

WASTEWATER TREATMENT BY NANOBUBBLE TECHNOLOGY

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering Degree in

Mechanical Engineering

by

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **PASTAPOOR PITHAMBER (38150076)**, **KRISHNA SAI VIKRANTH POLUPARTHI (38150054)** who carried out the project entitled "**WASTEWATER TREATMENT BY NANOBUBBLE TECHNOLOGY.**" under my supervision from Nov 2021 to March 2022.

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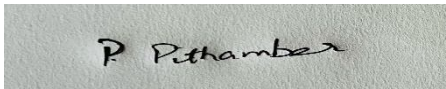
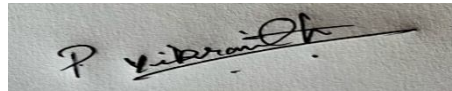
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DECLARATION

I **PASTAPOOR PITHAMBER** and **KRISHNA SAI VIKRANTH POLUPARTHI** hereby declare that the Project Report entitled “**WASTEWATER TREATMENT BY NANOBUBBLE TECHNOLOGY**”, done by me under the guidance of **Dr. G. SENTHILKUMAR, 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.

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DATE:19.4.22

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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 the necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude towards our 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

There is a growing demand for water treatment solutions due to global environmental concerns such as water resource deterioration and depletion. The use of micro- and nanobubble (MNB) technologies in sewage treatment has emerged as a promising solution to these problems. Bulk nanobubbles, which have great qualities different to microbubbles such as high water stability, longer retention time, and ability to create free radicals, have attracted attention in recent years for their technical advantages and potential uses in wastewater treatment. This article discusses the methods used to generate MNBs and highlights the most relevant papers on sewage treatment in the field of Micro Nano Bubbles.

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LIST OF ABBREVIATIONS:-

ACRONYM	ABBREVIATION
MNB's	Micro Nano Bubbles
DO	Dissolved Oxygen
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
SEM	Scanning Electron Microscope
AFM	Atomic Force Microscope
BNB	Bulk Nano Bubbles
NTA	Nano particle tracking analysis
DLS	Dynamic light scattering
BDL	Below Deduction Limit

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CHAPTER – 1

INTRODUCTION

This water supply is inextricably linked to global economic development. Water scarcity, inequities in water delivery and production models, wasteful water usage, drought, and other environmental issues plague water supplies in many emerging nations. Furthermore, as a result of increased urbanization and industrialization, the volume of wastewater produced is increasing, posing considerable issues in terms of both water supply and quality. As a result, treatment of wastewater and recycling are becoming increasingly important in order to assure enough water availability. Natural identification treatments, such as sludges, have been used to remove toxins from both industrial and domestic wastewater. However, such procedures have disadvantages, such as high energy prices and the creation of a huge amount of solid trash, which increases disposal expenses. As a result, there is a pressing need to create a water treatment technology that can efficiently and sustainably manage the growing difficulties of water scarcity.

Micro- and nanobubbles have a potential option technique for water treatment in such a scenario. Nanobubbles are spherical packets with a diameter of less than 1 μm that can be found at the solid-liquid boundary or scattered in a liquid medium. Bulk nanobubbles, unlike ordinary microbubbles (diameter less than 50 μm) or conventional large bubbles (diameter greater than 1 mm), have unique physical properties that have gained attention for applications in bioremediation, agriculture, and biomedicine, with technological advantages and prospects in wastewater treatment.

MNBs are commonly used in water treatment techniques such as electro flotation and dissolved air flotation. Because of the greater bioactivity of MNBs, such approaches have been widely used for decontamination of domestic and industrial water treatment in recent years. MNB-based water treatments are also being used in other industries, including industry and agriculture, due to its huge feasibility. Their unique attribute of having a large surface area, for example, allows for efficient mass transfer between the liquid and gas phases, which aids chemical reactions. As a result of these activities, the MNB collapses, causing shock waves in the water and the generation of OH radicals.

In recent years, research on MNBs for water-related applications has increased

dramatically, with the goal of determining their viability as a long-term water treatment technique. Despite a large number of research and experimental evidence, MNBs' use and use in water treatment is still limited. In this regard, the goal of this research is to provide an overview of the existing literature on micro–nanobubbles and their uses in wastewater treatment.

1.1 FUNDAMENTAL PROPERTIES OF MNBS

Ordinary macrobubbles, microbubbles (MBs), and nanobubbles are the three forms of water bubbles that can be found in nature (NBs). Macro-bubbles have a diameter ranging from 100 μ m to 2 mm. These bubbles rise fast to the liquid's surface before collapsing. Microbubbles are smaller than macro bubbles, with a diameter ranging from 1 μ m to 100 μ m, and they shrink in the water before dissolving. NBs, on the other hand, are extremely small gas bubbles with various unique physical features that distinguish them from ordinary bubbles. NBs are typically $<1 \mu\text{m}$ in diameter; However, NBs with a diameter of less than 99.9 nm drift randomly in so-called Brownian motion and have low buoyancy. It can be left suspended in liquid for a long time and has the ability to change the typical properties of time and water. Despite later research, there is still debate on the size of NBs and whether they exist in solutions under atmospheric circumstances. Because of the radius curvature limit, NBs cannot exist or be stable, according to classical thermodynamics theory. For instance, the tiny radius of curvature gives NBs a better internal pressure relative to the external pressure, which results in rapid dissolution. The key assumption behind these phenomena is that the NB's high internal pressure does not attain stability with the atmosphere, causing the bubbles to burst in a short period of time. Through AFM, Lou et al discovered NBs as bright and relatively stable spheres on a flat solid surface for the first time (atomic force microscopy).

However, additional approaches for NB study, including as neutron reflectometry, X-ray reflectivity, and quartz crystal microbalance, have been used in recent years. The extended lifespan of NBs allows them to have a wider contact angle and spend more time in liquids, which is one of their distinguishing characteristics.

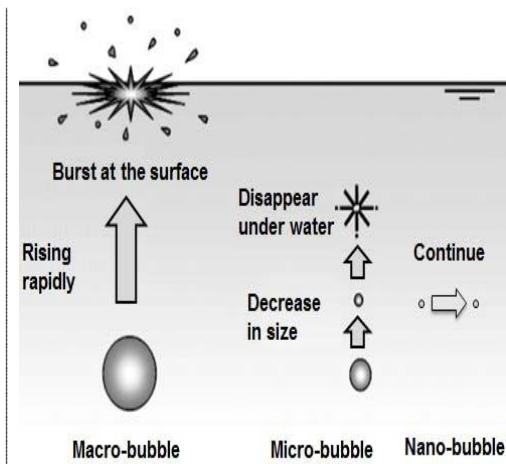


Fig: 1.1: Behavior of Macrobubble, microbubble (MB) and nanobubble

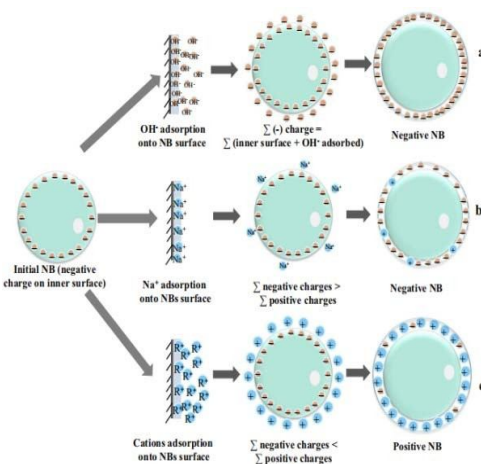


Fig: 1.2: Micro nano bubbles with negatively and favorably altered

1.1.1 High stability

Johnson and Cook published their first paper on studying large nanobubbles (1981). They found that shearing seawater could produce nanometer-scale gas-filled bubbles that were stable for up to 24 hours due to the presence of surface films produced by naturally occurring surfactants. The additional pressure exerted on the spherical bubbles in the liquid can be explained using the Young-Laplace equation by classical thermodynamics.

$$p_c = \sigma (1/R_1 + 1/R_2),$$

for above equation p_c =capillary pressure, and the pressure difference at the interface between the two liquids with respect to the surface tension σ and R_1, R_2 =principal curvatures.

However, with the advent of nanobubble tracking technologies such as laser diffraction techniques and other detection methods in the last ten years, more data has confirmed that nanobubbles can survive in liquid media for a long period. Their compact size and great interface potential are to blame for this. Ordinary huge bubbles will quickly rise to the surface due to buoyancy and dissipate, however bulk nanobubbles might float for days or even months.

1.1.2 Ionized potential of MNBs

Ionized potential is a physical property used to measure the magnitude of the attractive or electrostatic repulsive force between a particle and a bubble. This is an important property that determines the life of colloidal MNBs. The Smulochowski equation is used to determine the zeta potential. MB and NB have a negative charge

in the pH range of 2-12, depending on the kind of gas supplied, and a zeta potential of 50-40 mV and 30-20 mV at neutral pH, respectively. The excess of hydroxyl ions (OH) relative to hydrogen ions (H) at the gas-water interface determines the negative value of the zeta potential. The preferential adsorption of hydroxyl ions in the electrolytic solution is also linked to the charging mechanism of NBs. Furthermore, the NBs' stability is strongly reliant on hydrogen bonding at the water-gas interface, resulting in an impermeable, kinetically stable surface that is more diffusion resistant.

1.1.3 Mass transfer properties

The fuel transfer rate is a typical metric for determining the efficacy of different gas-liquid phase operations. As a consequence, mass transportation is a critical component of the system. Mass transfer efficiency is affected by bubble particles size, ascension rate, fuel hydraulics, decay flocculation and surface-area-to-volume ratio, as well as physical characteristics. According to the gaseous absorption two-membrane hypothesis, the mass flow rate of liquid-gas and the surface area define the diffusion coefficient of two phases. Volume ratio and concentration gradients exist within these phases. The unsteady state technique is used to compute the fuel mass transfer coefficient. In investigations, many correlation methodologies for measuring mass have been established.

Various mathematically based MB transfer coefficients model. Bredwell & Worden proposed a dynamic approach that focused on factors such as mass transfer coefficient reductions in bubble size. This was numerically solved with an unique Micro Bubble of size 22 μ m. Moreover, Ying et al. A model has been created to increase the mass transfer coefficient. This has something to do with the rate of CO₂ dioxide transport, which is governed by the bubble size. Following that, Li et al. constructed a stirring reactor. It was used to study mass transfer processes and has a memory of 51 megabytes. They discovered that sending solid liquid through the Micro Bubble generating raises its temperature and affects gas solubility, particularly for small volumes of bulk liquid. They calculated the mass transfer coefficient at 22 °C using the temperature correlation coefficient.

1.1.4 High gas-liquid mass transfer

Surrounding bulk nanobubbles in water, a fuel interface exists, generating bubble compression and, as a result, continual shrinkage of the bubbles as they rise to the water surface, as well as the appearance of a self-pressurization effect. As the size of the bubble shrinks, the amount of mass transfer from the inside to the surrounding

liquid increases, and the rate of gas flow from the elevated zone to the reduced zone is proportionate to the pressure gap (change of pressure per unit distance). Large nanobubbles have a high specific surface area because the contact area of a bubble is roughly related to its radius. Additional gas may dissolve into water across the bubble interface due to the self-pressurization effect of large nanobubbles, integration durations, and extremely large surface areas, and gas transfer efficiency to the liquid phase is significantly improved.

Unless their internal the explosion of nanobubbles and the formation of reactive oxygen species have been demonstrated in various studies using strong ultrasonic and hydrodynamic cavitation. As nanobubbles diminish, the induced electric density in the interlayer rapidly increases. Due to the quick change in the fuel interface, the huge concentration of ions accumulated on the interface at the time of bubble collapse releases the stored chemical energy. Meanwhile, when entrapped water molecules are compressed by dynamic stimuli, they are subjected to extremely high temperatures and pressures, causing cleavage and the generation of $\cdot\text{OH}$, O and $\cdot\text{O}_2$. The robust oxidation activity of these reactive species is increasingly being investigated for use in enhanced oxidation processes to address chronic organic contaminants in wastewater treatment and pathogen disinfection.

Due to the unique characteristics stated above, bulk nanobubbles are garnering growing interest in the wastewater treatment field, and they show exceptional potential in improving typical organic matter removal approaches. Mass nanobubbles can effectively remove contaminants from water in a variety of ways, according to previous research, including: (1) improving the air buoyancy process to remove fatty acids, oils, relatively low natural suspended matter, and colloidal particles; (2) promoting aerobic conditions in water to enhance the conventional anaerobic decomposition processes of physiological granular activated carbon, aeration tank, and membrane bioreactors; and (3) generating bulk nanobubbles.

1.2 MNB GENERATION MECHANISM

MNB develops on the top of hydrophilic particles. MNB formation can be caused by a variety of factors, based on whether it happens inside too or outside the body. Blisters are generated in the traditional method by burning the gas beneath pressure and afterwards expelling the gas while decreasing the pressure bubbles. A pump, a compressor, as well as an air tank are the main components of this technology. A water pump pushes circulating water at a specific pressure into the dissolving gas tank and air. The compressor pushes air into the dissolving gas tank, leading to a high gas-water mixed state. As a result of the abrupt compression, the gas precipitates out of the water as MNB. The fluid in the transparent acrylic tank is circulated between the gas dissolving container and the MNB production nozzle by the pump. On the suction side, air is introduced into the pumped fluid and expelled through a high-pressure system. Following that, because to the pressure decrease at the nozzle, the gas phase of MNB is formed from water supersaturated by air. When comparing different bubble creation principles, there are significant variances on how MNBs are created. When a homogenous liquid undergoes change due to abrupt pressure, NB is common. Is beneath the critical threshold, which is referred to as cavitation. Cavitation is most commonly induced by high pressure changes caused by ultrasonic waves or moving liquids (hydrodynamic cavitation). NBs can also be produced using technique is the method and commodity chemicals such as electrolysis.

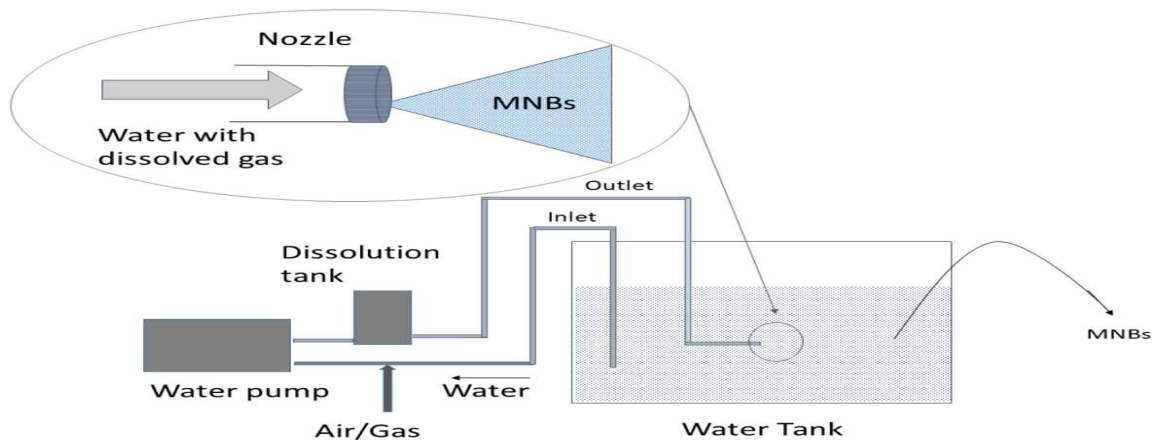


Fig:1.3: Methodology of MNB generation

The hydrodynamic cavitation mechanism is extensively employed to create NBs with the Venturi-type generator. The Venturi system is made up of three basic components: input flow, tubular output flow, and tapered output flow. By raising the

speed of the fluid in the converging portions of the narrow diameter pipe, the pressure in the Venturi tube can be reduced. To generate bubbles in a Venturi-type generating system, liquid and gas are sent through the Venturi tube at the same time. When pressurized liquid is fed into the tubular component, the fluid flow into the cylindrical throat increases, while the pressure in the input section decreases, resulting in cavitation. NBs are available in a variety of sizes (within several hundred nanometers).

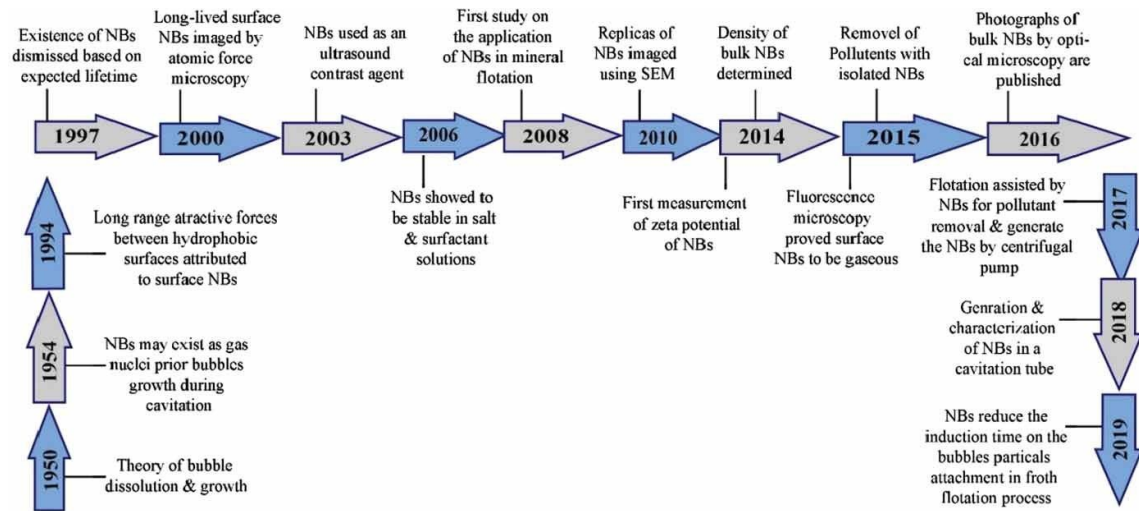


Fig: 1.4: A timeline of the study and development of the MNB application.

Figure 4 depicts a timeline of the MNB application's research and development. Ahmadi & Darban employed a Venturi tube to generate Nano Bubbles of 133–535 nm using the hydrodynamic cavitation approach [16]. Wu et al. created Nano Bubbles with a diameter of less than 500 nm via hydrodynamic cavitation. Cho et al. created Nano Bubbles with a mean size of 300–500 nm using a palladium electrodes and ultrasonication. According to Oeffinger & Wheatley, ultrasonication only with octa-fluoro propane generated NBs with a mean size of 452–704 nm.

Table 1.1 Advantages and disadvantages of commonly used MNB generation methods.

	Method	Principle	Advantage	Disadvantage
Dissolving– Gas method	Dissolving gas with pressure and releasing gas while reducing gas while reducing pressure.	Dissolve the gas in water at high pressure and form a supersaturation state , then enter the gas to reduce pressure and form a large number of fine bubbles.	The efficiency is low since the whole process is continuous.	At high pressure, the gas is highly soluble, so the number of bubbles is large and more bubbles rise stably.
	High speed rotation	Fine bubbles are produced directly By the gas dispersed by the impeller	The process is complex usually forms large bubbles (>50 μm) Simple principle, efficiently	Simple principle , efficiently produced in the combination of gas - water mixtures , more dissolution and release of the gas into the pump
Dispersing releasing method	Dissolving gas with pressure and releasing gas with impeller	The gas–water mixture flows into pressurized gas. The gas cuts into ultra-fine bubbles and rotates as the water passes	The flow path is difficult to design and produce.	Generally high quality and highly efficient.
	Fine porous materials	The flow cross-section slowly decreases and then quickly increases; the water collapses violently and vortices are formed. Repeating the process leads to stronger turbulence and finer bubbles.	A large flow path makes it easy to repair and less likely to block up.	Difficult to adjust oxygen content during streaming significant changes in conditions.
	Flow path process	The pressure gas forms fine bubbles through the strength of small porous materials	Stuck frequently	The quality of the bubbles mainly depends on the porous material.

1.3 Outcome of diverse operational situations on bubble length.

According to the literature, the dispersion and duration of MNBs are influenced by the device's design and operational conditions. The tension variations across the nozzle device, for example, are usually connected to the fraction and length of MBs. Because of the increase in air density, the bubble length decreases as the stress increases. However, for pressures more than 3.3% atm, the duration of MBs remains constant, whereas the scale of NBs is determined specifically by factors such as hose

scale and form, stress, and sonic power. Furthermore, different types of gases have different effects on the duration of NBs. For example, when atmospheric air is used to create the bubbles, the existence of NBs can be identified for days, whereas in the form of air bubble, the lifetime is limited for less than 1 h. The use of a higher molecular weight fueloline for macrobubbles compliments the density and thus impacts in smaller bubbles. In terms of chemical qualities, studies have compared the impact of electrolyte solutions (containing NaCl and other salty ion) and frothers (organic additions) on seawater, as well as rotor speed and inflow rate. The results showed that a lower rotor rate (4.3 m/s) or a high fueloline rate (0.4 cm/s) formed an 852 m-long bubble of sea salt solution, which was better to the sizes produced with the aid of frothers (610– 710 m). Similarly, the interaction of salt and frothers has been explained in relation to the evaluation on a single rotor rate and fueloline fluid velocity, which indicated that, with out frother, bubbles created in sea-salt solution and 0.4M NaCl were much smaller than in de - ionized water. In terms of the attention range of frothers, the research found that adding a tiny quantity of frother (10 ppm) to the NaCl aqueous solution (0.4 M) resulted in very long-length bubbles, but ionic responses above the interest of 10 ppm resulted in bubbles of comparable length. Furthermore, the research evaluated cases in which the ionic charge of the electrolyte was considered in relation to the essential coalescence attention. In comparison to the NaCl solution, the sea salt solution (0.8 ionic energy) produced huge bubbles (0.4 ionic energy). Because of the inter-movement of inorganic salts contained in the sea-salt solution, the size of the bubbles expanded in the comparison of NaCl and sea-salt solutions. Many studies used NaCl as a base with other salt ions (KCl, etc.) to analyse their impact on the size of the bubbles separately, finding that the varied salt ions had no discernible effect on the bubble length.

1.4 CHARACTERISTICS THAT MAKE NANOBUBBLE AN AERATION METHOD.

Nanobubbles are incredibly small gaseous bubbles with unique mechanical properties that distinguish them from regular bubbles. Nanobubbles are an excellent aeration solution for a variety of applications around the world due to these characteristics.

1.4.1 Neutral Buoyancy

Nanobubbles have a normal mean diameter of roughly 82nm, according to extensive testing undertaken by performing tests using Malvern's Tiny Sight Nanomaterials Monitoring Analysis programme. Because bubbles this tiny lack the buoyancy to reach the surface, they travel in Brownian motion instead. The nanobubbles float in the water for several quarters before dissolving, travelling about arbitrarily over the waterbody and effectively oxygenating the entire column of water. As a result, the levels of dissolved oxygen (DO) measured deep within the tank or pond will be identical to those measured above. The peculiar nature of nanobubbles enables them to give an even dispersion of O_2 throughout one body of water.

1.4.2 Surface charge

By definition, all bubbles have a surface charge. The generally smaller the bubble, the higher the surface charge. Zeta potential is the electro kinetic potential in colloidal dispersions, and nanobubbles have a high zeta potential. In zeta-sizer studies, nanobubbles with a high negative charge were shown to inhibit coalescence, showing that the bubble's integrity may be maintained at any depth for long periods of time. Furthermore, the particles' charge density, together with their great concentrations, enhances flotation removal efficiency by increasing the likelihood of collisions. This one-of-a-kind characteristic allows sewage, oil and natural gas, and mining companies to float significantly more suspended trash than they could previously.

1.4.3 Gas Reserve

Nanobubbles can stay in suspension for months due to their neutral buoyancy and negative surface charge. This occurs after the fluid has reached oxygen saturation. In this function, the nanobubbles serve as a gaseous reservoir in the solution. As oxygen is extracted from the water by life, chemistry, or off-gassing, the nanobubbles quickly diffuse new oxygen into the water, sustaining high dissolved oxygen concentrations till the nanobubbles are exhausted. This additional gas resource, estimated to be up to 20% over saturation, enables businesses to use gas more cost effectively than ever before.

1.4.4 Surface Area

Nanobubbles have 405 times the area of the surface of a normal microbubble, which has a diameter of 42 micrometers. Because of the higher surface area, mass transfer is increased, guaranteeing that almost any gas can be delivered successfully to water.

1.4.5 Oxygen Transfer Efficiency

Any aeration application must ensure that oxygen is delivered efficiently into the body of water. Conventional aeration systems only transfer 2 percent to 4 percent of oxygen per foot of water due to their size and associated rapid rise rate. Traditional aeration as a result is ineffective. As a consequence, aeration is estimated to consume between 1.5 and 2.5 percent of global energy, with most of it going towards sewage treatment. The Nanobubble System's innovation capitalises of nanobubbles' unique properties to reach an OTE of over 86 percent per foot of water, which is the highest in the industry. Nanobubbles in water have a long lifetime and a big surface area per volume, making them most efficient aeration technique currently available, allowing operators to significantly reduce operating costs.

1.4.6 Oxidation

The zeta potential is a basic metric for colloidal dispersion stability. The higher the ionized potential, more the stable the behaviour of interfacial particles. Nanobubbles have a higher zeta potential than larger bubbles, which means their connections with interfacial nanoparticles are more stable. Excess ions and free radicals are created as a result of the increased zeta potential. Oxidation can form free radical damage, which seem to be molecules with an unusual number of electrons, when it combines with particular chemicals. Free radicals are used in burning, atmospheric science, polymer, ionized chemistry, toxicology, and other chemical reactions.

1.4.7 Size of the bubbles

Nanobubbles are 490 times tiny than microbubbles, or approximately the length of a viral, and are the world's tiniest bubbles. Nanobubbles can fit significantly more in the same quantity of water as regular bubbles at this scale. They exhibit a range of unusual characteristics because to their small size, including water level, a strong electric charges, and a large flow efficiency. When compared to nanobubbles, bigger bubbles lack these features, making them less appropriate for a variety of applications.

1.5 Application of MNB technology in water treatment

1.5.1 Aeration in water

Aeration is essential for transport of oxygen in water treatment since oxygen is not only a crucial element for aquatic species' survival, but also an enzymatic reaction platform for the removal of oxidative contaminants. On the other hand, standard ventilation uses a lot of energy and only transfers 615 percent of the oxygen. When MNB is used instead of typical aeration bubbles, dissolved oxygen levels are increased, oxidation is encouraged, and oxygen mass transfer is increased. The oxygen consumption and mass transfer coefficient of synthetic wastewater treatment systems using MNB aeration are nearly double those of conventional bubble aeration systems. The effects of MB and traditional aeration on water purification in the Black Doll River were examined by Hong et al. At the same aeration intensity, MB can produce more dissolved oxygen (DO). After 58 minutes of aeration, the DO concentrations of MB and normal aeration were 9.83 mg/L and 7.54 mg/L, respectively. COD, NH₃N, Geosmin, and 2-methylisoborneol from MB, on the other hand, were 12 percent, 11%, 15%, and 13 percent greater than normal aeration, respectively. 4.2.

1.5.2 Degradation of organic pollutants and disinfection of water

Micro Nano Bubble not only increases chemical usage due to a high bulk transfer efficiency, but it may also generate hydroxyl when it decays and reacts with organic contaminants directly and non-selectively. Hydraulic cavitation-produced MNBs have been shown to significantly speed up the oxidative breakdown of refractory organic contaminants. Chuetal. The increased performance of MNB in ozone oxidation with sewage simulated with azo dyes was investigated, and it was discovered that the overall mass flow rate of ozone and the extraction efficiency of TOC rose by 82% and 35%, respectively. Panetal, To investigate the degradation process using MB produced by cavitation, Li. Phenol and chlorobenzene were chosen as model organic contaminants. The ozone mass transmission rate of MB is 1.32.8 times that of normal bubble aeration, and only 50% of ozone is required for roughly 70 MB of aeration. Traditional bubbling necessitates the use of this ingredient. Although the overall disintegration of phenol follows the main reaction rate, the apparent rate of a reaction constants of Microbubble is 1.8-4.3 times that of traditional bubbles. Moreover, study on the effects of Microbubbles on enteropathogens has revealed that hydroxide ions

and shock waves created by MB degradation are thought to be the primary causes of coliform deactivation.

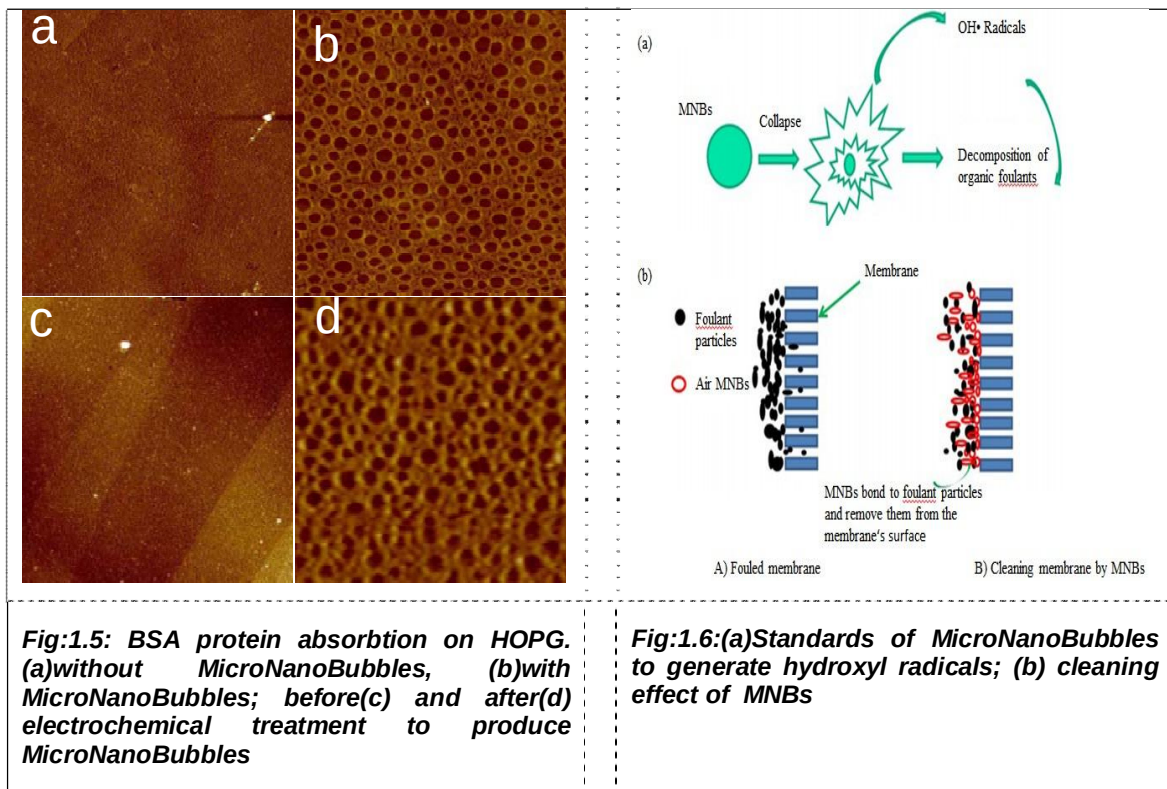
1.5.3 Flotation with MNBs

In the realm of trace polluted water and corporate wastewater treatment, air levitation is commonly employed as a develop breakthrough separation technology. The primary premise of the air flotation technique is to use highly distributed microbubbles precipitated from water as a carrier to bind to contaminants in wastewater and then transport the resulting floc utilizing buoyancy. Due to their unique characteristics of high particular contact area, high zeta potential, and extended residence time in water, MNBs promote longer contact duration and increased adhesion effectiveness of bubbles and suspended solids, resulting in solids liquid efficient separation. In print and dying sewage treatment studies, Liu et al used air flotation technology of classical bubbles and MNBs, which indicated that MNB air floatation technology speeds up pretreatment and successfully lowers flocculants. Fuel, COD, and chroma removal rates are 41 percent, 33 percent, and 108 percent greater, respectively, than those of an air flotation method utilizing standard bubbles.

1.5.4 Membrane cleaning

Micro Nano Bubbles are being used to avoid contact clogging and reduce the surface contamination as environmentally acceptable and inductive analysis cleaning agents, such as inhibiting the adhesion of bovine serum protein on the mica surface and assisting in the degradation of various pollutants on HOPG. Furthermore, a mixture of moderate, rising ultrasonic and MNB has been demonstrated to be effective in preventing germs and algae from adhering to solid surfaces. Dayarath neetal the effect of air Micro Nano Bubbles on permeate flux, TMP (penetration pressure), and solvent extraction using reverse osmosis membranes were evaluated in lab and pilot-scale crossflow filtering operations. MNB successfully reduced and/or prevented the formation of concentration polarisation layers, improving permeation flow and solute removal by 24.52 percent and 0.85 percent, respectively, according to the findings. Furthermore, simple physical purification can increase the recovery of membrane penetration flux to 100%. The absorption ratio of BSA on the Micro Nano Bubble-modified HOPG surface generated by Hu Jun et al. after 22 seconds of electrocoagulation is 66 percent 74 percent, which is 26% higher than the MNB-modified HOPG surface. AFM found a reduction of 34%. 1.5.1 Figure (b). BSA coverage was reduced to 81 after 52 seconds of electrocoagulation when it was

entirely applied to the surface of HOPG. 1.5.1 is a diagram (d).The continuous three-phase line forces the NB generated between both the HOPG and the BSA layers to shift the adsorption proteins from of the solid, liquid linking to the liquid-air contact by detecting its creation in situ. It was rumored that it had been completed. Low shear flow, in other words, virtually eliminates peptide destabilization at the liquid-air interface.



CHAPTER – 2

LITERATURE REVIEW

- Era and characterization of nanobubbles by ionization method for wastewater treatment A) C. Rameshkumar, B) Senthilkumar, C) R. SBLAKHMI, D) Risa Gogoid.
- New technology is constantly required to treat all or part of water. A small amount of water treated in the laboratory is brought into a suitable system and a large amount of water needs to be purified. The cost of this system is very low compared to other available systems and it is very easy to use.
- A case study of nanobubble technology to improve heat transfer of ethylene glycol refrigerant oils. a) A. Sobhanadri, b) G. Senthilkumar, C) S Lakshmi Sankar, d) m. Purusothaman, e) c. Rameshkumar In this study, the heat transfer potential of ethylene glycol ($C_2H_6O_2$) for doubling the refrigerant for each autobonne was examined experimentally. The fluid tested is a mixture of water and ethylene glycol at a rate of 50:50. Heat exchangers play an important role in energy saving, conversion and recovery.
- Application of ozone micro and nanobubble technology in water and drainage treatment a) j. Korean Society This review provides an overview of the application of micro and nano bubble ozone treatments for purifying water and wastewater. An efficient audit of the impediments of already talked about innovations and the application of hydrodynamic ozone treatment to manufactured fluid arrangements and different mechanical wastewaters.
- The basic phenomena of nanobubbles and their behavior in wastewater treatment technology. a) Anup Gurung. The importance of nanobubbles is widely recognized, especially with respect to their role in bubble size and stability. Nanobubbles are small crown-shaped bubbles that have some unique physical and mechanical properties.

- Use of ozone micro-nano bubbles for groundwater purification. a) Liming Hu. b) Zhiran Xia. In this paper, we introduced the high efficiency of gas supply and mass transfer in water using MNB. Ozone MNB technology has been applied to groundwater purification in the field at sites contaminated with organic matter. • Nanobubble stability. a) Jay N Meegoda, b) Shaini Aluthgun Hewage, and c) Janitha H Batagoda.
- Research on nanobubbles in aqueous solutions for a variety of applications. a) g. Senentilkumar, B) c. Rameshkumar, c) m. N. V. S. Nikhil and d) J. Navin Ram Kumar. This paper lists the simplest methods and practical applications for creating nanobubbles in various aqueous solutions. Tap water, distilled water, muddy water, and seawater containing or not containing nanobubbles, chemical oxygen demand, biochemical oxygen demand, total suspended solids, total dissolved solids, dissolved oxygen, nitrates, phosphates, Chromium, and sulfide levels were tested.
- Standards and applications of microbubble and nanobubble advances for water treatment. a) Ashutosh Agarwal, b) ZWun JernNg, Yu Liu. This article describes physics, how to generate microbubbles (MB) and nanobubbles (NB), and about the generation of free radicals from MB and NB, decomposing toxic compounds, disinfecting water, and solid surfaces. I will focus on cleaning / de-souling. Includes membrane. Due to its ability to generate free radicals, the future outlook for MB and NB is expected to be immeasurable and needs further investigation.
- Submicron size bubble generation and characterization. a) Chendiu, b) Kirsten Nassette, C) Jacob Maslier, D) Zhenhe Xu. The duration of movement and temperature showed only limit effects on the occurrence of submicron-sized foam. Surface properties such as zeta potential and submicron size bubble stability were largely dependent on the chemical properties of the solution in which air bubbles occur.
- Basic characteristics and use of micro nanobubbles in water treatment

A) Mengdi Zhang, B) Lip QIU1, C) GUICAI LIU. The application of MNBS in hydroxygen, decomposition of contaminants and membrane cleaning. These reviews are intended to provide guidance for the theoretical research and practical application of MNB.

- Use of micro-nano bubbles in groundwater purification. a) Sabeera Haris, b) Xiaobin Qiu, c) Harald Klammler, d) Mohamed M.A. Mohamed. This paper summarizes recent results on the use of MNB technology to repair contaminated groundwater bodies. Finally, we discuss the current challenges and limitations of using MNB for groundwater purification.
- Nano-ozone bubbles for drinking water treatment. a) Janitha Batagoda, b) Seasonal Aluthgun Hewage, C) Jay N. Meegoda. The original summarizes the method of manufacturing the nanobubbles for drinking water treatment on a commercial scale and showed a method of increasing the method of using a ceramic diffuser in a therapeutic plant. In addition, Costbenefit analysis was presented to emphasize the advantage of using ozone as a nanobubble.
- Basics and applications of nanobubbles. a) Elisavet D. Michailidi, b) George Bomis, c) Athanasios Varoutoglou, d) Eleni K. Efthimiadoua, e) Evangelos P. Favvasa
- • Comparative think about of microbubble arrangement by mechanical blending and sonication. a) Qingyi Xu, B) Nakajima Mitsu-san, C) Sichuan Kenichi, D) Nakamura Enri, E) Shiina Takeo. This paper evaluates the developmental efficiency of two frequently used methods, mechanical agitation and operation in two surfactant systems. As a result, superrational internation indicated that the higher gas holder, smaller bubble sizes and larger interface areas, which are more effective as mechanical motion in microbubbles.
- Generate microbubbles and strengthen the transportation process using microbubbles. a) Rajeev Parmar, b) Subrata Kumar Majumder. The purpose of this article is to provide an up-to-date assessment of previous research on microbubble-based transportation processes. In this article, we reported on various methods of creating microbubbles

and the characteristics of microbubbles.

- Microbubble-separated yeast breeding fermentation process for bioethanol production. a) Vijayendran Raghavendran¹, b) Joseph P. Webb, c) Michaël L. Cartron, d) Vicki Springthorpe, e) Tony R. Larson, f) Michael Hines.
- <https://nanocomposix.com/pages/zetapotentialmeasurements>. The conclusions reached relate to the measurement of zeta potential and the method used to measure it.
- Micro and nano bubble technology as a new horizon for water treatment technology. a) Tatek Temesgena, b) Thi Thuy Bui, c) Mooyoung Han, d) Chungil Kim, e) Hyunju Park. This review ranks studies conducted in the areas of microbubbles and nanobubbles with a particular focus on water treatment. The basic definition of bubble type and its size range is also presented based on the explanations of various researchers.
- Nanobubble technology offers the opportunity to improve water treatment. a) Ariel J. Atkinson, b) Onur G. Apple, c) Oren Schneider, d) Sergi Garcia Segura, e) Paul Westerhof. The paper states that NB will open up opportunities to improve current technologies or allow new technologies to produce fewer by-products and achieve cleaner water.
- Standards and applications of microbubble and nanobubble propels for water treatment. a) Ashutosh Agarwal, b) Wun Jern Ng Yu Liu. This paper describes physics, how to generate microbubbles (MB) and nanobubbles (NB), and for free radical generation from MB and NB, decomposition of toxic compounds, disinfection of water, and solids including membranes. The focus will be on cleaning the surface.
- Impacts and applications of little scale and nanobubbles in water refinement. a) Baljinder Singh, b) Nutan Shukla, c) Chan Hyun Cho, d) Byung Sun Kim, e) Myoung Hwan Park, f) Kibeom Kim. This study describes the current applications of microbubbles and nanobubbles using traditional advanced techniques such as flotation, aeration, and ozone treatment, capable of removing impurities and colors,

disinfecting water, and oxidizing organic pollutants. To do. Bubble technology has emerged as a potential platform for successfully extracting harmful pollutants from water using these technologies.

- Micro-nano bubble technology and water-related applications. a) Palwasha Khan, b) Wenjing Zhu, c) Feng Huang, d) Wanlin Gao, e) Nasir Abbas Khan This study is true despite the promising role of MNB in water-related applications. We conclude that we have not reached the possibility of. In particular, MNB applications need to be improved more extensively.

CHAPTER – 3

AIM AND SCOPE OF PRESENT INVESTIGATION

3.1 AIM.

The main goal of this work is to use nanobubble technology to purify wastewater from urbanization waste, such as wastewater from laundry and wastewater from cleaned utensils, etc. In addition to the various technologies that exist in the world today, such as seawater desalination and distillation, purification of wastewater from urbanized waste through the nanobubble technology is the modern strategy for the refinement of wastewater. Nanobubble technology is an up-and-coming technology with a wide range of applications.

3.2 SCOPE.

We humans pollute water for our desires and uses. There are many other water treatment processes, such as desalination, but this nanotechnology has been chosen because of its low complexity and cost effectiveness. This nanotechnology is a technology that is emerging in today's world. Therefore, they are used to purify wastewater.

CHAPTER - 4

MATERIALS AND METHODS

Nanobubble generator and wastewater are the components used in this method. To begin, we gathered wastewater from urbanization waste, such as wastewater from laundry and wastewater from cleansed utensils.



Fig: 4.1: Wastewater Sample.

The wastewater sample above was taken from urbanization waste. The water is now being tested for purity. And I requested several tests from the Chennai Mettlex lab private limited, which is located near Guindy in Chennai. pH reading at 25 degrees, dissolved oxygen content (DO), total amount of dissolved solids (TDS), total suspended solids (TSS), amount of phosphate content, amount of chromium content, amount of sulphides present in the sample, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD). As stated in the table below, are the values reported.

Table 4.1. These are the test findings for the wastewater sample (before purification).

Sl.No	Test parameters	Results
1.	pH at 25°C	6.25
2.	Dissolved Oxygen (DO)	5.9 mg/l
3.	Total Dissolved Oxygen (TDS)	1225 mg/l
4.	BOD at 27°C for three days	17 mg/l
5.	COD	93 mg/l
6.	Total Phosphate as P	0.23 mg/l
7.	Total Chromium as Cr	0.201 mg/l
8.	Sulphides as H ₂ S	0.136 mg/l
9.	Total Suspended Solids (TSS)	18 mg/l

We can confirm that the wastewater from urbanized waste is contaminated based on the preceding test results. The key goal now is to use nanobubble technology to purify this ground water. As a result, the first and most important step is to create nanobubbles. The technique of hydrodynamic oxidation is used to create nanobubbles. The figure 4.2 is the equipment for nanobubble generation. A motor, inlet valves, outlet valves, a nozzle, and a pressure regulator these are the equipment's used for MNB generation.

To provide a controlled flow of air, the amount of air to be drawn from the oxygen cylinder is adjusted using an inlet valve. So that nanobubbles can be generated in a controlled manner in the water. Bulk nanobubbles, micro-nanobubbles, and macro-nanobubbles are among the nanobubbles produced. The figure 4.3 shows the inlet valves in which the pressure is regulated and the figure 4.4 shows the motor.

The generation of nanobubbles is done for various oxidation times such as 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes, and 30 minutes. The density of bubbles increases as the oxidation times increase.



Fig: 4.2: Nanobubble Generation Equipment

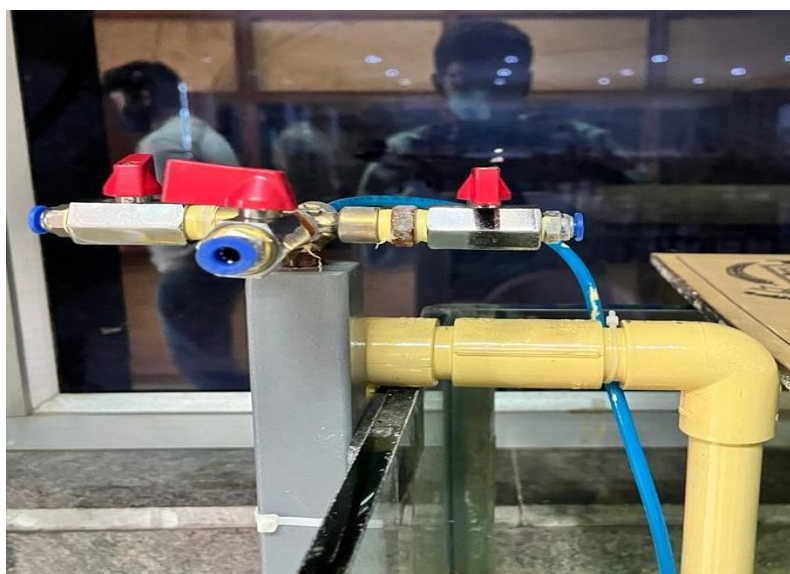


Fig: 4.3: Inlet Valves



Fig: 4.4: Motor

After creating the nanobubbles, the waste is collected from the water and treated with reverse osmosis. And after this the water is collected from the outlet valve. The water is now being sent to the Chennai Mettlex lab in Guindy, Chennai, for purification testing.

CHAPTER - 5

RESULTS AND DISCUSSION

5.1 RESULTS.

Nanobubbles are produced at various oxidation times such as 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes and 30 minutes. In each case, it was observed that the thickness of the number of bubbles increased by 10 to 8 times. Therefore, we conclude that the bubble number density is proportional to the oxidation time. In other words, the longer the oxidation time, the higher the bubble number density.

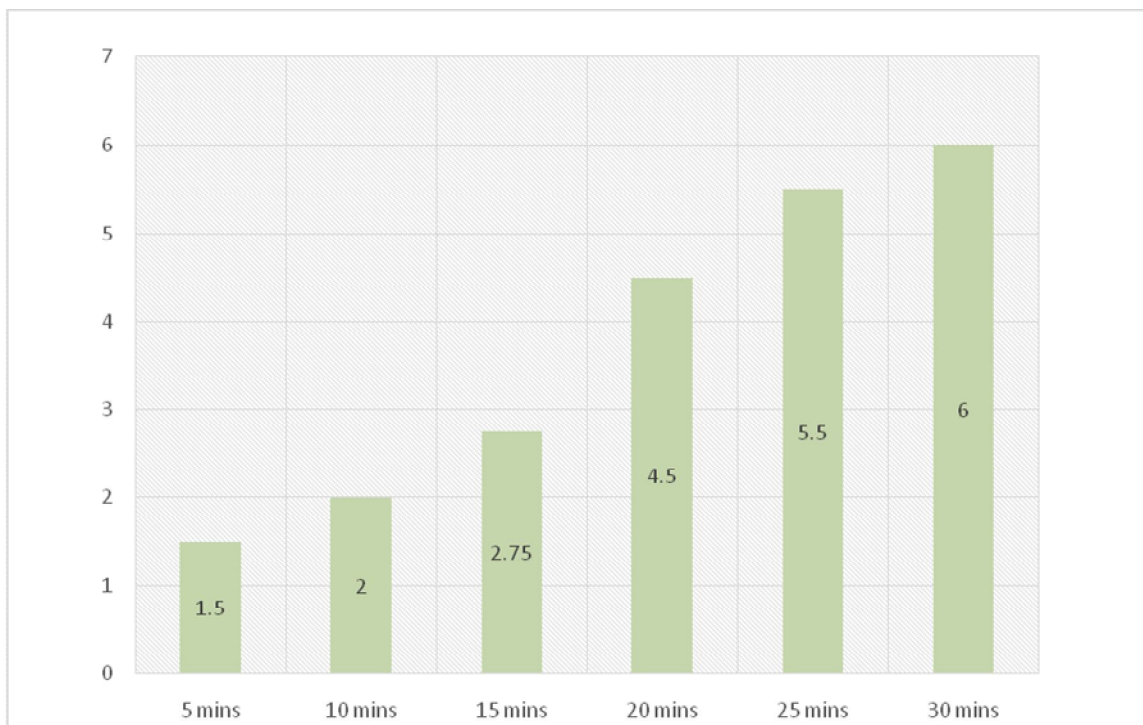


Fig: 5.1: bubble density with oxidation time

The x-axis shows the oxidation time, and the y-axis shows the bubble number density of 10 to the 8th power.

This technique also examines the characteristics of the bubble and draws specific conclusions. This is illustrated in the figure 5.1 For a clear understanding, the steps are performed before and after freezing. This will result in the following cases:

Case 1 : From the above figure we can conclude that, the pH of the water is also depending on the oxidation time.

That means, the pH is indirectly dependent on the bubble number density. because, if the oxidation time, the bubble number density also increases. we can see from the graph, that the curve rapidly moving up. Figure 5.2 indicates the graph between ph and the time period.

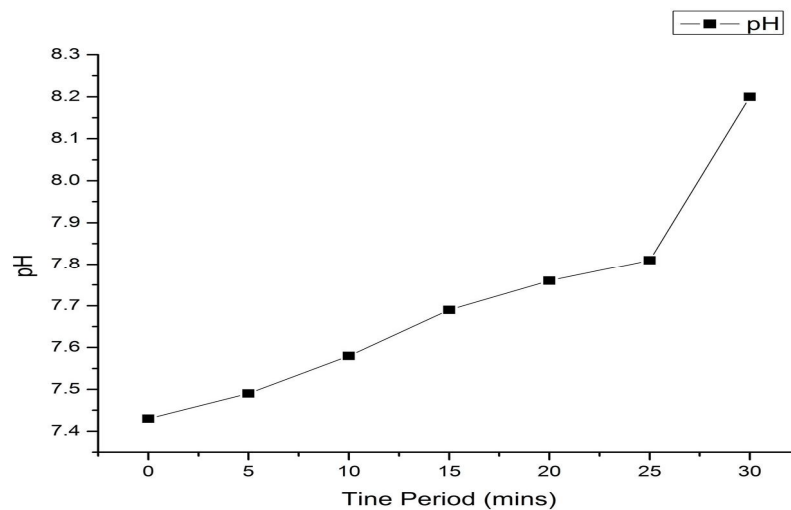


Fig: 5.2: ph. vs Time period graph

Case 2 : now coming to the case 2, in water the total suspended solids should be low. In order to get that, we need to generate the nanobubbles more to reduce the total suspended solids. The graph depicts that the total suspended solids are decreasing with the increase in the oxidation time. and that's why we can see the graph is coming down that implies, that the total suspended solids are reduced. Initially, the total suspended solids are nearly 21 ppm. but after 5 mins of oxidation, the total suspended solids are reduced to 17 ppm, in the same way at 30 mins of oxidation, the total suspended solids are almost 4ppm.

Figure 5.3 shows the relation between TSS and time period.

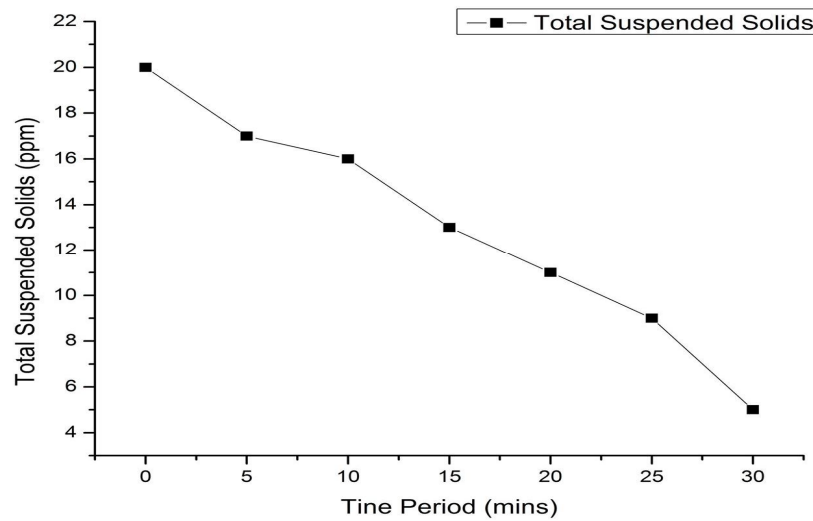


Fig: 5.3: TSS vs Time period

Case 3 : In water the total dissolved solids should also be low. in order to get that, we need to generate the nanobubbles more to reduce the total dissolved solids. The graph depicts that the total dissolved solids are decreasing with the increase in the oxidation time. and that's why we can see the graph is coming down that implies, that the total dissolved solids are reduced. Figure 5.4 depicts the graph between TDS and time period.

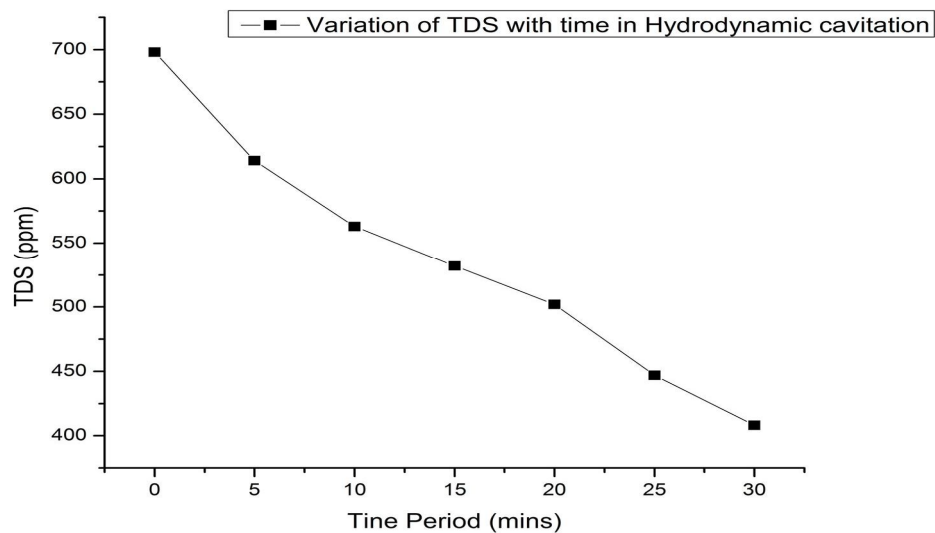


Fig: 5.4: TDS vs Time period

Case 4 : Dissolved oxygen of pure water is 8.11 mg/l. in the wastewater we collected, the dissolved oxygen content is near to 6.0 mg/l. this needs to be increased. Dissolved oxygen is nothing but, the amount of oxygen content present in the water. since we are using hydrodynamic oxidation for the generation of the nanobubbles, this will increase the dissolved oxygen content present in the water. oxidation means addition of oxygen. hence, more oxidation time leads to more amount of dissolved oxygen. however excess of dissolved oxygen content is also not safe. Figure 5.5 show the graph of DO vs time period.

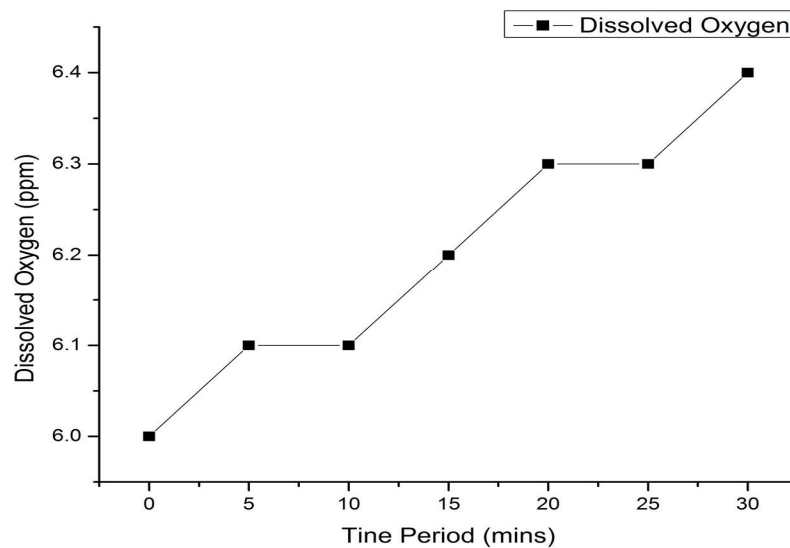


Fig : 5.5. DO vs Time period

The amount of oxygen that is present in the water is called as dissolved oxygen. The amount of dissolved oxygen content present in water , tells us a lot about the pure water. Adequate dissolved oxygen amount is good for all water bodies and plants. High amounts of dissolved oxygen can cause issues just as low concentrations can. After the observation and study on the nanobubbles, we found that, the dissolved oxygen content is increasing with the increase in sonication time i.e., oxidation time. This is because, the nanobubbles are being generated by using air. Air itself contains oxygen content in it. And so that's why, the dissolved oxygen content is drastically increasing with the increase in the oxidation time. The below graph shows the amount of dissolved oxygen content present in different oxidation times.

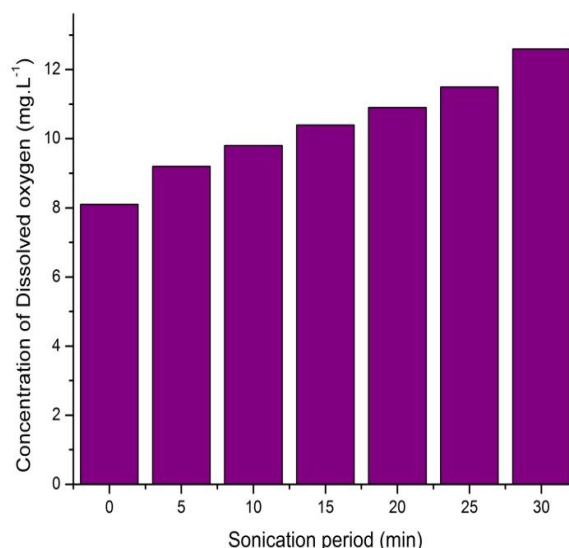


Fig: 5.6: Concentration of DO vs Sonication period

5.2 DISCUSSION.

After analyzing the characteristics of nanobubbles and determining the bubble number density, bubble diameter, and dissolved oxygen content, we are now moving on to the next phase, which is determining the extent to which water may be purified utilizing nanobubble technology. The water collected after the nanobubbles are created is delivered to a laboratory. pH reading at 25 degrees, dissolved oxygen content (DO), total amount of dissolved solids (TDS), total suspended solids (TSS), amount of phosphate content, amount of chromium content, amount of sulphides present in the sample, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Biological Oxygen Demand (COD). The test results are now available after a week. And the tests results are shown in the below figure 5.7. The below is the report sent from the Chennai Mettix lab private limited.

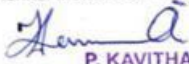
E-mail : test@mettexlab.com Web : www.mettexlab.com		Phone : 044-22323163, 22311034 42179490, 42179491	
		CHENNAI METTEX LAB PRIVATE LIMITED Jothi Complex, 83, M.K.N. Road, Guindy, Chennai - 600 032.	
			
TEST REPORT			
		Page No. 1 of 1	
ISSUED TO : Mr. Dr.Purusothaman.M, Dr.Senthil Kumar.G, P.K.S.Vikranth, Sathyabama Institute of Science and Technology, Chennai - 600 119.		T.C Date : 18.02.2022 T.C No : CML/21-22/67722	
Cust. Ref : SRF Dated : 12.02.2022		Date Of Receipt : 12.02.2022 Analysis Commenced On : 12.02.2022 Analysis Completed On : 18.02.2022	
Lab No : 2274264			
Sample Description : Water - Purified using Nano Bubble Technology (as stated by customer)			
S.No	Test Parameters	Protocol	Results
Discipline : Chemical			Group : Water
01	pH at 25°C	IS 3025 Part 11:1983 (Reaff. 2017)	8.20
02	Dissolved Oxygen	IS: 3025 Part 38-1989 (Reaff.2014)	6 mg/l
03	Total Dissolved Solids	IS 3025 Part 16:1984 (Reaff. 2017)	408 mg/l
04	BOD @ 27°C for 3 days	IS 3025 Part 44:1993 (Reaff. 2014)	6 mg/l
05	COD	IS: 3025 Part 58:2006 (Reaff. 2017)	36 mg/l
06	Total Suspended Solids	IS:3025 Part 17:1984 (Reaff.2017)	20 mg/l
07	Total Phosphate as P	IS:3025 Part 31:1988 (Reaff.2014)	0.423 mg/l
08	Sulphide as S	IS:3025 Part 29:1986 (Reaff.2014)	BDL (DL:0.01 mg/l)
09	Total Chromium as Cr	IS:3025 Part 65 (Reaff 2014)	BDL (DL:0.02 mg/l)
Abbreviation : BDL: Below Detection Limit, DL: Detection Limit			
End of Report 		For Chennai Mettex Lab Private Limited  P. KAVITHA Technical Manager	
NOTE: Any unauthorized alteration, forgery or falsification of the content or appearance of this document is unlawful and offenders will be liable for legal action. Unless otherwise stated the submitted results in this test report refer only to the sample(s) tested and such sample(s) are retained for 15 days only from the completion date of testing -- except in case of regulatory samples, which will be retained for a specific period as per statutory requirement; while perishable & environmental testing related remnant samples will be discarded consequent upon completion of testing. Samples are not drawn by us unless otherwise stated. This document cannot be reproduced Except in full, without prior written approval of the laboratory. This report is for the exclusive use of Chennai Mettex Lab's customer, and is provided in accordance with the agreement between Chennai Mettex Lab and its Customer.			

Fig: 5.7:Results from mettex lab

CHAPTER 6

SUMMARY AND CONCLUSION

6.1. SUMMARY.

Nanotechnology refers to scientific disciplines that utilise tiny occurrences in the development, characterization, production, and usage of materials, objects, sensors, and networks. Nanotechnology is rapidly being used in water treatment procedures. The process of controlling molecules on a nanoscale is known as nanostructures. Nano membranes are used in nanotechnology to soften water while also removing impurities such as physical, microbiological, and chemical contaminants. It is possible to make nanobubbles utilizing hydrodynamic oxidation. After that, the nanobubbles will be used to remediate ground water. After that, the water is transported for testing to determine its quality. The results are then used to conduct some analysis.

6.2. CONCLUSION.

Using the hydrodynamic oxidation technique, the bubble number density created after 30 minutes of oxidation time is 6×10^8 bubbles/ml.

- The water is cleansed to a higher extent when nanobubbles are generated.
- The pH level is raised from acidic to alkaline, bringing it from 6.25 to 7.43.
- From NTA, the bubbles are between 100nm and 200nm in size.
- With a longer oxidation period, the nanobubbles' stability improves even more.
- The 8.14 percent increase in dissolved oxygen concentration in the water demonstrated that nanobubble technology can be used in desalination and other water purification procedures to improve water quality.
- Micro-nano bubbles have received a lot of scrutiny in recent years because of their unusual character. The process of Micro Nano Bubble production has now been investigated thus far. The production of bubble that replace air, bubbles that make air, and bubbles produced by electrolysis. Micro Nano Bubble generators are extensively used in mineral buoyancy, sewage treatment, vessel drag reduction, medicine administration, and thermal jet printing. However, certain Micro nano bubbles application patterns appears to be more viable in particular places.
- The use of MNB has considerable promise for sustainability in terms of water treatment, for example, enhancing cost and time efficiency due to minimal chemical consumption. Increased energy transmission rates, impact

effectiveness, reduced lag rate, adjusted surface charge, and radicals are all characteristics.

- MNB is more likely to play an up this role water purification technologies such as disinfecting and floating as a result of generations. In consisting of organic removal of pollutants, flotation, biological treatment aeration efficiency, and advanced oxidation employing OH radicals, such treatments are projected to lead to high time cost efficiency. When employing ozone-based Micro Nano Bubbles in the oxidation process, the biochemistry that creates free radicals has a lot of promise. Furthermore, the greater burst energy and aeration efficiency of MNB have the potential to reduce membranes clogging and scum production in bioreactors. Micro Nano Bubbles component in other sectors, such as industry and agriculture. Advanced automating based on smart technology control, for example, allows for more accurate work of Micro Nano Bubbles-based water purification in farming and can help fulfil the growing need for water treatment on a variety of sizes. Finally, despite the fact that MNB has enormous potential as an intelligent, efficient, and low-cost treatment method, its uses are still confined to the laboratory. As a result, future research and initiatives should be more focused on the development and deployment of industrial and agricultural scale technologies.
- Nanotechnology refers to scientific disciplines that utilise tiny occurrences in the development, characterization, production, and usage of materials, objects, sensors, and networks. Nanotechnology is rapidly being used in water treatment procedures. The process of controlling molecules on a nanoscale is known as nanostructures. Nano membranes are used in nanotechnology to soften water while also removing impurities such as physical, microbiological, and chemical contaminants. Hydrodynamic oxidation can be used to produce nanobubbles. The nanobubbles will then be used to clean up groundwater. The water is then transferred to be tested to assess its quality. The data is then used to perform some analysis.

The bubble number density obtained using the hydrodynamic oxidation technique is 6×10^8 bubbles/ml after 30 minutes of oxidation time.

- When nanobubbles are formed, the water is purified to a greater level.
- The pH is changed from acidic to alkaline, increasing from 6.25 to 7.43.
- The bubbles range between 100nm and 200nm in size, according to NTA.

The stability of the nanobubbles improves considerably more with a longer oxidation duration. Nanobubble technology can be utilized in desalination and other water purification techniques to improve water quality, as evidenced by the 8.14 percent increase in dissolved oxygen concentration in the water.

REFERENCES

- 1 Achaoui, Y., Metwally, K., Fouan, D., Hammadi, Z., Morin, R., Debieu, E., Payan, C., Mensah, S., 2017. Tunable microbubble generator using electrolysis and ultrasound. AIP Advances 7, 015011. <https://doi.org/10.1063/1.4973720>
- 2 Alheshibri M, Qian J, Jehannin M, Craig VSJ (2016) A history of nanobubbles. Langmuir 32(43):11086-11100. <https://doi.org/10.1021/acs.langmuir.6b02489>
- 3 Alheshibri M, Qian J, Jehannin M, Craig VSJ (2016) A history of nanobubbles. Langmuir 32(43):11086–11100. <https://doi.org/10.1021/acs.langmuir.6b02489>
- 4 Ashutosh Agarwal; Wun Jern Ng; Yu Liu (2011). Principle and applications of microbubble and nanobubble technology for water treatment. , 84(9), 1175–1180. doi:10.1016/j.chemosphere.2011.05.054
- 5 Atchley AA, Prosperetti A (1989) The crevice model of bubble nucleation. J Acoust Soc Am 86(3):1065-1084. <https://doi.org/10.1121/1.398098>
- 6 Atchley AA, Prosperetti A (1989) The crevice model of bubble nucleation. J Acoust Soc Am 86(3):1065–1084. <https://doi.org/10.1121/1.398098>
- 7 Atkinson AJ, Apul OG, Schneider O, Garcia-Segura S, Westerhoff P (2019) Nanobubble technologies offer opportunities to improve water treatment. Acc Chem Res 52(5):1196-1205. <https://doi.org/10.1021/acs.accounts.8b00606>
- 8 Atkinson AJ, Apul OG, Schneider O, Garcia-Segura S, Westerhoff P (2019) Nanobubble technologies offer opportunities to improve water treatment. Acc Chem Res 52(5):1196–1205. <https://doi.org/10.1021/acs.accounts.8b00606>
- 9 Azevedo A, Etchepare R, Calgaroto S, Rubio J (2016) Aqueous dispersions of nanobubbles: generation, properties and features. Miner Eng 94:29-37. <https://doi.org/10.1016/j.mineng.2016.05.001>
- 10 Azevedo A, Etchepare R, Calgaroto S, Rubio J (2016) Aqueous dispersions of nanobubbles: generation, properties and features. Miner Eng 94:29–37. <https://doi.org/10.1016/j.mineng.2016.05.001>

- 11 Batagoda JH, Hewage SA, Meegoda JN (2019) Nano-ozone bubbles for drinking water treatment. J Environ Eng Sci 14(2):57-66. <https://doi.org/10.1680/jenes.18.00015>
- 12 Batagoda JH, Hewage SA, Meegoda JN (2019) Nano-ozone bubbles for drinking water treatment. J Environ Eng Sci 14(2):57–66. <https://doi.org/10.1680/jenes.18.00015>
- 13 Boshenyatov BV, Kosharidze SI, Levin YK (2019) On the stability of nanobubbles in water. Russ Phys J 61(10):1914-1921. [https://doi.org/10.1007/\\$11182-019-01618-x](https://doi.org/10.1007/$11182-019-01618-x)
- 14 Boshenyatov BV, Kosharidze SI, Levin YK (2019) On the stability of nanobubbles in water. Russ Phys J 61(10):1914–1921. <https://doi.org/10.1007/s11182-019-01618-x>
- 15 Bui TT, Han M (2020) Decolorization of dark green Rit dye using positively charged nanobubbles technologies. Sep Purif Technol 233:116034. <https://doi.org/10.1016/j.seppur.2019.116034>
- 16 C.Rameshkumar, S. LakshmiSankar, G. Senthilkumar, Characterisation of seed germination using nanaobubbled water, Int. J. Ambient Energy (2019), <https://doi.org/10.1080/01430750.2019.1672581>.
- 17 Calgaroto S, Azevedo A, Rubio J (2016) Separation of amine-insoluble species by flotation with nano and microbubbles. Miner Eng 89:24–29. <https://doi.org/10.1016/j.mineng.2016.01.006>
- 18 Calgaroto S, Wilberg KQ, Rubio J (2014) On the nanobubbles interfacial properties and future applications in flotation. Miner Eng 60(6):33–40. <https://doi.org/10.1016/j.mineng.2014.02.002>
- 19 Cen C, Zhang K, Zhang T, Zhou X, Pan R (2020) Algae-induced taste and odour problems at low temperatures and the cold stress response hypothesis. Appl Microbiol Biotechnol 104(21):9079–9093. <https://doi.org/10.1007/s00253-020-10884-6>

- 20 Colic M, Morse W, Miller JD (2007) The development and application of centrifugal flotation systems in wastewater treatment. *Int J Environ Pollut* 30(2):296. <https://doi.org/10.1504/ijep.2007.014706>
- 21 Daryabor, M., Ahmadi, A., Zilouei, H., 2017. Solvent extraction of cadmium and zinc from sulphate solutions: Comparison of mechanical agitation and ultrasonic irradiation. *Ultrasonics Sonochemistry* 34, 931–937. <https://doi.org/10.1016/j.ultsonch.2016.07.014>
- 22 Demangeat JL (2015) Gas nanobubbles and aqueous nanostructures: the crucial role of dynamization. *Homeopathy* 104(2):101–115. <https://doi.org/10.1016/j.homp.2015.02.001>
- 23 El-Zahaby AM, El-Gendy AS (2016) Passive aeration of wastewater treated by an anaerobic process—a design approach. *J Environ Chem Eng* 4(4):4565–4573. <https://doi.org/10.1016/j.jece.2016.10.025>
- 24 Etchepare R, Oliveira H, Azevedo A, Rubio J (2017) Separation of emulsified crude oil in saline water by dissolved air flotation with micro and nanobubbles. *Sep Purif Technol* 186:326–332. <https://doi.org/10.1016/j.seppur.2017.06.007>
- 25 Fan M, Tao D, Honaker R, Luo Z (2010) Nanobubble generation and its applications in froth flotation (part II): fundamental study and theoretical analysis. *Mining Sci Technol* 20(2):159–177. [https://doi.org/10.1016/s1674-5264\(09\)60179-4](https://doi.org/10.1016/s1674-5264(09)60179-4)
- 26 Fan, M.; Tao, D.; Honaker, R.; Luo, Z. Nanobubble generation and its application in froth flotation (part I): Nanobubble generation and its effects on properties of microbubble and millimeter scale bubble solutions. *Min. Sci. Technol.* 2010, 20, 1–19.
- 27 Fan, W., An, W., Huo, M., Yang, W., Zhu, S., Lin, S., 2020. Solubilization and stabilization for prolonged reactivity of ozone using micro-nano bubbles and ozone-saturated solvent: A promising enhancement for ozonation. *Separation and Purification Technology*, <https://doi.org/10.1016/j.seppur.2019.116484>.
- 28 G Senthilkumar, AM Rakesh, BRS Aravind Sri Krishna, Nivin Joy, S Ganesan, J Hemanandh (2020) Experimental investigation on the effect of nanobubbled

- water in evaporative cooling and oxygen enrichment in air cooler Materials Today: Proceedings doi.org/10.1016/j.matpr.2020.09.759,44(5), pp.3622-3626.
- 29 Geisse, N.A., 2009. AFM and combined optical techniques. Materials Today, [https://doi.org/10.1016/S1369-7021\(09\)70201-9](https://doi.org/10.1016/S1369-7021(09)70201-9)
- 30 Ghadimkhani A, Zhang W, Marhaba T (2016) Ceramic membrane defouling (cleaning) by air nano bubbles. Chemosphere 146:379–384. <https://doi.org/10.1016/j.chemosphere.2015.12.023>
- 31 Gurung A, Dahl O, Jansson K (2016) The fundamental phenomena of nanobubbles and their behavior in wastewater treatment technologies. Geosyst Eng 19(3):133–142. <https://doi.org/10.1080/12269328.2016.1153987>
- 32 H. Joost, Weijs and Detlef Lohse, why surface nanobubbles live for hours Physical review letters, 110(5), (2013) 054501.
- 33 H. Tsuge, Fundamental of microbubbles and nanobubbles, Bulletin of the Society of Sea Water Science Japan 64 (2010) 4–10
- 34 Hao R, Fan Y, Anderson TJ, Zhang B (2020) Imaging single nanobubbles of H₂ and O₂ during the overall water electrolysis with single-molecule fluorescence microscopy. Anal Chem 92(5):3682–3688. <https://doi.org/10.1021/acs.analchem.9b04793>
- 35 Hashimoto K, Kubota N, Okuda T, Nakai S, Nishijima W, Motoshige H (2021) Reduction of ozone dosage by using ozone in ultrafine bubbles to reduce sludge volume. Chemosphere 274:129922. <https://doi.org/10.1016/j.chemosphere.2021.129922>
- 36 Hewage SA, Batagoda JH, Meegoda JN (2020) In situ remediation of sediments contaminated with organic pollutants using ultrasound and ozone nanobubbles. Environ Eng Sci 37(8):521–534. <https://doi.org/10.1089/ees.2019.0497>
- 37 Hu X, Meneses YE, Stratton J, Lau SK, Subbiah J (2021) Integration of ozone with co-immobilized microalgae-activated sludge bacterial symbiosis for efficient on-site treatment of meat processing wastewater. J Environ Manage 285:112152. <https://doi.org/10.1016/j.jenvman.2021.112152>

- 38 Huang, J., Sun, L., Liu, H., Mo, Z., Tang, J., Xie, G., Du, M., 2020. A review on bubble generation and transportation in Venturi-type bubble generators. *Exp. Comput. Multiph. Flow* 2, 123–134. <https://doi.org/10.1007/s42757-019-0049-3>
- 39 Iorhemen OT, Hamza RA, Tay JH (2016) Membrane bioreactor (MBR) technology for wastewater treatment and reclamation: membrane fouling. *Membranes*. <https://doi.org/10.3390/membranes6020033>
- 40 Jin, J., Feng, Z., Yang, F., Gu, N., 2019. Bulk Nanobubbles Fabricated by Repeated Compression of Microbubbles. *Langmuir* 35, 4238–4245. <https://doi.org/10.1021/acs.langmuir.8b04314>
- 41 Johnson BD, Cooke RC (1981) Generation of stabilized microbubbles in seawater. *Science* 213(4504):209–211. <https://doi.org/10.1126/science.213.4504.209>
- 42 Kang, B.-K.; Kim, M.-S.; Park, J.-G. Effect of Dissolved Gases in Water on Acoustic Oxidation and Bubble Growth Rate in 0.83 MHz Megasonic of Interest to Wafer Cleaning. *Ultrason. Sonochem.* 2014, 21, 1496–1503
- 43 Khuntia S, Majumder SK, Ghosh P (2015) Quantitative prediction of generation of hydroxyl radicals from ozone microbubbles. *Chem Eng Res Des* 98:231–239. <https://doi.org/10.1016/j.cherd.2015.04.003>
- 44 Kim S, Kim H, Han M, Kim T (2018) Generation of sub-micron (nano) bubbles and characterization of their fundamental properties. *Environ Eng Res* 24(3):382–388. <https://doi.org/10.4491/eer.2018.210>
- 45 Komaba, K., Goto, H., 2019. Micro-Bubble Sonic-Electrochemical Preparation of Polyaniline. *ECS Trans.* 92, 57. <https://doi.org/10.1149/09210.0057ecst>
- 46 Krishnan JS, Dwivedi P, Moholkar VS (2006) Numerical investigation into the chemistry induced by hydrodynamic cavitation. *Ind Eng Chem Res* 45(4):79–83. <https://doi.org/10.1021/ie050839t>
- 47 Kyzas GZ, Bomis G, Kosheleva RI, Efthimiadou EK, Favvas EP, Kostoglou M, Mitropoulos AC (2019) Nanobubbles effect on heavy metal ions adsorption by

- p>activated carbon. Chem Eng J 356:91–97.
- <https://doi.org/10.1016/j.cej.2018.09.019>
- 48 Li H, Hu L, Song D, Al-Tabbaa A (2013) Subsurface transport behavior of micro-nano bubbles and potential applications for groundwater remediation. Int J Environ Res Public Health 11(1):473–486. <https://doi.org/10.3390/ijerph110100473>
 - 49 Li H, Hu L, Song D, Lin F (2014) Characteristics of micro-nano bubbles and potential application in groundwater bioremediation. Water Environ Res 86(9):844–851. <https://doi.org/10.2175/106143014x14062131177953>
 - 50 Liu H, Cao G (2016) Effectiveness of the Young-Laplace equation at nanoscale. Sci Rep 6:23936. <https://doi.org/10.1038/srep23936>
 - 51 Liu S, Kawagoe Y, Makino Y, Oshita S (2013) Effects of nanobubbles on the physicochemical properties of water: The basis for peculiar properties of water containing nanobubbles. Chem Eng Sci 93:250–256. <https://doi.org/10.1016/j.ces.2013.02.004>
 - 52 Liu S, Oshita S, Kawabata S, Makino Y, Yoshimoto T (2016) Identification of ROS Produced by Nanobubbles and Their Positive and Negative Effects on Vegetable Seed Germination. Langmuir 32(43):11295–11302. <https://doi.org/10.1021/acs.langmuir.6b01621>
 - 53 Liu S, Oshita S, Makino Y, Wang Q, Kawagoe Y, Uchida T (2015) Oxidative Capacity of Nanobubbles and Its Effect on Seed Germination. ACS Sustain Chem Eng 4(3):1347–1353. <https://doi.org/10.1021/acssuschemeng.5b01368>
 - 54 Ljunggren S, Eriksson JC (1997) The lifetime of a colloid-sized gas bubble in water and the cause of the hydrophobic attraction. Colloid Surf A Physicochem Eng Asp 129:151–155. [https://doi.org/10.1016/S0927-7757\(97\)00033-2](https://doi.org/10.1016/S0927-7757(97)00033-2)
 - 55 Lucas MS, Peres JA, Lan BY, Puma GL (2009) Ozonation kinetics of winery wastewater in a pilot-scale bubble column reactor. Water Res 43(6):1523–1532. <https://doi.org/10.1016/j.watres.2008.12.036>
 - 56 Luttrell GH, Yoon RH (1992) A hydrodynamic model for bubble particle attachment. J Colloid Interf Sci 154(1):129–137. [https://doi.org/10.1016/0021-9797\(92\)90085-Z](https://doi.org/10.1016/0021-9797(92)90085-Z)

- 57 Lyu T, Wu S, Mortimer RJG, Pan G (2019) Nanobubble technology in environmental engineering: revolutionization potential and challenges. *Environ Sci Technol* 53(13):7175–7176. <https://doi.org/10.1021/acs.est.9b02821>
- 58 Maoming FAN, Daniel TAO, Rick HONAKER, Zhenfu LUO, Nanobubble generation and its application in froth flotation (part I): nanobubble generation and its effects on properties of microbubble and millimeter scale bubble solutions, *Mining Science and Technology (China)*, Volume 20, Issue 1, 2010, Pages 1-19, [https://doi.org/10.1016/S1674-5264\(09\)60154-X](https://doi.org/10.1016/S1674-5264(09)60154-X).
- 59 P. Pattekari, Z. Zheng, X. Zhan g 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
- 60 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
- 61 Parmar, Rajeev; Majumder, Subrata Kumar (2013). *Microbubble generation and microbubble-aided transport process intensification—A state-of-the-art report. Chemical Engineering and Processing: Process Intensification*, 64(), 79–97. doi:10.1016/j.cep.2012.12.002
- 62 Rameshkumar, C., Senthilkumar, G., Subalakshmi, R., Risa Gogoi.: Generation and characterization of nanobubbles by ionization method for wastewater treatment” *Desalination and Water Treatment*, 164,98-101 2019.
- 63 Rameshkumar, C., Senthilkumar, G., Subalakshmi, R.: Purification of tap water to Drinking water: Nanobubbles Technology;” *Desalination and Water Treatment*, 233, 11-18 2021.
- 64 Sabeera Haris, Xiaobin Qiu, Harald Klammler, Mohamed M.A. Mohamed, DOI: <https://doi.org/10.1016/j.qsd.2020.100463>
- 65 The use of micro-nano bubbles in groundwater remediation: A comprehensive review
- 66 Vijayendran Raghavendran, Joseph P. Webb, Michaël L. Cartron, Vicki Springthorpe, Tony R. Larson, Michael Hines, Hamza Mohammed, William B. Zimmerman, Robert K. Poole and Jeffrey Green1 A microbubble-sparged yeast propagation–fermentation process for bioethanol production

Biotechnology for Biofuels 2020) 13:104 <https://doi.org/10.1186/s13068-020-01745-5>

- 67 Wu, T. Y.; Guo, N.; Teh, C. Y.; Hay, J. X. W. Theory and Fundamentals of Ultrasound. Advances in Ultrasound Technology for Environmental Remediation; Springer: Netherlands, Dordrecht, 2013; pp 5–12.
- 68 Xu, Q., Nakajima, M., Ichikawa, S., Nakamura, N., Shiina, T., 2008. A comparative study of microbubble generation by mechanical agitation and sonication. Innovative Food Science and Emerging Technologies 9, 489–494. <https://doi.org/10.1016/j.ifset.2008.03.003>.