inside the aqueous solution. Nanobubbles possess the properties of a strongly negative surface charge that helps them to get stability in the liquid and allow them to actively participate in the physical, biological as well as chemical interactions. The hyper-efficient gas transfer is delivered after the connection of the bubble surface with the water. The stimulation of nanobubbles makes them destabilize which results in the release of the hydroxyl radical (Wang et al. 2020).

All the contaminants present in the water get destroyed due to the hydroxyl radical. The purpose of the study is to understand the various properties of nanobubbles that make them different from the other bubbles. The nanoscopic natures of the nanobubbles make them different from the large bubbles. Surface charge, stability, oxidation, and neutral buoyancy are some of the major properties of nanobubbles due to their small size. The small size of the nanobubbles makes them provide the most efficient gas transfers as well as allow them to participate in physical, biological, and chemical reactions. In the present time, water population is one of the major challenges faced by the industries and agricultural sector therefore nanobubbles technology helps them to effectively use the water as well as allow them to manage their water quality as well as get water treatment (Wang et al. 2020).

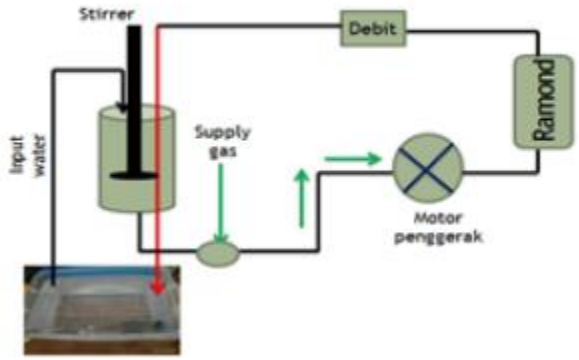

Figure 1: Working scheme of the nanobubble device

(Source: Chen et al. 2021, p. 107051)

The recent advancement in nanobubble production methods are evolving therefore the study helps to understand how the nanobubble properties can solve the different kinds of the problem. In the present world, molar's technology is used by the industries due to its reliability, and efficiency. The beneficial properties of the nanobubbles are still in the progress of research by researchers. The studies signify the advancement in the science of nanobubbles as well as validate the efficacy of nanobubbles (Maharshi and Harifa 2019). In the present time, most businesses use nanobubbles for adding value to their business. The study will help to understand how nanobubbles help in adding value to the different businesses.

3. Objective of the study

Objectives of the study are given below:-

- To understand the effectiveness of the nanobubbles in the various fields.
- To understand the challenges faced in the generation of nanobubbles.
- To determine the various methods for the generation of nanobubbles.
- To analyze the future trends for the growth of nanobubbles applications.

5. Methodology

5.1 Time and place

An instrumentation development center has been chosen in this study to understand the opportunities and challenges of using nanobubbles. The study has been conducted in are pathology laboratory and fishery pond of Indonesia (Zhang et al. 2022). The performance of Luthor (Bubble generator) has been measured by introducing the nanobubbles in the fish tanks. The patented prototype has been used in this study. All the activities in the study have been performed in the container to determine the characteristics and properties of the tool.

Figure 2: Prototype of tutor

(Source: Wang et al. 2021, p.11074)

5.2 Nanobubble Lutor test

BPI LIPI has provided three prototypes that are used for the fish culture. The volume of each water stock is 120 L. Three variations of test tools were found in the nanobubble Luthor test: 1st Lutor vertical, 2nd Lutor horizontal, and 3rd water which is used without Luthor in the air stone. Dissolved oxygen was taken as a parameter for testing (Lei et al. 2020). Particle Image Velocimetry has been used to measure the value bubble size. Biological performance research was done to research the largest value of dissolved oxygen.

5.3Nano bubble experiment design

A randomized design was used for conducting the experiment design and providing three replications and treatments to the fishes. In treatment A 12 fish for 60 l were chosen, In treatment B 30 fishes for 60 LO were chosen and for treatment C 45 fishers were chosen for 60 L. Dissolved oxygen, daily water quality, water, temperature, and ph are the test parameters chosen whereas oxygen consumption level was present in the physiological response parameters (St-Hilaire and Dong 2021). The amount of blood was taken from the fish to measure the oxygen consumption and cholesterol of the fish with a plastic syringe of 1 ml. After preparation of the blood sample, it was poured into the icebox, Clinical method was used to measure the sample. Survival; rate, specific growth rate, absolute rate, and final biomass rate of the fish were measured through the sample.

5.4 Preparation n of Koi fish sample

The fish chosen for the sample study is koi fish whose length was 7.49 +- 0.29 cn and weight was 11.42 +- 1.90 g. Fish. The fish was collected from the river, and raceway ponds. Twice a week the water in the pond was changed to maintain the quality of the water. During the experiment, the aquaculture fishes were provided commercial feed with a high stocking density.

5.5 Statistical analysis

The differences between the parameters during the treatments were performed by ANOVA. A post hoc test was carried out to analyze the characteristics and growth of fishes. IBM SPSS Statistics version and Microsoft Excel were used to perform all the statistical analyses.

7. Data collection techniques

Data collection methods are used from gathering the relevant data for completing the objective of the study. Primary and secondary data collection tools are the two types of data collection methods used in the study based on the nature of the study. The primary data collection method uses primary sources for gathering relevant data such as surveys, observation, and interviews. The secondary data collection method uses secondary sources for gathering the data such as journals, pdfs, and articles (Ramon et al. 2021). In this study, all the relevant data related to the generation of nanobubbles have been collected through a secondary data collection method. The secondary data collection method helps to gather the data that shows the opportunities for the nanobubbles technologies in different areas. By using a secondary data collection method all the methods for generating nanobubbles have been analyzed. Future trends of the nanobubbles have been analyzed through secondary data collection tools.

8. Result of the data tables

Parameter	Nanobubble	Diffuser aerator
Survival rate (%)	90	75
Feed conversion ratio	1.0	1.3
Productivity (Kg.m3)	8.5	4.5
Total harvest (kg)	435	220

Table 1: nanobubbles vs diffuser aerator in raceway pond

(Source: created by author)

Parameter	**Unit**	**Water Container by Lutor**	**Quality Standard**
Dissolved Oxygen	mg.L-1	5.19 +- 0.78	>3
Temperature	uC	27.02 +- 0.42	25-30
TAN	mg.L-1	0.18 +- 0.14	<5
pH	degree	6.31 +- 0.45	6-9
TOM	mg.L-1	3.92 +- 1.59	<10
Nitrite	mg.L-1	0.88 +- 1.59	<0.1

Table 2: Chemical characteristics (water quality) of Luto vertical

(Source: created by author)

Parameters	**A**		**B**		**C**		**Quality Standard**
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	
Oxygen Consumption rate (mg. L-1)	0.18 +-	0.12 +-	0.18+-	0.10	0.18+-	0.10	(DO) = < 2
Cholesterol (mg.dL-1)	112	131.65	112	124	112	135.65	151.6

Table 3: Physiological response parameters

(Source: created by author)

9. Graphical Representation

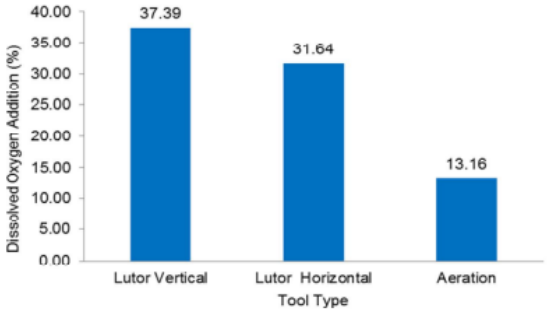

Figure 1: Result of dissolved oxygen

(Source: created by author)

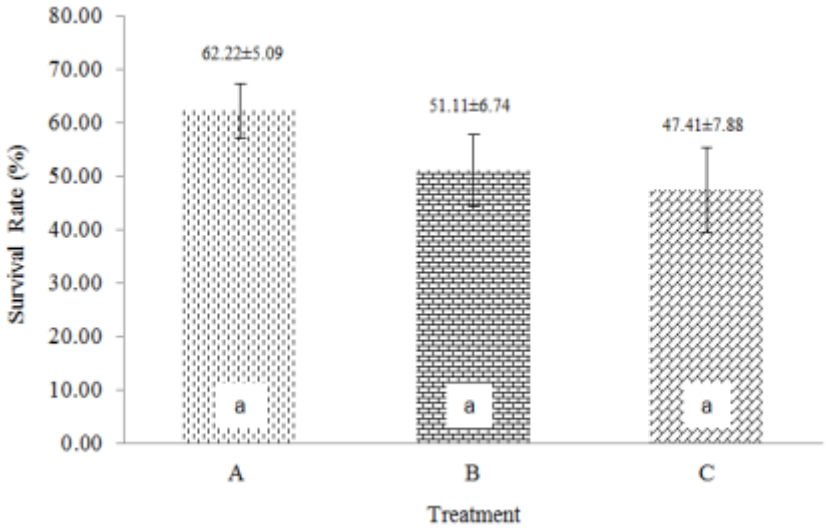

Figure 2: The survival rate of Koi fish with Lutor

(Source: Saputra et al. 2018)

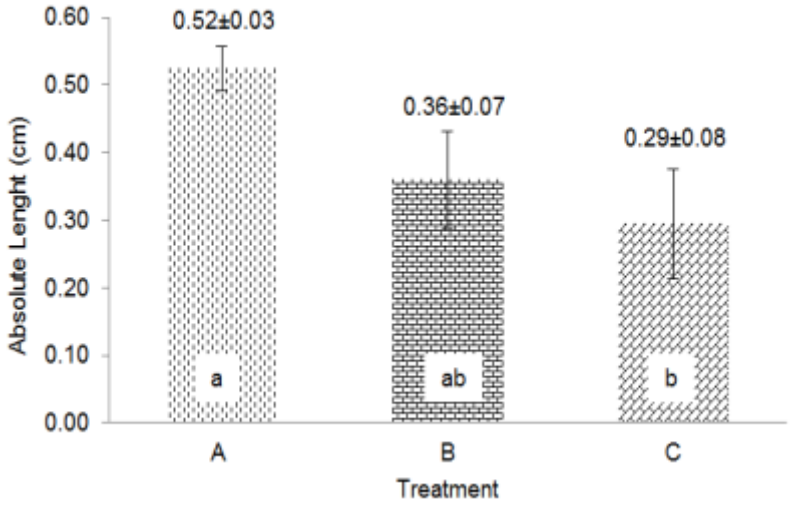

Figure 3: Absolute length of Koi fish with Lutor

(Source: Saputra et al. 2018)

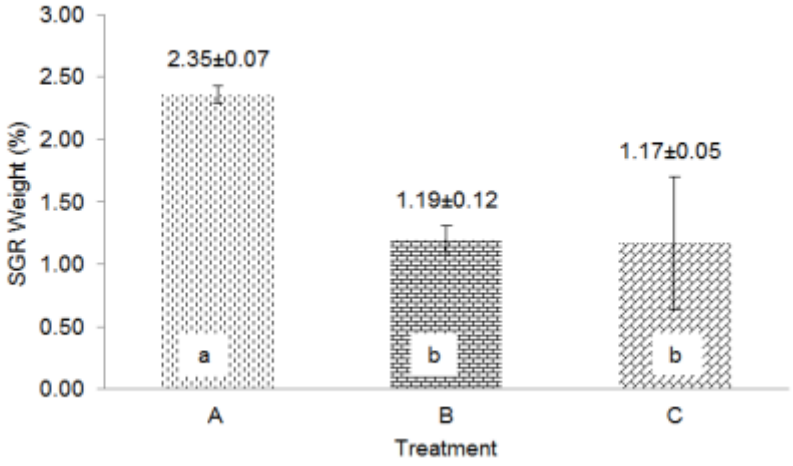

Figure 4: SGR weight of koi fish with Lutor

(Source: Omni-Akuatika 2018, p.29-36)

10. Analysis of the data

Table 1 shows the growth of the shrimp by using nanobubbles in a raceway pond which is situated in Indonesia. From the table it has been cleared that nano bubble generators provide higher growth rates in the production of shrimp indoor raceway ponds. The result found from table 1 shows that dissolved oxygen (DO) is managed by the nanobubble at the optimal range and also affects the growth of the shrimp. The effects of nano bubble generators have been understood through table 1 on the environmental growth. In Indonesia white leg shrimp farming is steadily growing where nanobubbles can effectively manage the dissolved oxygen and improve water quality (Lei et al. 2020).

Nano-sized bubbles are produced by the nanobubble that increases the level of dissolved oxygen in the water. Gas-liquid flow gets combined with the honeycomb structure by the machine for generating high-efficiency nanobubbles. During the cultivation days, the dissolved oxygen is easily managed by the nanobubble generator. Unique characteristics of the nanobubbles improve the level of dissolved oxygen in the ponds. From table 1, positive correlations have been found between shrimp biomass and oxygen consumption rate. In the nanobubble pond, the shrimp has higher energy due to the proper management of dissolved oxygen in the pond (Jhunkeaw et al. 2021).

Physiological response parameters of the fish have been shown in table 3. Figure 3 shows the survival rate of fish. It was found that in treatment A the survival rate of fish was maximum with 62.22 whereas in treatment C the value was a minimum of 47.41. The length of the fish shown in figure 4 and absolute length in treatment A was maximum whereas found lowest in treatment C. As compared to treatment B and C treatment A differs that has been shown in figure 5.

11. Findings of the study and Results

Physical characteristics of nanobubble

PVC was used as material, maximum distance spray by the horizontal bubbles was 150 cm whereas 50 cm was found as 50 cm (Ramon et al. 2021). The formation of the size of nanobubbles is unstable. The magnitude of the pumping power influences the stability of 80% of the bubble.

Chemical characteristics of nanobubble Lutor

The value of water quality was affected by using Lutor in different treatments of the Koi fish density. From table 2, it has been found that among all the parameters nitrate was not matched with the standard for the koi fish aquaculture. Conversion of nitrite to nitrate is quite low by the bacteria as their association with water is difficult, Table 2 has shown the chemical characteristic of Lutor vertically.

Best position of Lutor in water

From the result, it has been found that initial DO treatment was 4.33 mg.L. After 20 minutes of Lutor application the values of the treatments increased. In the Lutor the value of the highest dissolved oxygen was found was 37.39. The physiological response was measured with several parameters such as cholesterol and total oxygen consumption. In the C treatment, the highest value of cholesterol was found which was about 135.67 +- to 30.83 (Zhang et al. 2018). The rate of mortality was highest in treatment A which was 131.67 +- 16.07 mg. dL. In treatment, B mortality rate was low which was about 124.00 +- 11.14 mg. dl. In treatment A , the cholesterol value was maximum which was about 112.00 mg dl. The quality standard for cholesterol in treatment C was found to be 151.7.

In the treatment C cholesterol value was high as many deaths took place due to high nitrite. The process of taking blood samples affects the value of cholesterol. In treatment A the fish density was lowest as well as the mortality rate was also lowest due to which cholesterol value was best. In treatment A the difference was minimum among the final and initial rates of oxygen consumption. The mortality rate of treatment A was lower as compared to treatment B and C (Wang et al, 2020). The need for dissolved oxygen has been increased due to the lower amount of fish density. Energy requirements get decreased due to the low oxygen consumption level that helps in the adjustment of the fish.

12. Discussion

Nanobubbles are small gas bubbles whose size is less than 100 nm that make them different from the other large bubbles. Several arguments have been made on the size of NB and their existence is still under progress. Due to the limitation of radius curvature, NBs cannot exist or are stable. Ultrasonication, electrolysis and hydrodynamic citation mechanism are the various methods through which NB can be generated. The promising futures of nanobubbles have extended their applications in various fields including aquaculture, medical field, and agriculture as well as for domestic use. Nanobubble technology improves the biological as well as the physiological condition of the soil.

Nnaobbuble increases the aerobic microorganisms that help in improving the soil practical structure that is responsible for the growth of the plant. CH4 emission is also reduced by the Nanobubbles that helps in the reduction of constraints present in the water. Nanobubbles are also used in the hydroponics solutions that help in-ceiling and sterilization of irrigation water.

In aquaculture, nanobubbles improve the life of aquatic animal by improving the blood flow. Environmental pressure puts lodge near the sea which is reduced by nanobubbles that helps in improving the decomposition of the organic matter. Nutrient uptake is also improved by nanobubbles that increase the growth of aquatic animals (Fujaya et al. 2020). Ultrasonic imaging is used by a nanobubble that helps in the diagnosis of the tumor in the brain. Malaria is also detected by using nanobubbles. Water reusability is one of the best uses of nanobubbles: it separates oil and carbon which is mixed in the water by using polyelectrolytes with hydrogen. The most common use of the nanobubbles is in the laundry and tableware. Nanobubbles are used in the bathtubs, showers and swimming pools for cleaning dust particles, bacteria, and any chemical residue present in the water.

13. Conclusion

In the present time nanobubbles are considered as a promising technology and their applications are covering diverse areas including agriculture, industry, aquaculture, and the energy sector. In this article, we have discussed the potential of nanobubbles as well as the challenges faced by nanobubbles technology. More attention has been provided to the nanobubbles in recent years due to their size. Nanobubbles have a great future in the upcoming future and the optimization of nanobubbles generators will provide customized nanobubbles generation mechanisms. The practice of nanobubbles technologies has been increased due to its cost-effectiveness as well as providing efficient treatment technology. From the study, it has been concluded the size of the bubble generated through Lutor was unstable which was between 800 nm to 25 nm.

14. Recommendation

- In this study fundamental properties of the nanobubbles such as their stability have not been explained, therefore it is recommended to example the fundamental properties in further study.
- Stability and longevity of nanobubbles have been slightly mentioned in this study therefore it is recommended to study the different properties of nanotubes such as separation and stability of the nanobubbles.
- This study has provided limited information regarding the bubble growth, performance techniques, and size of the bubbles therefore it is recommended to have a deep study on the generation methods of bubbles as well as their automated optimization.
- The application of nanobubbles is limited therefore it is recommended to increase their applications in the various other fields.

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