

EXPERIMENTAL INVESTIGATION ON STABILITY OF NANO BUBBLES

Submitted in partial fulfillment of the requirements for the award of
Bachelor of engineering degree in
Mechanical Engineering.

By

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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MARCH – 2022



SATHYABAMA



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **GANTA SRINIVAS (38150030)**, **GEESALA HARSHITH (38150031)** Who carried out the project entitled **"EXPERIMENTAL INVESTIGATION ON STABILITY OF NANO BUBBLES"** Under my supervision from Nov 2021 to March 2022.

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We **GANTA SRINIVAS (38150030)**, **GEESALA HARSHITH (38150031)** here by declare that the Project Report entitled “**EXPERIMENTAL INVESTIGATION ON STABILITY OF NANO BUBBLES**”, done by me under the guidance of Dr. **G.SENTHIL KUMAR, M.E., Ph.D.** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, CHENNAI** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

DATE: 20-04-2022



PLACE: Chennai

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** for their kind encouragement in doing this project and for completing it successfully .I am grateful to them.

I convey my thanks to **Dr. S. PRAKASH, M.E., Ph.D., Dean, School of Mechanical Engineering** and **Dr. G. ARUN KUMAR, M.E., Ph.D., Head of the Department, Department of Mechanical Engineering** for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. G. SENTHILKUMAR, M.E., Ph.D., Associate Professor, Department of Mechanical Engineering** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of **MECHANICAL ENGINEERING** who were helpful in many ways for the completion of the project.

ABSTRACT

Micro-nano bubbles (MNBs) are very tiny bubbles measured in micrometers and nanometers. A thorough research facility examination was led to analyze bubble size disseminations and zeta possibilities of nano-bubbles, first and foremost with 4 particular gases (test series I), then with various salt fixations, pH levels, and arrangement temperatures (test series II). The NANOTRAC Wave IIQ / Zeta analyzer from Micro MRB is a flexible Dynamic Light Scattering (DLS) analyzer that gives particle size, zeta potential, concentration, and molecular weight information. Thanks to more trustworthy technology, it enables for quicker measurements as well as greater precision and accuracy. All of this was packed into a small DLS analyzer with a ground-breaking fixed optical probe. The typical air pocket size was demonstrated to be subject to the gas' capacity to frame OH-particles at the water/gas interface, and the zeta potential was found to be reliant upon the gas' dissolvability in water. Rises with extensive negative zeta possibilities can shape in arrangements with high pH, low temperatures, and low salt fixations, as indicated by test series II information. In high pH arrangements, nano-bubbles produced were more modest yet more steady. As the salt level increased, the diameter of the bubbles grew larger. The technique for survey and concentrating on particles in fluids known as nano-molecule following examination (NTA) associates the pace of Brownian movement to molecule size. The pace of Brownian movement is connected to molecule size in nano-molecule following examination (NTA), a technique for recognizing and dissecting particles in fluids. The speed of not entirely settled by the thickness and temperature of the fluid; molecule thickness and refractive record have no bearing. The size assignment profile of second particles in liquid suspension with a width of around 10-1000 nanometers may be surveyed using NTA (nm).s These two tests will be carried out, with the findings analysed. Although there are several advantages to generating bubbles, the research allows us to establish a baseline for their effectiveness.

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LIST OF ABBREVIATIONS

ACRONYM	ABBREVIATION
MNB	Micro Nano-Bubbles
DO	Dissolved Oxygen
NB	Nano Bubbles
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
TSS	Total Suspension Solids
TDS	Total Dissolved Solids
HC	Hydro Dynamic Cavitation
DLS	Dynamic Light Scattering
NTA	Nano-particles Tracking Analysis

CHAPTER-1

INTRODUCTION

Water quality determines the long-term viability of all species, including plants, humans, and animals [1]. Nanobubbles are spherical bundles with a diameter of less than 1 micrometre that can be found distributed in a liquid medium or at the solid-liquid boundary. They are delegated strong fluid connection point nanobubbles (surface nanobubbles) or mass nanobubbles in light of their morphologies and areas. Nanobubbles are vaporous spaces tens to many nanometers in width that are undetectable to the unaided eye and ordinary magnifying lens. The MNBs were small gas bubbles in a liquid media with particle sizes ranging from 200 nanometers to ten micro metres [2]. Though the research is still in its early stages, MNB applications include waste water treatment [3], drug delivery [4], ozone treatment [5], marine operation, H₂ storage, seed germination activity [6], anti-microbial activity, aquaculture [7], oyster sterilization, heat transfer [8,] engine performance [9], and vessel cleaning. Because the buoyancy force of MNBs is lower than that of big bubbles due to their particle size, they can last for months [10]. The MNB is a spherical air cavity in a liquid medium with a surface area density of $A/V=3/r$ (where A=surface area of MNBs, V=volume of MNBs, and r=radius of MNBs of spherical shape). As the size of MNBs is reduced, the density increases. Because smaller bubbles have a higher surface tension, they shrink and have a higher internal pressure inside the bubble cavity. Attempts to decrease the MNB to such a small size resulted in infinite pressure being applied, causing MNBs to collapse (Senthil kumar, Rakesh and Aravind Sri Krishna 2020). As a result, OH⁻ free radicals are formed. The most notable aspect of OH⁻ ions is their oxidising behaviour and ability to remove contaminants such as phenol, which is difficult to remove using other methods. MNB stability is directly influenced by the ionizing potential [11]. The zeta potential (electrical potential of a particle in the slip plane) of MNBs varies between -34mV and -45mV for oxygen, -29mV and -35 mV for nitrogen, -20mV and -17 mV for air, -20mV and -27 mV for CO₂, and -11mV and -22mV for Xenon.

The zeta potential has a direct impact on MNB stability. MNBs had a dissolving potential that was far greater than that of ordinary big bubbles [12]. When air NBs were in a water medium, they were spherical in shape [13, 14]. The presence of MNBs in water enhanced the dissolved oxygen (DO) percent in water [15, 16]. The MNBs were able to survive for months without shrinking in size. The presence of MNBs was also influenced by the pH of the water and the presence of additional salts, if any. The usual Laplace pressure for a 100 nm bubble was roughly 30 N/m². The water containing MNBs was found to be electrically charged, having negative zeta potential values in all of the O₂, CO₂, Xe, and N₂ samples. Nanobubbles water curcumin extract could be a good substitute for nourishment when doing exercises. The vacuum degasification procedure was utilized to manufacture bulk nanobubbles in ultra pure water using a syringe. The brownian mobility of nanobubbles in deionized water was investigated using a molecular dynamics simulation. The ozone microbubbles were capable of eliminating organic contaminants from the environment. The gas-oil engine with air nanobubbles helped to save energy. The presence of Nanobubbles changed the physiochemical characteristics of water. The coalescence of nanobubbles generated was the function of temperature variations as predicted by response surface methodology.

1.1 CHARACTERISTICS OF MNB's:

MNBs have a smaller capacity, allowing for less buoyancy and a stronger surface, preventing them from collapsing soon. As per study, MNBs move more modest than 1m develop at a significantly more slow rate than Brownian movement (irregular movement of particles suspended in a liquid brought about by crashes with quick atoms or atoms in the gas or fluid), subsequently they seem to remain stable in water for quite a while. Since the mass exchange region of the gas-fluid stages impacts the mass exchange pace of a gas, MNBs have an altogether higher mass exchange rate. MNBs have a high point of interaction zeta potential, practically identical to colloid particles, because of particles retention on the outer layer of air pockets and the development of counter particles on the inside surface. The parameters of the chemical reagent solution, as well as the gas source, influence the Zeta potential of MNBs.

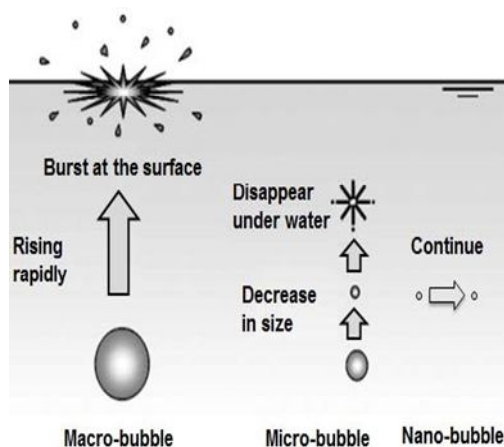


Fig: 1.1: behavior of Macro, Micro and Nano bubbles in water

1.2 ZETA POTENTIAL MEASUREMENT:

The zeta potential of particles floating in water and big molecules, among other things, is a physical feature. The potential or voltage at the edge of the sliding or shear plane in reference to the bulk dispersion media, where ions are no longer in contact with particles in the surface region, is referred to as the "zeta potential." Any two adjoining micro bubbles with a high zeta magnitude repel each other due to the electrostatic repulsive force (due to same charge on the surface). The zeta potential is a key bubble surface feature that affects nanoparticle stability. The surface charge of particles in a colloidal system is determined using the zeta potential measurement technique.

1.3 SIZE MEASUREMENT:

Nanoparticles' sizes are also utilized to identify them. To quantify size, scientists utilize dynamic light scattering techniques, scanning electron microscopes, atomic force microscopes, acoustic spectroscopy, optical microscopy, image analysis, and other methods. The device we used to estimate the size of the nanoparticles among all of these was dynamic light scattering.

1.4 HYDRODYNAMIC CAVITATION:

Hydrodynamic cavitation (HC) is a process in which a large amount of energy is produced in a flowing liquid when a bubble implodes due to a fall in local pressure

and subsequent increase. While cavitation has been a significant issue in hydraulic systems, its energy can be used for a variety of physical and chemical processes. The principle of HC has been used in the food and beverage sectors to homogenize, pasteurize, break, or combine food macromolecules. The idea, design characteristics, and many applications of hydrodynamic cavitators in food and beverage processing are discussed in this review article.

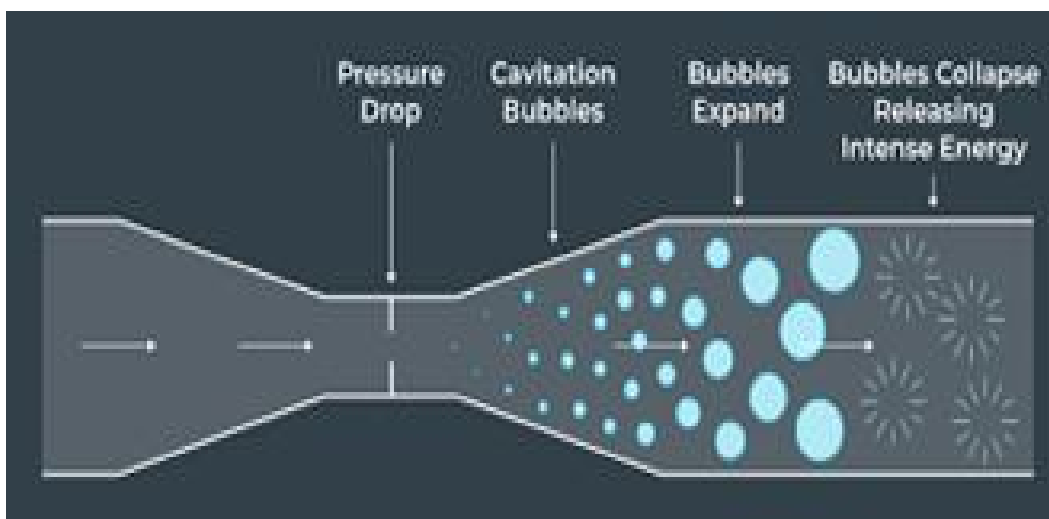


Fig: 1.2: Hydrodynamic cavitation

1.4.1 Practical Applications:

Food sectors are thriving in this fast-developing world by using energy-efficient modern technologies. Dairy research facilities and enterprises use hydrodynamic cavitators. Hydrodynamic cavitation provides the benefits of cutting capital costs, reducing manufacturing time, increasing production efficiency, and improving food safety while maintaining product quality. Extraction, emulsification, sterilising, and homogenization can all be done with hydrodynamic cavitators. The use of hydrodynamic cavitators on a large scale is currently uncommon, but there is potential for them in the food and beverage industries.

1.5 STABILITY OF NANOBUBBLES:

The surface charge density of nano bubbles, is influenced by a variety of factors, including bulk solution viscosity and density, temperature, pH, chemical surfactant type and concentration, and others. Bubbles can have high zeta potential values regardless of gas type if enough energy or pressure is given under regulated gas

flow rates. Even though the zeta potential is high, bubbles will combine to produce bigger, more unstable macrobubbles if the gas flow velocity is high and the bubble concentration is high. Small bubbles with a low rising velocity and high zeta potential values are stable nanobubbles that reduce the likelihood of bubble coalescence. The surface charge density of nano bubbles, is influenced by a variety of factors, including bulk solution viscosity and density, temperature, pH, chemical surfactant type and concentration, and others. Bubbles can have high negative potential values regardless of gas type if enough energy or pressure is given under regulated gas flow rates. Even though the zeta potential is high, bubbles will combine to produce bigger, more unstable macrobubbles if the gas flow velocity is high and the bubble concentration is high. Small bubbles with a low rising velocity and high zeta potential values are stable nanobubbles that reduce the likelihood of bubble coalescence. Little amounts of phosphatidylglycerol (anionic) or stearylamine (cationic) were added to a traditional intravenous lipid emulsion settled by egg phospholipid to change the surface charge. A four-stage dynamic model was utilized to ascertain the paces of hydrolysis in the water stage, oil stage, interface, and fluid micellar stage at pH 8.0.

Scientific procedures are utilized in the ZP way to deal with decide the surface charge of NPs in colloidal arrangement. At the point when a charged molecule diffuses in arrangement, an external diffuse layer containing inexact related particles draws in and solidly ties to it, shaping a slim fluid layer known as the Stern layer; when the molecule diffuses in arrangement, an external diffuse layer containing approximately related particles is involved, bringing about the development of an electrical twofold layer; when the molecule diffuses in arrangement, an external diffuse layer containing inexact related particles is involved, bringing about the arrangement of an electrical twofold layer; When a molecule diffuses in arrangement, it is gulped by a diffuse layer comprised of inexact connected particles, bringing about the arrangement of an electrical twofold layer (Clogston and Patri, 2011). a scattered droplet or particle vs. a distant continuous phase point In other words, the zeta potential is the potential difference between the dispersion medium's mobile and stationary layers that is linked with the dispersed particle. In colloidal systems, electro kinetic potential (or zeta potential) is an abbreviation for zeta potential (or potential).

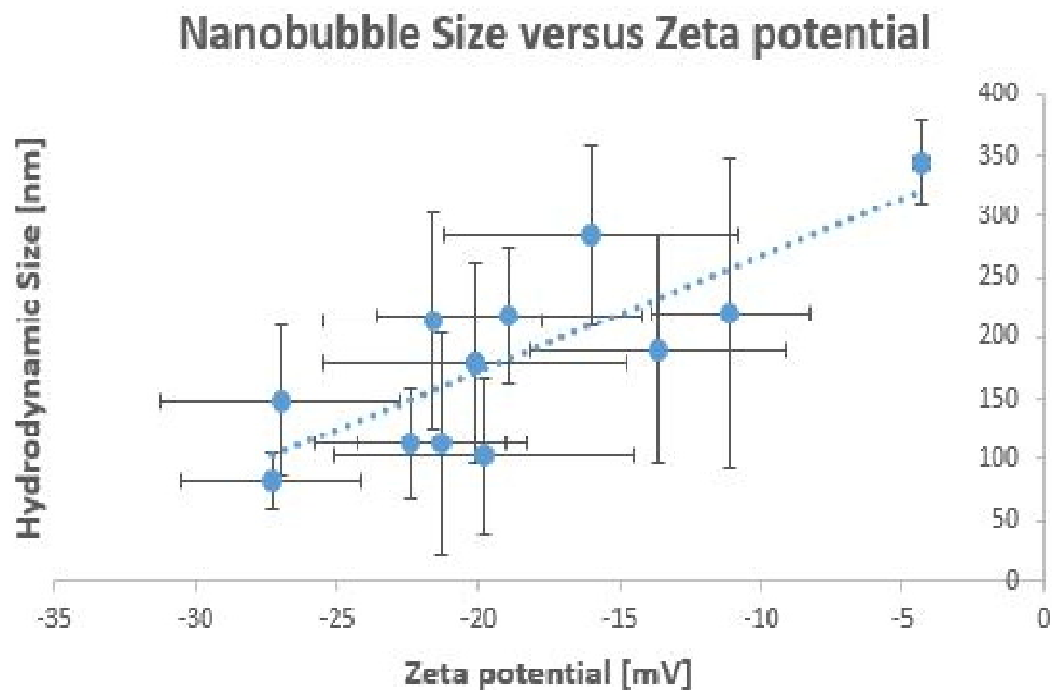


Fig: 1.3: Nanobubble size versus Zeta potential

The zeta potential is the electric potential in the interfacial twofold layer of a scattered molecule or drop versus a point in the consistent stage a long way from the connection point.

At the end of the day, the zeta potential is the possible contrast between the versatile and fixed layers of the scattering medium that is related to the scattered molecule. The pH of the medium greatly affects zeta potential. Extra contemplations incorporate ionic strength, added substance fixation, and temperature.

The significance of zeta potential is that it very well may be connected to emulsion dependability in the short and long haul. Emulsions with a high zeta potential (positive or negative) are electrically steady, while those with a low zeta potential coagulate or flocculate, bringing about poor actual dependability. At the point when the zeta capability of an emulsion is high, unpleasant powers dwarf appealing powers, bringing about a generally steady framework.

According to Losso et al., the surface features of most emulsions were linked to their half-life stability (2005).

Phosphatidylcholine-settled emulsions with a zeta capability of 11 mV had a lower half-life dependability than phosphatidylglycerol-balanced out emulsions with a zeta capability of 53 mV. Emulsions with zeta potentials between 11 and 20 mV were deemed to be near the agglomeration threshold, while those with zeta potentials between 41 and 50 mV were said to be stable. Arts et al. (1994) discovered that phosphatidylcholine was the most effective additive for increasing the zeta potential of tristearoylglycerol crystals in olive oil when compared to oleic acid, stearic acid, and monostearoylglycerol – yielding a positive zeta potential ranging from roughly 10 to 60 mV. The contaminants had a significant impact on the zeta potential as well.

The zeta potential is one of several physical stability indicators. However, when the zeta potentials of multiple emulsions differ, it is not always a simple metric of stability. According to Roland et al., there was no correlation between the zeta potential (43.1 to 50.2 mV) and overall stability (2003). In this circumstance, the emulsions with the lowest zeta potential were the most optically stable. To predict unique stability, absolute variations in zeta potential levels appear to require to be at least 10 mV. Other factors, such as size reduction, also played a role in the emulsions' stabilization.

The influence of surface charge on the rate of deterioration in oil-in-water emulsions was investigated using Methylparaben (MP) as a model chemical (Pongcharoenkiat et al., 2002). Small quantities of phosphatidylglycerol (anionic) or stearylamine (cationic) were added to a conventional intravenous lipid emulsion stabilized by egg phospholipid to change the surface charge.

A four-phase kinetic model was used to calculate the rates of hydrolysis in the water phase, oil phase, interface, and aqueous micellar phase at pH 8.0. The zeta potential was shown to influence the rate of hydrolysis in the aqueous phase. This has to do with the surface acidity phenomena, which is generated by surface charge. MP hydrolyzed at a speed not entirely settled by the pH of the microenvironment as opposed to the watery stage's mass pH. The impact of the solute's parcel coefficient was analyzed by supplanting ethylparaben (EP), propylparaben (PP), and butylparaben (BP) for MP in the emulsions. The pace of hydrolysis was contrarily relative to the parcel coefficient. Surface charge had the

biggest influence on hydrolysis in emulsions comprising MP and EP, though dividing had the best effect in emulsions containing PP and BP. Accordingly, when the parcel coefficient was low, the effect of surface charge prevailed.

CHAPTER 2

LITERATURE SURVEY

- A study of nanobubbles in aqueous solutions for a variety of purposes. G. Senthil Kumar, C. Rameshkumar, M. N. V. S. Nikhil, and J. Navin Ram Kumar are the candidates. This document lists the easiest methods for producing nanobubbles in various aqueous solutions, as well as their uses. Chemical oxygen demand, biochemical oxygen demand, total suspended particles, total dissolved solids, dissolved oxygen, nitrate, phosphate, chromium, and sulphide levels were measured in tap water, distilled water, slurry water, and sea water with and without nanobubbles.
- On the existence and stability of bulk nano-bubbles. N. Nirmalkar, A.W.Pacek, and M. Barigou.
- Generation and stability of size-adjustable bulk Nanobubbles based on periodic pressure change. Qiaozhi Wang, Hui Zhao, NaQi, YanQin, XuejieZhang & Ying Li.
- Case Study on Nanobubbles Technology for Ethylene Glycol Coolant Oil Heat Transfer Enhancement A. Sobhanadri, G. Senthilkumar, S. Lakshmi Sankar, M. Purusothaman, C. Rameshkumar Due to its strong anti-freezing properties, the heat transfer potential of Ethylene Glycol ($C_2H_6O_2$), a coolant for vehicle radiator nanofluids, is examined experimentally in this study. The fluid being examined is a 50:50 mixture of water and ethylene glycol by volume. In the realm of energy conservation, conversion, and recovery, heat exchangers play a critical role.
- Effect and application of micro- and nanobubbles in water purification. a) Baljinder Singh, b) Nutan Shukla, c) Chan-Hyun Cho, d) Byung Sun Kim, e) Myoung-Hwan Park, f) Kibeom Kim. The present uses of micro- and nanobubbles employing classic and sophisticated techniques such as flotation, aeration, and ozonation, which are capable of removing impurities and colour, disinfecting water, and oxidising organic pollutants, are discussed in this paper. Bubble technology has emerged as a possible platform for extracting dangerous chemicals from water utilising these approaches. The conclusion

reached concerns the measurement of the zeta potential and the methods utilised to do so. Microbubble and nanobubble technology for water treatment:

- principles and applications a) Ashutosh Agarwal, b) ZWunJernNg, YuLiu; c) ZWunJernNg, YuLiu; d) ZWunJernNg, YuLiu; e) The physics and techniques of generating microbubbles (MBs) and nanobubbles (NBs) are discussed in this study, as well as the formation of free radicals from MBs and NBs, with an emphasis on hazardous chemical breakdown, water disinfection, and cleaning/defouling of solid surfaces, including membranes. Because of their propensity to create free radicals, MBs and NBs are believed to have enormous future potential, with much more to be discovered.
- Groundwater cleanup using micro-nano bubbles. Sabeera Haris, Xiaobin Qiu, Harald Klammler, Mohamed M.A. Mohamed This study summarises current findings on the utilisation of MNBs technology for polluted groundwater remediation. Finally, the present problems and limits of MNB's groundwater remediation application are explored.
- Nanobubble fundamentals and applications Elisavet D. Michailidi, George Bomis, Athanasios Varoutoglou, Eleni K. Efthimiadoua, Evangelos P. Favvasa, a) Elisavet D. Michailidi, b) George Bomis, c) Athanasios Varoutoglou, d) Eleni K. Efthimiadoua,.
- Microbubble generation and microbubble-aided transport process intensification. a) Rajeev Parmar, b) Subrata Kumar Majumder. This article intends to present a current state-of-the-art appraisal of the scientific work in microbubble-assisted transport mechanisms that has been done so far. This page discusses the many ways for creating microbubbles as well as the qualities of microbubbles.
- Ariel J. Atkinson, b) Onur G. Apul, c) Orren Schneider, d) Sergi Garcia-Segura, and e) Paul Westerhoff, "Nanobubble Technologies Offer Opportunities to Improve Water Treatment." According to this article, NBs provide chances to improve existing technologies or enable new ones in order to produce fewer by-products and cleaner water.

CHAPTER 3

AIM AND SCOPE

3.1 AIM:

The main goal of this research is to use nanobubble technology to create a purified form of water. It is critical to understand the rationale for these bubbles' long-term stability in order to make effective and useful use of them. Temperature and salt concentrations, as well as bubble size, were used to establish bubble size distributions and zeta potentials of nanobubbles. Based on experimental results and information gained through a literature search, a discussion on nanobubble stability was offered. By delivering sufficient energy or pressure under controlled gas flow rates, stable bubbles with high magnitude zeta potentials can be created independent of gas type. Bubble stability can also be improved by creating an environment that favours the growth of larger concentrations of OH ions on the bubble surface.

3.2. SCOPE:

Observe changes and improvements in retention & cavitation period, as well as salt concentrations, in order to stabilise the mixture and repeat the development in the water. Nanobubbles or ultra-fine bubbles, with diameters ranging from tens to hundreds of nanometers, are rapidly evolving in terms of generation, measurement, and application technologies. Nanobubbles are employed in a variety of applications due to their unique features, including the production of functional materials, decontamination, medication delivery, and food product disinfection. The six significant characteristics of MNBs, which remember higher gas dissolvability for fluid arrangement, expanded dynamic oxygen in water, better air pocket adsorption execution, and a solid oxidation property, give an assortment of significant advantages. Accordingly, MNBs have stimulated researchers' advantage. MNB innovation (MNBT) is showing rising mechanical advantages and demonstrating likely development. The MNBT is by and by utilized for surface water filtration, sewage (squander) water treatment, soil and groundwater remediation, and ooze treatment in ecological contamination control.

CHAPTER 4

MICRO NANOBUBBLES GENERATION PROCEDURE

The hydrodynamic cavitation (HC) approach is a one-of-a-kind technique for producing MNBs based on the properties of the liquid medium and application criteria. In our experiment, we employed an ultrasonic syndicator in conjunction with an air compressor to generate tangential force in the water.

For the observation of MNBs, the sample was first subjected to hydrodynamic cavitation for 15 minutes under isothermal conditions, and then the process was repeated 3-4 times. The consideration of oleic corrosive, lime, and baking soft drink as surfactants at convergences of 0.025 percent, 0.05 percent, 0.075 percent, and 0.1 percent by volume premise kept up with the strength, zeta potential, and size appropriation of the MNBs.

Our MNBs ranged in size from 100 nm to 400 nm in diameter. Because of its better influence on humans, this surfactant was chosen. The 300ml of water that would be tested was placed in a 500ml beaker, placed in the sonicator, and vibrated for nearly an hour at a constant temperature of 30oC. MNBs were created using an air compressor with a capacity of 0- 5 bar that injected air with shearing action into the water at a constant pressure of 1.5 bar.

The macro bubbles generated during the process moves up due to the buoyancy and collapses near the top surface of the beaker. The pH of the sample was improved due to the surfactant addition which lead to solution became alkaline in nature.

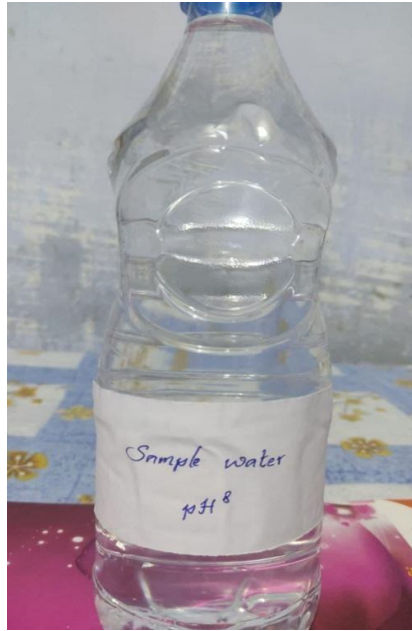


Fig: 4.1: Collected sample water



Fig: 4.2: Equipment for generating Nanobubbles

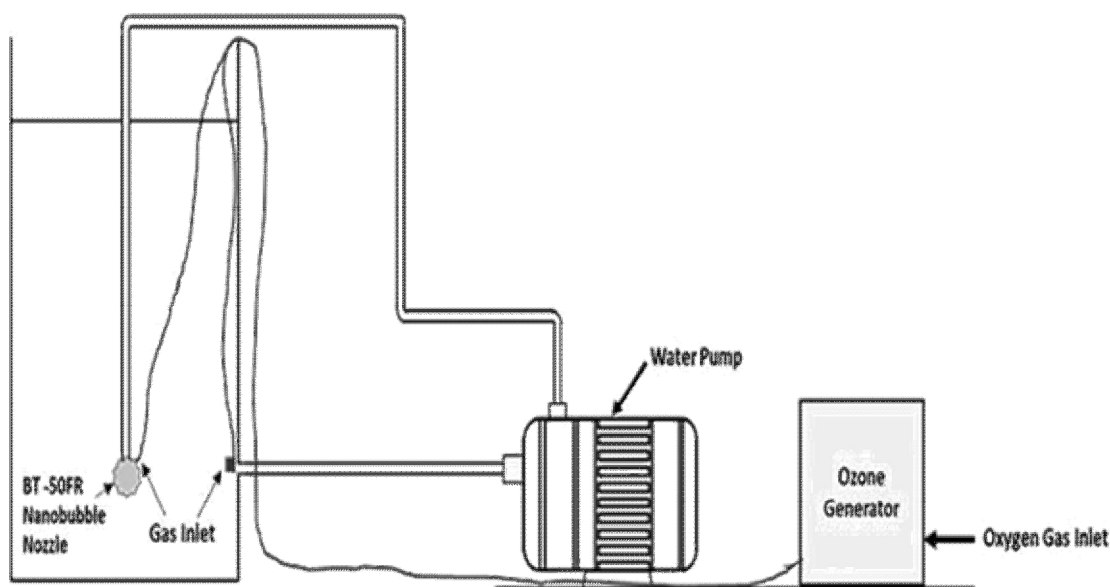


Fig:4.3: Setup for an experiment. (The ozone nanobubble generating setup is shown in the diagram.) Instead of the ozone generator, the gas input is directly linked to the gas cylinder to make additional gas bubbles.)

4.1 DLS - DYNAMIC LIGHT SCATTERING:

The physics method of dynamic light scattering (DLS) is used to determine the size distribution profile of tiny particles suspended in solution or polymers in solution. The power or photon auto-connection work is generally used to inspect transient varieties in DLS (otherwise called photon relationship spectroscopy or semi versatile light dispersing). In time space examination, the autocorrelation work (ACF) rots from zero postpone time, coming about in speedier de-relationship of scattered power follows because of quicker elements connected with more modest particles. The DLS method may be used to investigate the behaviour of complicated fluids such concentrated polymer solutions.

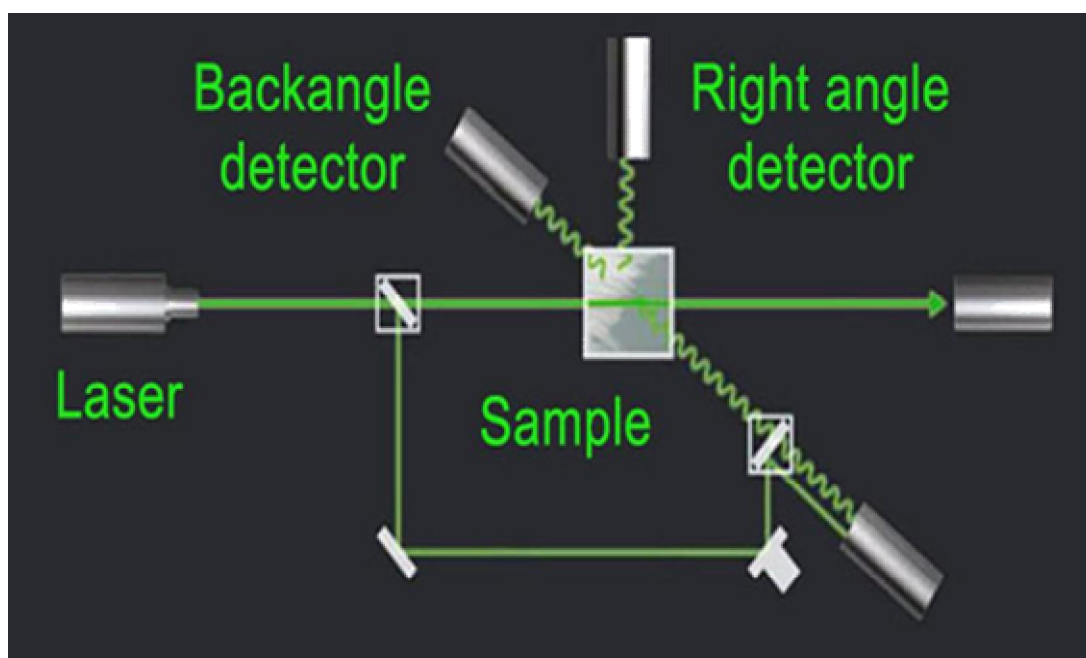


Fig: 4.4: Dynamic light scattering (DLS)

4.1.1 Practical Applications:

DLS is utilized to survey molecule size in proteins, polymers, micelles, vesicles, polysaccharides, nanoparticles, natural cells, and gels. In the event that the framework isn't dissipated in size, the mean successful measurement of the particles not entirely settled. This estimation is impacted by the size of the molecule center, the size of surface highlights, molecule focus, and the sort of particles in the medium. Since DLS fundamentally screens varieties in dispersed light power produced by diffusing particles, the dissemination coefficient of the particles still up in the air.

The particle population at various diameters is often shown using DLS software for commercial devices. In a monodisperse system, there should be just one population, whereas in a polydisperse system, there should be several particle populations. If a sample comprises more than one size population, the CONTIN analysis or the power spectrum technique for photon correlation spectroscopic equipment or the power spectrum technique for Doppler shift devices should be used.

Stability testing are made easier with DLS. By examining whether the particle's hydrodynamic radius expands over time, periodic DLS measurements of a sample can indicate if particles agglomerate. If particles merge, there will be a bigger population of particles with a larger radius. In some DLS devices, temperature-dependent stability may be examined by changing the temperature in situ.

4.2 NTA-NANOPARTICLE TRACKING ANALYSIS:

In nanoparticles following examination (NTA), a strategy for noticing and investigating particles in fluids, the pace of Brownian movement is relative to molecule size. The thickness and temperature of the fluid direct the speed of development; molecule thickness and refractive list have no bearing. NTA might be utilized to assess the size conveyance profile of little particles in fluid suspension with a distance across of around 10-100 nanometers (nm).

Small particles in liquid suspension can be seen moving under Brownian motion with this approach, which requires an ultra microscope and a laser illuminating apparatus.

Depending on the particle type, NTA can now process particles with diameters ranging from 10 to 1000 nm. Only particles consisting of materials having a high refractive index, such as gold and silver, can be analysed at the lowest end of this spectrum.

4.2.1 Practical Applications:

Exosomes, miniature vesicles, bacterial layer vesicles, and other small natural particles, virology and antibody age, ecotoxicology, protein accumulation, muscular embeds, inks and tones, and nanobubbles have all been concentrated on utilizing NTA..

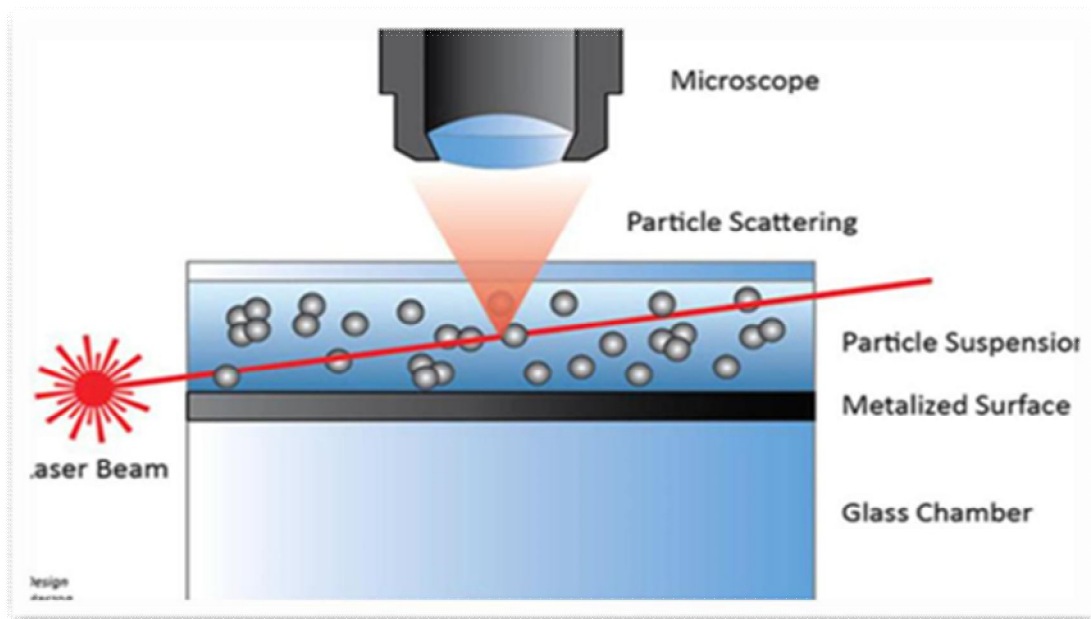


Fig:4.5:Nano-particle tracking analysis (NTA)

4.3 Influence of DO over Time Due to Nano-bubbles:

Before nitrogen desorption, the DO content in the water varied from 9.10 to 9.64 at 20°C. Because the tap water had a high DO value that would take a long time to decrease to near zero, the dissolved oxygen content was initially lowered to around 4 mg/L using nitrogen gas [19]. When the air NBs supply was taken off, the DO concentrations stabilised at an average of 13.5 mg/L for all starting DO values.

The concentration remained practically constant over the next 24 hours after the generator was switched off. The DO concentration dropped to 9.3 mg/L, which is the saturated threshold, after two more days. The concentration had reached 9.1 mg/L after another day, which was the saturation level. When looking at the variance in oxygen gas NBs DO concentration over time, it's clear that the value peaked.

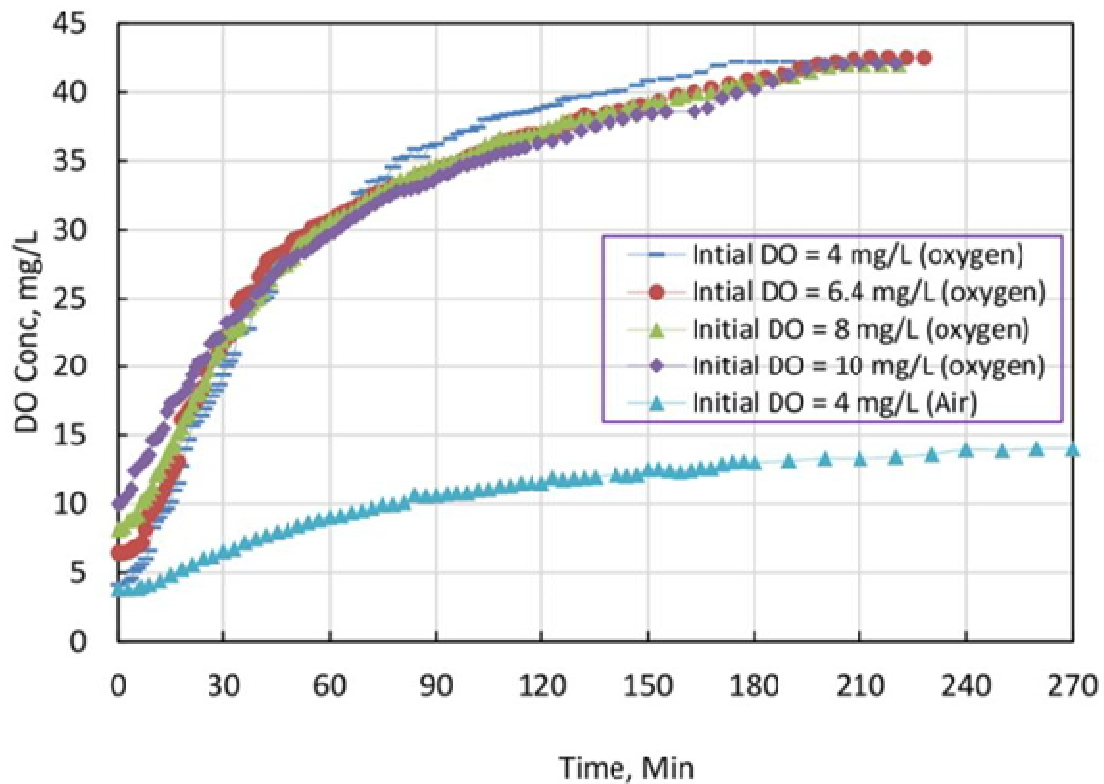


Fig: 4.6: shows Variation of disintegrated oxygen (DO) with time for the different introductory DO Concentrations supersaturated degree of 42.0mg/L.

Following 1 day, it remained almost steady before step by step diminishing to the immersion balance of 9.1 mg/L at 20°C. On the 10th day, the DO fixation approached immersion (9.3 mg/L), and after one more day, it accomplished the immersion harmony of 9.1 mg/L. The DO developed rapidly after the NBs creation started in this examination, until it arrived at 30 mg/L after about 60 minutes. In any case, following that, the pace of rise eased back and swayed about the high worth of 42.0 mg/L.

VOTR, Initial DO = 3.14 mg/L

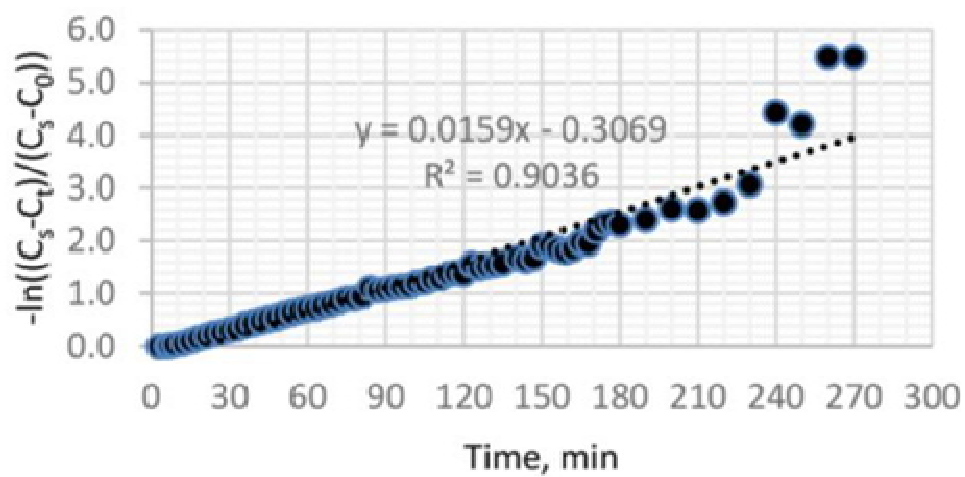


Fig: 4.7: VOTR at DO-3.14 mg/L

VOTR, Initial DO = 5.2 mg/L

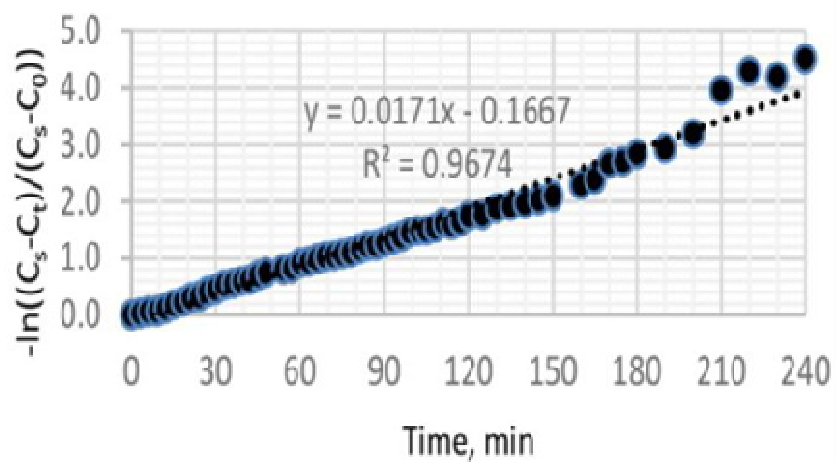


Fig: 4.8: VOTR at DO-5.2 mg/L

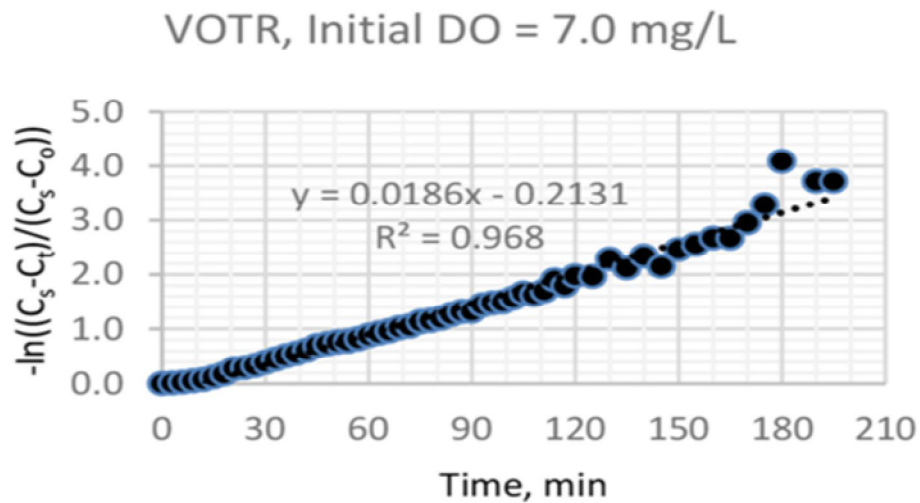


Fig: 4.9: VOTR at DO-7.0 mg/L

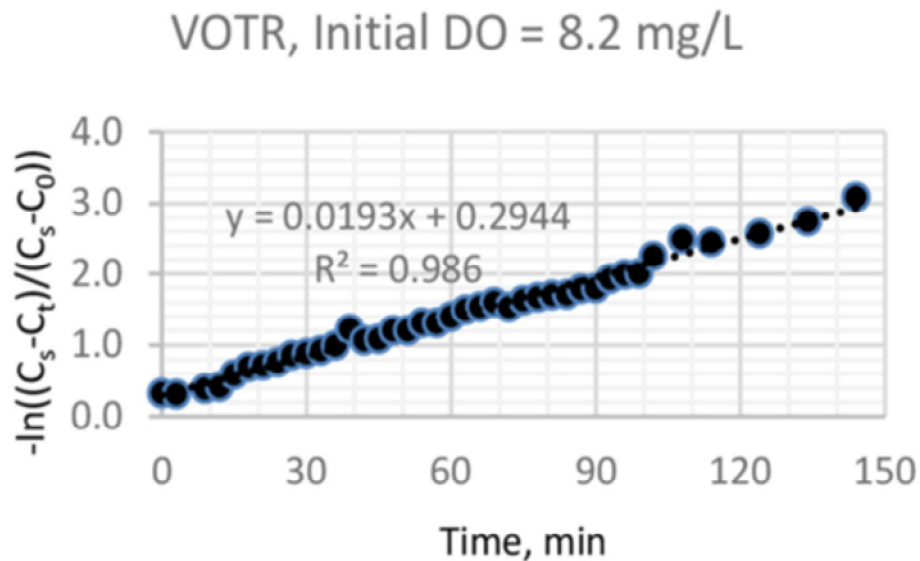


Fig: 4.10: VOTR at DO-8.2 mg/L

The more noteworthy the beginning air DO, the higher the $k_L a$ esteem, but the example, as shown in the diagram, is one of moderate development. The $k_L a$ an incentive for nano-percolating was not especially high because of the low limit of the NB generator (0.0159-0.0193 min⁻¹ for air). The $k_L a$ value fell significantly as the initial DO increased when oxygen was utilised instead of air, but it was still 3 times larger than air. Therefore, the pace of oxygen disintegration from NBs into

not entirely set in stone by the gas type and starting oxygen fixation. How much oxygen broke up in water is corresponding to the fractional strain of oxygen in air, as indicated by Henry's regulation. The AIDOIR identifies the bulk.

NBs' rate of transfer (Fig. 4.7). It reflects the number, rate, and size of bubbles created and is connected with the generator limit. Li et al. [22] indicated that converting one 1 mm-distance across air bubble into 800,000 10 m-width air bubbles increments mass exchange rate by 10,000, which makes sense of why AIDOIR of miniature nano bubbles was significantly more prominent than large scale bubbles. It required an alternate measure of investment to accomplish the pinnacle immersion fixation, showing that AIDOIR was something other than a change in DO focus values. AIDOIR's essential outcome over the long haul was DOPV.

Fig 4.8 To compare the AIDOIR result with another universal parameter, displays the influence of starting oxygen content in terms of OTE. The oxygen transfer efficiency (OTE) is the ratio of the mass rate of oxygen transferred to the mass rate of oxygen provided. As a result, the bar graphs depict the influence of gas type and beginning DO.

This conclusion was reached as a result of changes in dissolved oxygen levels. When microbubbles are used to oxygenate water, the bubbles survive just a few minutes, whereas NBs might remain for days. As a result, DO may be well-maintained for a long time while employing NBs. The number and length of stay of NBs are closely linked to their effectiveness. The initial DO concentration had an effect on the time it took to reach saturation equilibrium, perhaps because a high initial DO caused a greater number of particles to nucleate.

At low DO focuses, cavitation bubbles are more challenging to produce, and the distance between bubbles is too lengthy to even think about keeping the size of the air pockets little, since there is less blend of air pockets. To expand the quantity of air pockets, combination between bubbles is rehashed at higher DO focuses. Countless air pockets with a sensible size appropriation were reasonable made because of the combination between the air pockets at higher DO focuses. Mass transfer and ST are also affected by the kind of gas used, with oxygen NBs having a higher OTE and a longer-lasting DO enhancement than air NBs.

Subsequently, providing oxygen as NBs has potential in oxygen conveyance systems, for example, water body oxygenation, which might be used to oversee algal sprout and related water quality issues. DO developed with electrolyte fixation as the little air pockets balanced out, expanding their life in water. The gas-fluid point of interaction charge, then again, was impacted by electrolyte fixation to the point that, when saltiness surpassed 1.5 g/L, Cl subbed Na⁺ at the point of interaction, adsorbing more than Na⁺. More oxygen was delivered into the climate thus, diminishing the DO top. A high concentration of particles, which causes turbidity, hinders the NBs effect in oxygen mass transfer to water by establishing a barrier to the passage of gas molecules at the gas-liquid interface. Although suspended particles are the most common source of turbidity in the water column, other factors such as organic matter and bacteria also have a role; the latter is hypothesised to absorb DO. As a result, the actual water state should be considered in applications. The usage of NBs can also help with the mineralization of organic molecules, improving the efficacy and profitability of biological aeration processes.

The development of OH extremists on NBs has been found to help in the expulsion of natural materials, making NBs compelling for speeding up the decay of natural matter. The utilization of NBs brought about a breakdown of glucose as an agent natural matter of up to 7.2 percent. Despite the fact that thermodynamic hypothesis can't describe the inward tension of the NB, its soundness and arrival of OH-revolutionary sweep help to long haul natural cleanup. The sturdiness of nano-sized rises in water as far as DO focus and their capacity to endure past as far as possible was examined in this work. The factors are obviously made sense of by a quantitative portrayal of the actual properties of the NBs, for example, the zeta potential and molecule size.

CHAPTER 5

RESULT AND DISCUSSION

5.1 Variation of Micro constituents:

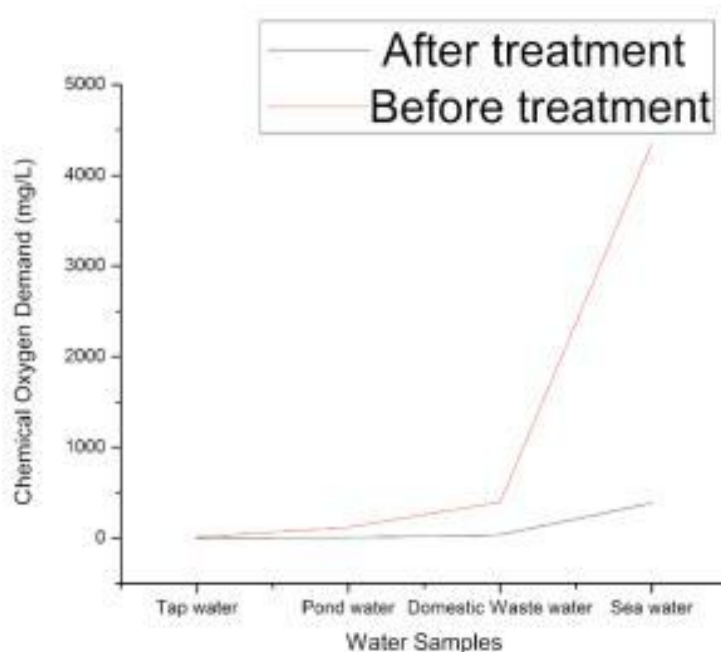


Fig: 5.1: COD Variation after treatment with MNBs

The chemical oxygen interest (COD) depicts the oxidation conduct of natural builds in water, and is utilized to evaluate the nature of both typical and squander water. Chemical oxygen interest (COD) and biochemical oxygen interest (BOD) are signs of how much foreign substances in water. Many commercially available COD analyzers integrated in the measurement of COD, according to prior research findings. In a wide spectrum of waste water treatment systems, COD is the decisive factor for plant efficiency. One of the conflicting discoveries was that greater COD in any water samples resulted in reduced DO. The figure which is shown in here has some variations in it like change if percentage decrease in chemical oxygen demand in water (tap, pond, residential waste and sea). As shown in Figure 5.1, the percentage decrease in COD in tap water, pond water, residential waste water, and sea water was 11 percent, 121 percent, 400 percent,

and 430 percent, respectively. Under all testing circumstances, the number of biologically oxidised compounds is less than the quantity of chemically oxidised compounds.

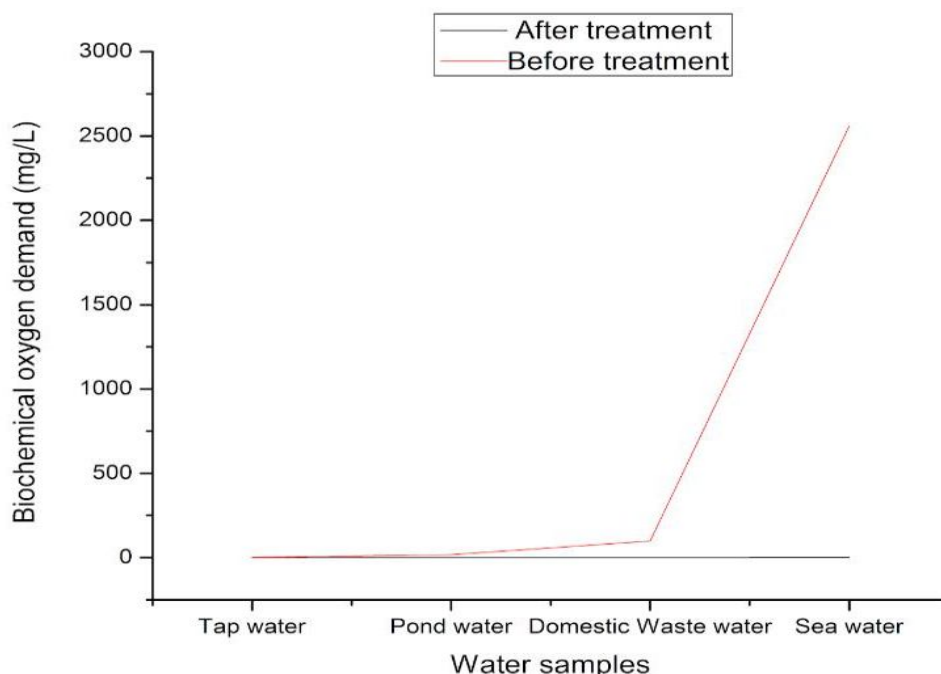


Fig: 5.2: BOD Variation after treatment with MNBs

The presence of biological organic pollutants in water causes a rise in aerobic bacteria, which require more oxygen to breakdown these pollutants, resulting in greater biochemical oxygen demand (BOD) in all studied water samples. Figure 3 shows that following the production of MNBs in the above specified samples, the percentage decrease in BOD for tap water, pond water, waste water, and sea water was around 3%, 18%, 105 percent, and 2500 percent, respectively. Due to the presence of organic stuff in biological nature, waste water and sea water were found to have greater BOD. As indicated by Figure 5.2, the rate decline in COD in regular water, lake water, private waste water, and ocean water was 11%, 121%, 400%, and 430 percent, individually.

Under all testing circumstances, the number of biologically oxidised compounds is less than the quantity of chemically oxidised compounds. Due to the actions of inter molecular force, the presence of dissolved oxygen in any liquid is proportional to the temperature in an indirect manner. Biological oxygen demand,

fertilisers, and bacterial development are some of the additional factors that contribute to a lower DO content in water. Following the production of free radicals by MNBs, a 50% rise in DO may be attained in tap water, as shown in the figure. MNBs were responsible for around 66 percent of the stagnant pond water. In both home trash and seawater, this increase in trend was measured to be 300% and 44% respectively as given in figure 4. The interesting factor of the experimental results was that stable zeta potential values for the entire DO measured outputs.

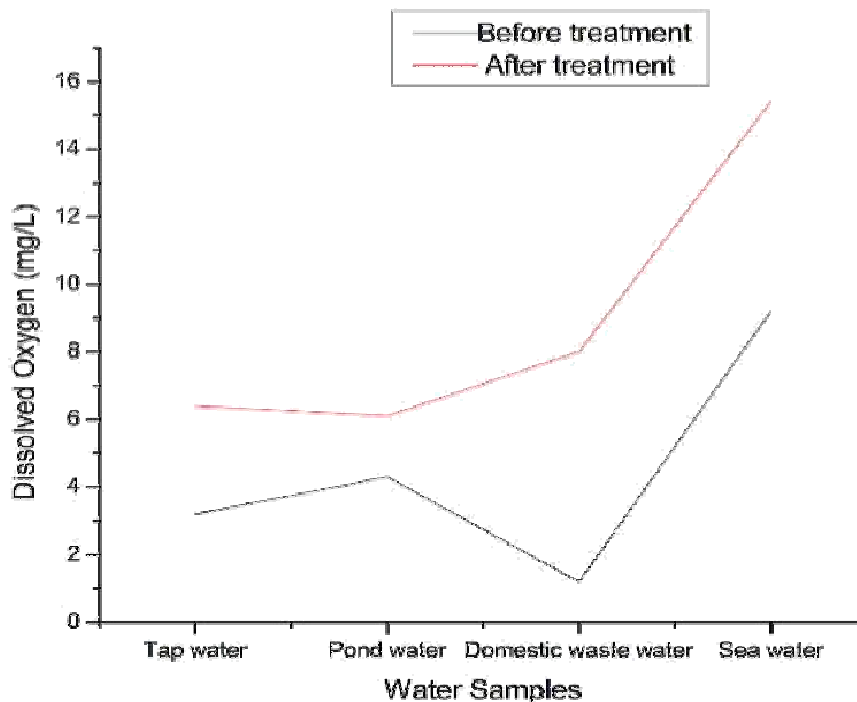


Fig: 5.3: DO Variation after treatment with MNBs

The oxygen diffused into the water from the ambient depending on the intensity of heat present in tested water samples at controlled thermal settings to guarantee the correct degree of dissolved oxygen saturation. Due to the actions of inter molecular force, the presence of dissolved oxygen in any liquid is proportional to the temperature in an indirect manner. Biological oxygen demand, fertilisers, and bacterial development are some of the additional factors that contribute to a lower DO content in water. The presence of MNBs in surface water aided the increase in biological activity.

For live marine fishes, the negligible DO prerequisite is in the scope of 5 mg/L. The formation of MNBs in sea water owing to an increase in O₂ allows for the enrichment of sea water quality. A high-accuracy dissolved oxygen (DO) metre (0-100 mg/L range) was used to quantify the volume fraction of dissolved oxygen (DO). Following the production of free radicals by MNBs, a 50% rise in DO may be attained in tap water, as shown in the figure. MNBs were responsible for around 66 percent of the stagnant pond water. This rise in trend was observed at 300 percent and 44 percent in residential waste water and sea water, respectively, as shown in figure 5.3.. The interesting factor of the experimental results was that stable zeta potential values for the entire DO measured outputs.

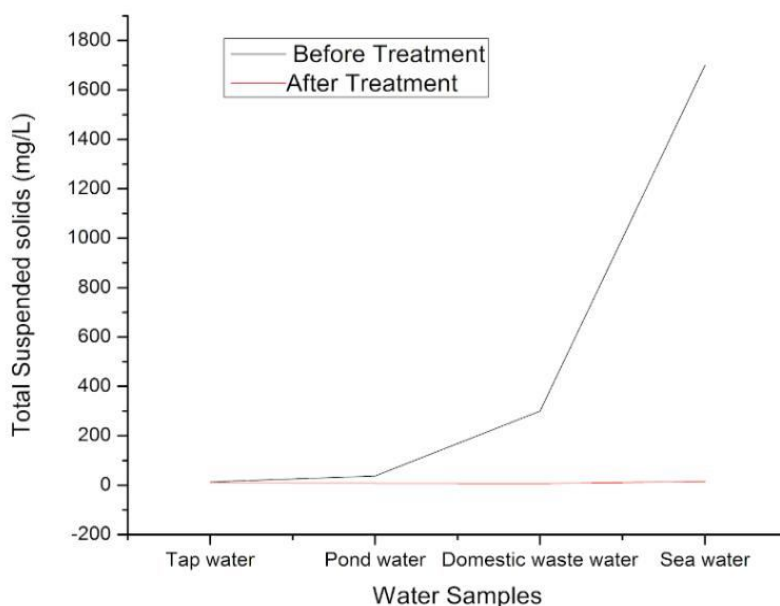


Fig: 5.4: TSS Variation after treatment with MNBs

Total suspended solids (TSS) are particles (size less than 2 m) that were not dissolved in a liquid medium owing to their weight and have been credited for major research in many disciplines of science and engineering. The majority of the TSS was inorganic, with the exception of algae and bacteria. It was referred to as a conventional contaminant in water in countries such as the United States. Filtering across a permeable membrane is one of the most basic ways for measuring TSS. Other important parameters for accurate TSS measurement in any liquid sample are the porosity mesh size and surface roughness of the filter.

TSS was decreased by 30.77 percent, 78.9%, 300%, and 1500 percent when MNBs were created in faucet water, lake water, home waste water, and ocean water, individually as displayed in figure 5.4.

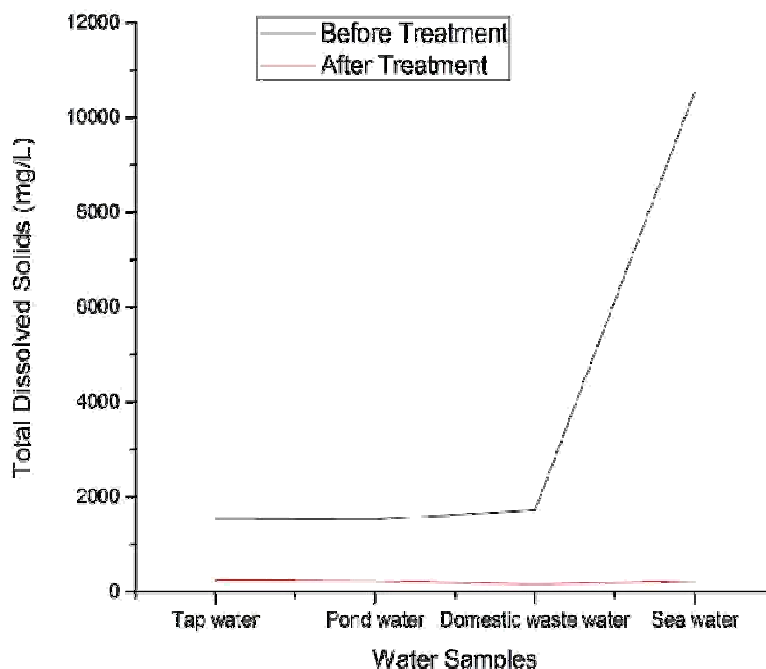


Fig: 5.5: TDS Variation after treatment with MNBs

TDS (total dissolved solids) is a term that refers to both the organic and inorganic components of liquids. The largest expense paid in the reduction of TDS by waste water treatment facilities is due to their variable sizes and behaviours. TDS levels dropped by 83 percent and 84.26 percent in tap water and pond water, respectively, before and after MNB treatment. Figure 6 shows that the percentage decrease in household waste water and sea water was 89.6% and 97.7%, respectively. Before treatment, one of the significant drawbacks was that corrosion increased and decreased the conductivity of the water samples. Different types of analyzers were used to conduct the various tests at the Mettex facility in Chennai.

5.2 Stability Improvement:

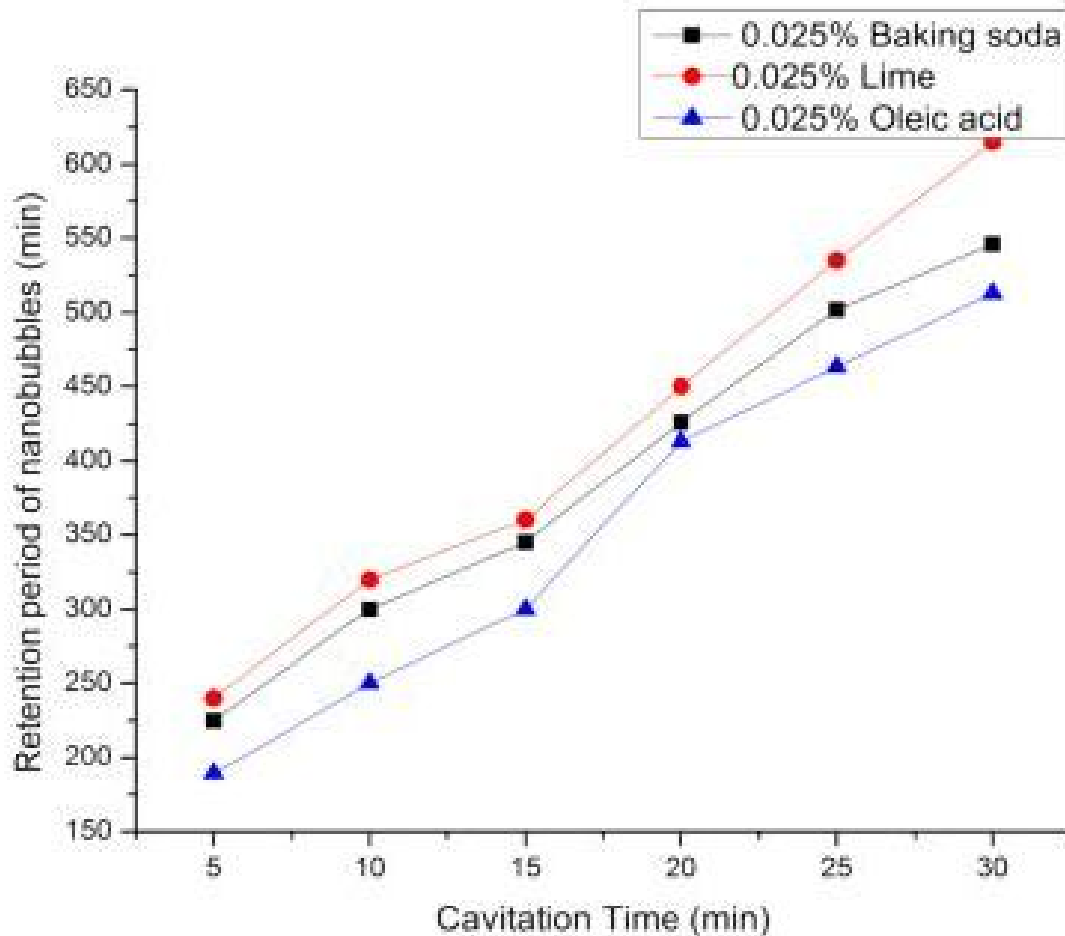


Fig: 5.6: Cavitation time Vs Retention period of nanobubbles for different surfactants at 0.025% concentration.

5.2.1 Cavitation time:

At the point when a volume of fluid is exposed to an adequately low tension, it might break and form a pit. This peculiarity is instituted cavitation initiation and may happen behind the edge of a quickly pivoting propeller or on any surface vibrating in the fluid with adequate plentifulness and speed increase. This

phenomenon which will happen for a certain period of time interval is called Cavitation time.

5.2.2 Retention period:

The time a solute spends in a section, or the time spent in the fixed and portable stages, is alluded to as maintenance time. The communication of the analyte with the fixed stage decides the more drawn out maintenance span.

The addition of Oleic acid, Lime and baking soda with a concentration of 0.025% has improved the retentionin according to cavitation time as per shown in the graph. Apparently, the stability has increased.

When Oleic acid is added to the water The polar finish of the oleic corrosive atom is drawn to polar water particles. Therefore, when a drop of an oleic corrosive arrangement is put on the outer layer of water, the oleic corrosive particles structure a slender layer as liquor dissipates. The baking powder responds with water to create bubbles,

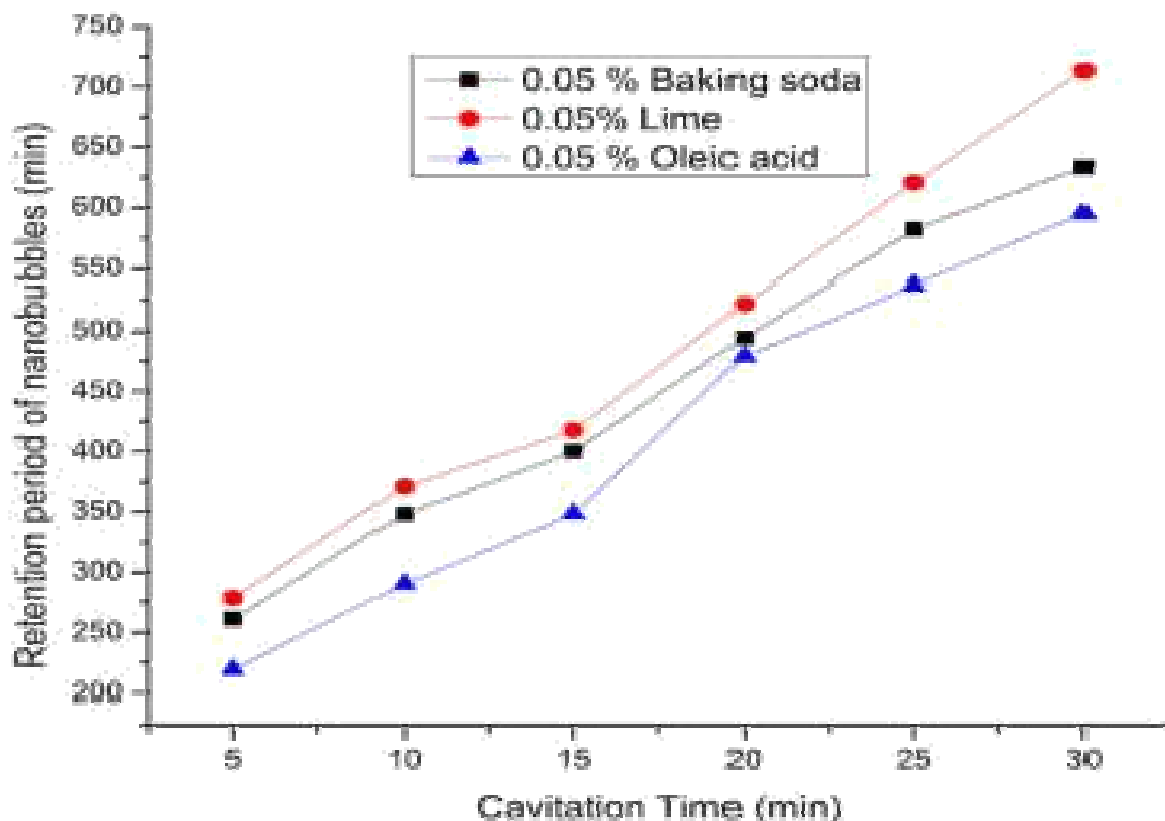


Fig : 5.7: Cavitation time Vs Retention period of nanobubbles for different surfactants at 0.05% concentration.

The addition of Oleic acid, Lime and baking soda with a concentration of 0.05% has improved the retention in according to cavitation time as per shown in the graph. The stability has been increased compared to 0.025%.

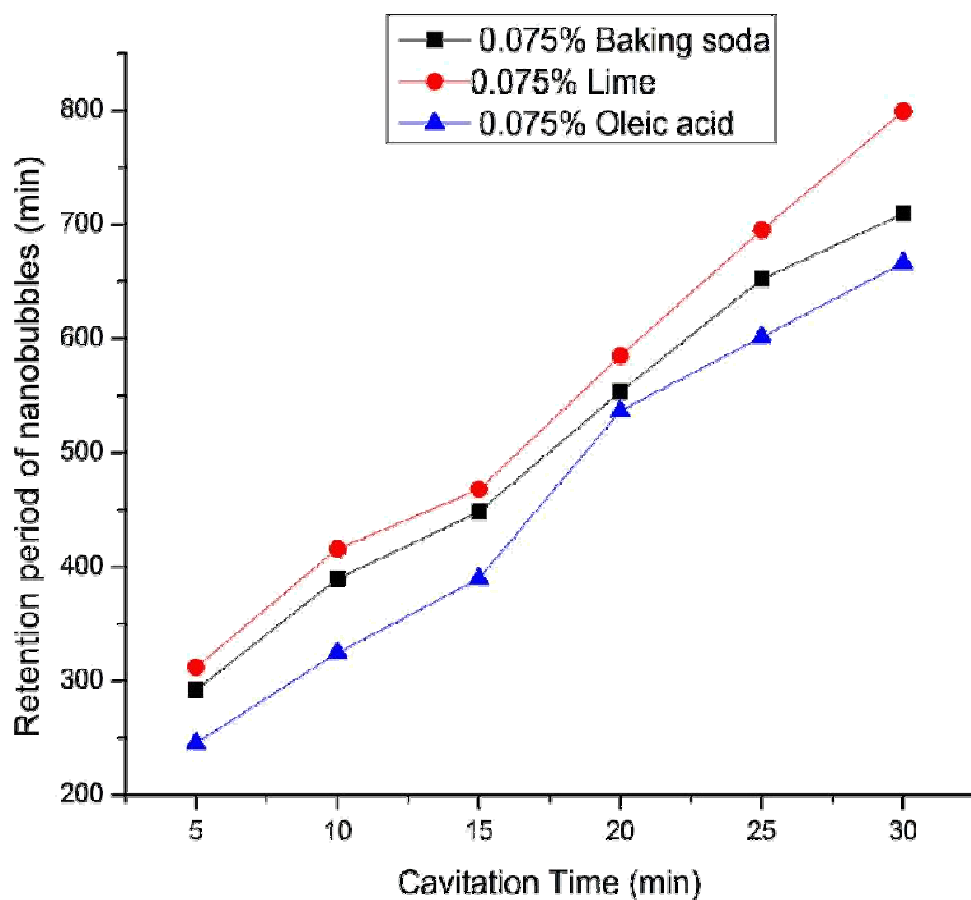


Fig: 5.8: Cavitation time Vs Retention period of nanobubbles for different surfactants at 0.075% concentration.

The addition of Oleic acid, Lime and baking soda with a concentration of 0.075% has improved the retention in according to cavitation time as per shown in the graph. The stability has been increased compared to 0.025% and 0.05%.

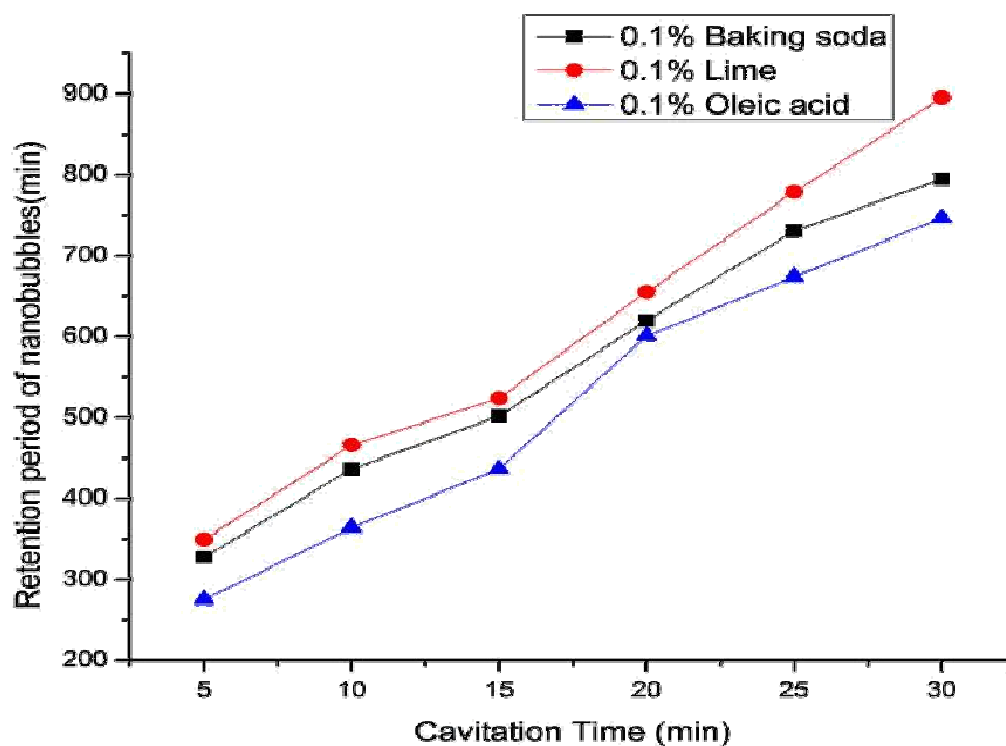


Fig: 5.9: Cavitation time Vs Retention period of nanobubbles for different surfactants at 0.1% concentration.

The addition of Oleic acid, Lime and baking soda with a concentration of 0.1% has improved the retention in according to cavitation time as per shown in the graph. The stability has been increased compared to 0.025%, 0.05% and 0.075%.

CHAPTER 6

SUMMARY AND CONCLUSION

A number of industrial applications need an understanding of the physics and behaviour of nanobubbles. An assortment of research center tests was completed to more readily comprehend the way of behaving of nanobubbles. The unique hydrodynamic cavitations approach was employed to manufacture MNBs from all water samples, including tap, pond, domestic waste, and sea water. It was obvious that the dissolved oxygen enrichment had been greatly increased in all of the instances. TSS and TDS levels have been brought down to a safe level. COD was decreased by approximately 400% in sea water and just 11% in tap water because sea water contains more chemical compounds than tap water. The quantity of organic pollutants originating from biological sources was decreased by 2500 percent. The use of MNBs decreases BOD in saltwater. The DO % is raised in all four water samples analysed, but the zeta potential readings are unaffected. In tap, pond, and house waste water samples, as well as sea water tests, TSS, a prevalent pollutant, was reduced by 30 to 300 percent. Based on experimental results and information gained through a literature search, a debate on nanobubble stability was presented. By providing adequate energy or strain under managed gas stream rates, stable air pockets with high extent zeta possibilities might be made autonomous of gas type. Furthermore, by establishing an environment that encourages the development of higher concentrations of OH⁻ ions on bubble surfaces, bubble stability can be increased.

CHAPTER 7

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