

INVESTIGATION OF PHYSICAL PROPERTY OF NANOBUBBLED WATER USING GAS WATER CIRCULATION METHOD

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

By

P.G. LOGESH (Reg. No. 39150073)

HARIHARAN.R (Reg. No. 39150045)



DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A" by NAAC | 12B Status by UGC | Approved by AICTE

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

APRIL 2023



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

www.sathyabama.ac.in

DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **P.G.LOGESH (39150073)** and **HARIHARAN.R (39150045)** who carried out the project entitled **"INVESTIGATION OF PHYSICAL PROPERTIES OF NANOBUBBLED WATER USING GAS WATER CIRCULATION METHOD"** under our supervision from December 2022 to April 2023.

Internal Guide

Dr. NIVIN JOY, M.E., Ph.D.,

Head of the Department

Dr. G. ARUNKUMAR, M.E., Ph.D.,

Submitted for Viva voce Examination Held on 26.04.2023

Internal Examiner

External Examiner

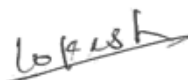
DECLARATION

We, **P.G.LOGESH (Reg No: 39150073)** and **HARIHARAN.R (Reg No: 39150045)**, hereby declare that the Project Report entitle "**INVESTIGATION OF PHYSICAL PROPERTIES OF NANOBUBBLED WATER USING GAS-WATER CIRCULATION METHOD**" is done by us under the guidance of **Dr.Nivin Joy M.E., Ph.D.**, at Sathyabama Institute of Science and Technology is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

DATE: 26.04.2023

PLACE: Chennai

1.



2.



SIGNATURE OF THE CANDIDATES

ACKNOWLEDGEMENT

We are pleased to acknowledge my sincere thanks to **Board of Management of SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks to **Dr. S. Prakash, M.E., Ph.D.**, Dean, School of Mechanical Engineering and **Dr. G. Arunkumar, M.E., Ph.D.**, Head of the Department, Department of Mechanical Engineering for providing us necessary support and details at the right time during the progressive reviews.

We would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. NIVIN JOY M.E., Ph.D.**, for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

We wish to express our 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

Physical properties of Nano bubbles (70-120 nanometers in size) are attributed their uses within the field of varied Engineering fields, Agriculture, the Drug Industry, Pharmaceutical delivery, etc. This Research paper examines the physical properties of Nano Bubbled water (Viscosity, Density, Temperature.) produced through the method of Gas-water circulation using a generator and Investigating of the size of nano bubbles by measurement of density, viscosity, beam width, and time is taken for heating and cooling of water with and without the presence of nano bubbles were also presented in this experimental investigation. Within the presence of nano bubbles, the porous nature of the fabric increases drastically so the original properties of the material change. While the density of the fabric changes, its fluidity, and other properties were changed. Currently, skilled is a increasing demand for water situation sciences considering worldwide incidental challenges to a degree depravity and exhaustion of water money. Micro- and nanobubble (MNB) electronics and allure application for wastewater situation has arisen as a logical alternative for specific challenges. This paper reviews the main studies on water situation in the districts of MNBs and discusses their fundamental characteristics, in the way that bubble cohesion (as puny systems in water resolutions), era methods, and miscellaneous synthetic and tangible looks. The paper further overviews the current rank of MNB use in water situation processes in the way that flotation, aeration, and cleansing and allure uses in differing subdivisions, containing farming, growing plants in liquid, medical, and manufacturing. This study concludes that regardless of the hopeful part of MNBs in water-accompanying use, the current rank of research has not attained its real potential.

TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	v
	LIST OF FIGURES	viii
	LIST OF TABLES	ix
	LIST OF ABBREVIATION	x
1	INTRODUCTION	1
2	LITERATURE SURVEY	3
3	MATERIALS AND METHODOLOGY	7
	3.1 MATERIALS	7
	3.1.1 WATER PUMP	7
	3.1.2 OXYGEN CYLINDER	8
	3.1.3 OSTWALD'S VISCOMETER	8
	3.1.4 TDS METER	8
	3.1.5 VENTURIMETER	9
	3.2 METHODOLOGY	12
	3.2.1 FUNDAMENTAL PROPERTIES OF MICRO NANOBUBBLES	12
	3.2.2 MNB GENERATION PROCESS	13
	3.2.3 AERATION PROCESS	14
	3.2.4 MNB APPLICATION IN WATER TREATMENT	15

CHAPTER NO.	TITLE	PAGE NO.
4	INVESTIGATION ON PROPERTIES OF NANOBUBBLED WATER	17
	4.1 GAS WATER CIRCULATION METHOD	17
	4.2 OSTWALD'S VISCOSITY METHOD	17
	4.3 DENSITY MEASUREMENT	19
	4.4 HEATING AND COOLING	19
	4.5 LASER BEAM FOR CONSERVATION OF NANOBUBBLE	20
5	PROPERTIES OF MNB	22
	5.1 DENSITY	23
	5.2 VISCOSITY	23
	5.3 PH (POTENTIAL HYDROGEN)	21
	5.4 TOTAL DISSOLVED SOLIDS (TSS)	24
	5.5 TOTAL SUSPENDED SOLIDS (TSS)	25
6	RESULT AND DISCUSSION	26
	6.1 RESULT AND DISCUSSION	26
7	CONCLUSION	31
	REFERENCE	32

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO
3.1	WATER PUMP	6
3.2	OXYGEN CYLINDER	7
3.3	OSTWALD VISCOMETER	8
3.4	TDS METER	9
3.5	VENTURIETER	10
3.6	NANOBUBBLE GENARATION TANK	12
4.1	WATER CIRCULATION SYSTEM	15
4.2	SCHEMATIC DIAGRAM OF VISCOMETER	16
4.3	DENSITY MEASUREMENT	17
4.4	LASER BEAM METHOD	19
5.1	GRAPH COMPARING DENSITY	20
5.2	GRAPH COMPARING VISCOSITY	21

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO
6.1	TABLE DESCRIBING TDS	24
6.2	TABLE DESCRIBING TSS	25
6.3	TABLE DESCRIBING PH	26
6.4	TABLE DESCRIBING TURBIDITY	26

LIST OF ABBREVIATIONS

MNB	MICRO NANOBUBBLE
NB	NANO BUBBLE
AFM	ATOMIC FORCE MICROSCOPY
TSS	TOTAL SUSPENDED SOLIDS
TDS	TOTAL DISSOLVED SOLIDS
PH	POTENTIAL HYDROGEN

CHAPTER 1

INTRODUCTION

Water resources are integral to global economic development, but are facing significant challenges due to water scarcity, unequal distribution, inefficient usage, environmental concerns, and increasing amounts of wastewater from urbanization and industrialization. To address these issues, wastewater treatment and reuse have become crucial to ensure an adequate water supply. While biological methods like activated sludge have been used to remove contaminants from wastewater, they have drawbacks such as high energy costs and large volumes of solid waste. Therefore, there is an urgent need to develop sustainable water treatment technologies. One promising technology is micro- and nanobubbles (MNBs), which have unique physical characteristics that make them effective for water treatment. MNBs are small bubbles with sizes in the nanometer and micrometer range that can help address the challenges of water scarcity and pollution. Another innovative technology that uses ultrasound, ozone, and nanobubbles has been proposed for the decontamination of sediments, providing a cost-effective and environmentally sustainable solution with minimal adverse impact on the region. Nanobubbles also have numerous biomedical applications, including drug delivery and emergency procedures. Nanobubbles are widely used in various industries to improve the properties of their product. For instance, they can facilitate seed germination, reduce drying time and increase mold resistance in paints, and enhance the retention of sparkling beverages and sports beverages with gas. Additionally, by altering the ionic equilibrium of dissolved ions in solutions, they can be used as simulated flotation agents with water to change the surface charge of particles. Nanobubbles are also used in the food business to control the pH of liquids. Through the addition of suspended carbon dioxide (CO₂) bubbles, which can effectively maintain a desired solution pH for extended periods of time. Nanobubbles have also been used in fish farming because studies have shown that fish metabolism and consumption of food can be negatively impacted by low oxygen levels, which will eventually slow their growth rate. Therefore, by introducing nano air bubbles, adequate oxygenation of the water can be achieved, resulting in high fish survival rates. The long-term stability of nanobubbles formed from four different gases in different aqueous solutions with

varying salt concentrations, pH levels, and temperatures was investigated in a laboratory study.

CHAPTER 2

LITERATURE SURVEY

Choi SUS, Eastman JA (2001) - Utilizing nanofluids to increase heat transfer The technique and equipment for This idea aim at increasing heat transmission among fluids like distilled water. using fluids like ethylene glycol or oil to disperse nanocrystalline particles of materials like copper, oxidized copper, aluminum oxide, or the like. Nanocrystalline By heating the material to be dispersed in a vacuum and passing a thin film of the fluid close to the heated material, particles are formed and dispersed in the fluid. The vapor pressure of the fluid is managed by cooling.

Xie, H., Lee, H., Youn, W., and Choi, M., (2003) - With the use of oleylamine as a surfactant, The dispersion of treated CNTs was successful. in nonpolar fluids like decene as well as polar liquids like ethylene glycol and distilled water. using a temporary hot wire setup, we evaluated the suspensions of these nanotubes' thermal conductivities. The thermal conductivities of suspensions of nanotubes with a tiny number of CNTs are noticeably greater than those ofThe improvement improves with the volume percent of CNTs compared to the basic fluids. As The base fluid's thermal conductivity rises., the enhanced thermal conductivity ratios for suspensions with the same loading drop. A comparison of actual results with the theoretical model suggests that the interfacial layer that develops between the nanotube and the liquid appears to have a substantial influence in the heat conduction properties of nanotube suspensions.

Bingbing Wang., xiangjie.,Yanzhao Ren., (2022) - different studies have formulated that the characteristic outcome of ozone-based AOP method is influenced by the chemical and physical parameters, such as pH of the solution (Deng and Zhao, 2015;Boczkaj and Fernandes, 2017;Koc-Jurczyk and Jurczyk, 2019). There is an ongoing discussion that pH is an essential parameter since it plays an important role

during O₃ decomposition process (Temesgen et al., 2017). The ozonation combined with UV-radiation (O₃/UV) is an efficient catalytic wastewater system for the degradation of refractory pollutants. ... Here, we found that fine control of ozone exposure under pH-neutral media accommodates the organic contaminants' physical degradation. Our finding regarding COD reduction that operated at neutral pH in agreement with the previous reports (Lucas et al., 2009; Takahashi et al., 2012; Yang et al., 2012; Temesgen et al., 2017).

Omar Ei Arwadi., Zubar Mumin Wahed., Zuruzi Abu Samah., (2023) - The most notable characteristic of Nanobubbles is their extraordinary durability, which may endure for months. Nanobubbles exhibit a high Laplace pressure, around 30 bar in a 100 nm diameter bubble, according to physics. Microbubbles are distinguished by their lack of buoyancy and their physical stability. Sub-5µm-diameter bubbles do not rise because their buoyant force is negligible compared to the forces exerted by their interactions with other particles in the liquid.

Sabareh Nazari., Jinlong Li., Hamid Koshdash., Jiaho Li (2023 March) - Flotation was developed for the separation of spent vehicle lithium-ion batteries (LIBs) in the presence of micro-nanobubbles (MNBs). For this purpose, roasting technology along with MNBs was applied to overcome the challenge of poor efficiency of electrode active materials flotation. The roasting properties (temperature: 300-500 °C and time: 1 h) and corresponding surface alterations of the electrode active materials (zeta potential, contact angle, and X-ray photoelectron spectroscopy (XPS)) were analyzed to explore the surface properties of roasting materials in the presence of MNBs. MNB-assisted flotation was employed to effectively separate the cathode active materials (CMs) from anode active materials (AMs). Results showed that the efficiency of electrode materials flotation without the roasting process was low due to the existence of residual organic binders and electrolytes.

Malgorzata Grzegorzczak-Franczak., Danuta Barnat Hunek., Kalini Materak., Grzegorz

Lagod (2022 November) - In particular, the effect of micro-nano bubbles on the durability and frost resistance of concrete was analyzed. Concretes with two types of micro-nano bubbles were studied. The physical properties of both the modified concretes and the reference concrete were determined, i.e., specific and apparent density, porosity, weight absorption and coefficient of water absorption. Mechanical parameters based on compressive and flexural strength were tested after 14 and 28 days of curing. Concrete durability was determined on the basis of frost resistance and resistance to salt crystallization. The pore distribution in the cement matrix was determined based on porosimetry studies. The use of water with micro-nano bubbles of O₂ and O₃, among others, contributed to a reduction in the water absorption coefficient from 42.7% to 52.3%, in comparison to the reference concrete. The strength characterizing the concrete with O₃ increased by 61% after 28 days, and the frost resistance after 150 F-T cycles increased by 2.4 times. Resistance to salt crystallization improved by 11% when water with O₃ was used.

G. Cheng., M.N. Zhang., Y.L.Li.Ee Von Lau., (2022 October) – The flotation process of micro-fine minerals have historically been hampered by slow flotation rate, poor selectivity, high reagent consumption, and low recovery. These disadvantages are mainly due to the large specific surface area attributed to the small-sized mineral particles. As such, research have revolved around enhancing their recovery by process intensification as one of the known effective methods. Micro/nanoparticles, on the other hand, possess many attributes, for instance, strong chemical activity, high reactivity, high surface free energy, and large adsorption capacity, all of which can contribute to improve the separation of micro-fine minerals. The mechanisms and preparation methods of nanoparticle collectors (NPCs) as well as ultrafine bubbles (UFBs) are described in this paper. Furthermore, the influences of NPCs and UFBs on the flotation of micro-fine minerals are also discussed. NPCs and UFBs are capable of providing hydrophobicity selectivity to the desired minerals to improve the flotation performance of mineral particles. This paper offers an overview of the underlying properties of NPCs and UFBs in intensifying flotation applications.

V.A. Babenko., Andrey. A., Nikoley Bunkin., (2022 February) - A distinctive feature of

our theoretical model, confirmed in experiment, is that in our case the optical breakdown develops on heterogeneous centers-clusters of gas nanobubbles. To the best of our knowledge, this is the first study of the role of clusters of gas nanobubbles in the optical breakdown of liquids that are transparent to pump radiation. In the experiment described in this paper, it was found that when initially degassed water is saturated with dissolved air, the breakdown threshold decreases. A theoretical model describing this phenomenon is suggested. This model includes the development of an electron avalanche inside individual nanobubbles, followed by the stimulated optical coalescence of a nanobubble cluster. According to our estimates, this regime occurs at laser radiation intensities of about 10^6 – 10^7 W/cm². It is important that at such low intensities the breakdown flash (the basic endpoint of optical breakdown) does not appear due to the deficit of input laser energy. We provide an experimental proof of the coalescence regime, stimulated by a laser pulse in nanosecond range. The experimental threshold of stimulated coalescence is in good agreement with the theoretical estimates. Since the stimulated optical coalescence mode occurs at very low laser intensities, its excitation does not result in mechanical side effects in eye tissues, i.e., a shock wave should not be excited. Note that shock wave always occurs during optical breakdown, which is traditionally excited at intensities of 10^{12} W/cm². In our experiment, the generation of a shock wave at such pump intensities was also observed.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 MATERIALS

3.1.1 WATER PUMP

A water pump is a device that combines electrical and mechanical components to facilitate the movement of water from one location to another by increasing its pressure. It is widely used in various applications, including municipal water supply, industrial processes, agricultural irrigation, and residential plumbing. In essence, a water pump serves as an essential tool to ensure the efficient and reliable delivery of water to meet various needs and demands around the world.



Fig:3.1: Water Pump

3.1.2 OXYGEN CYLINDER

Oxygen cylinders serve as reservoirs that store oxygen and are used to administer oxygen to patients via a surgical mask or nasal cannula. The capacity of the cylinder is determined based on the patient's condition. Different sizes of cylinders are available to cater to varying needs.



Fig:3.2: Oxygen cylinder

3.1.3 OSTWALD VISCOMETER

The Ostwald viscometer, also referred to as the U-tube or capillary viscometer is a device utilized to measure the viscosity of a liquid with a known density. To determine the viscosity of a liquid using this instrument, a known volume of the liquid, enclosed between marks A and B, is allowed to flow through a capillary tube under the influence of gravity, and the time taken for the liquid to pass is recorded. This device is named after Wilhelm Ostwald, a German chemist who lived from 1853 to 1932.

Before using the Ostwald viscometer to measure the viscosity of a liquid, it must first be calibrated with materials of known viscosity, such as pure or deionized water. With the value of viscosity of one liquid known, it is possible to calculate the viscosity of other liquids.

$$\eta_1 = \eta_2 \cdot \frac{\rho_1 t_1}{\rho_2 t_2}$$



Fig: 3.3: Ostwald viscometer

3.1.4 TDS METER

A TDS meter is a device utilized to determine the concentration of total dissolved solids present in a solution, often water. Total dissolved solids represent the combined amount of inorganic solids that have dissolved in the water. This instrument finds application in various sectors, including the water packaging industry, industries that use cooling towers and boilers to prevent scaling and rusting, and laboratories, among others. The World Health Organization suggests that drinking water with a Total Dissolved Solids (TDS) level of up to 300 parts per million is suitable for consumption. However, water with a TDS level of 1,000 or higher is not advisable for drinking, as it may have

a bland taste and lack essential minerals that are beneficial for health.



Fig:3.4: TDS Meter

3.1.5 VENTURIMETER

The Venturi meter is a flow measurement tool that utilizes a constricted section of a pipe to accelerate fluid flow and subsequently lower the pressure, allowing for the measurement of gas, liquid, and solid suspension flow rates. This device has gained widespread popularity in the water supply industry due to its precision and the consistent pressure drop it produces. The Venturi Effect, which governs the behavior of fluid flow through a narrow pipe section, is a fundamental principle in fluid mechanics with numerous practical applications, including preventing pipeline blockages and monitoring airflow in carburetors of combustion engines. Furthermore, the absence of moving parts in Venturi devices makes them ideal for use in harsh or low-temperature environments, minimizing the possibility of failure.

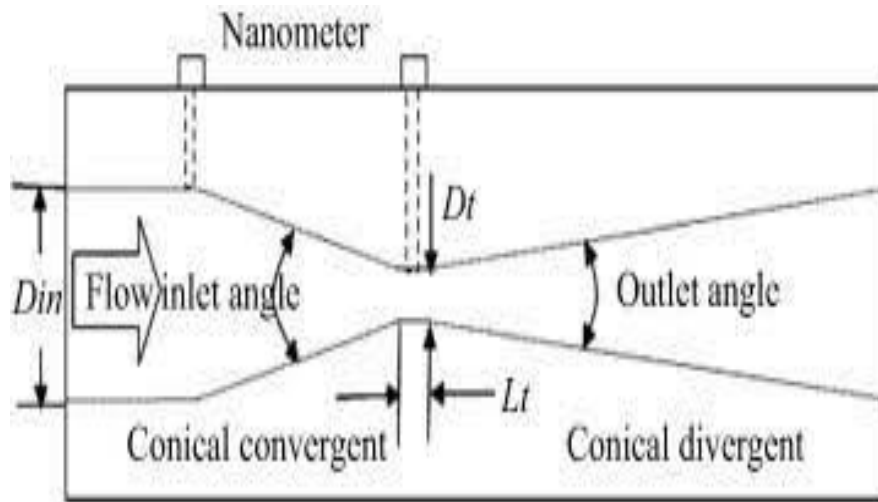


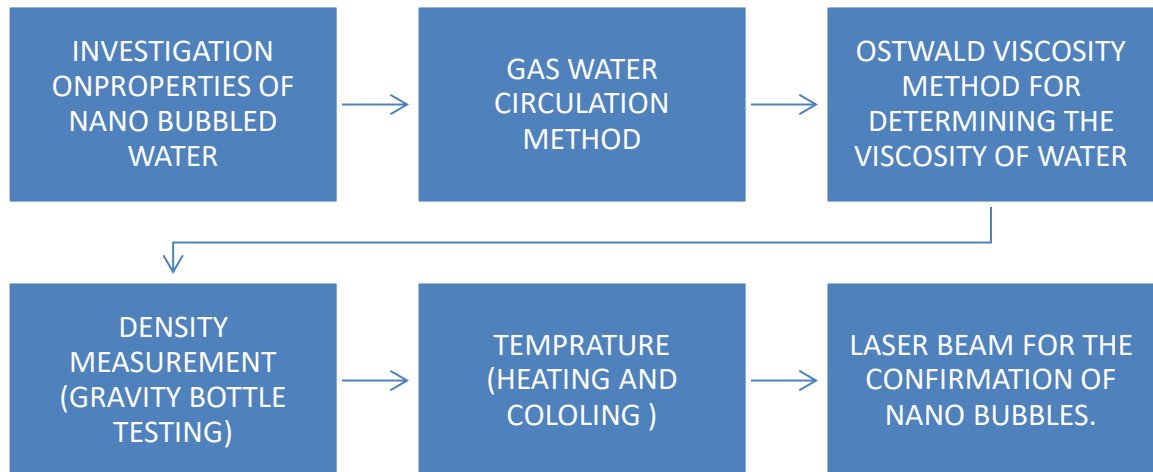
Fig:3.5: Venturimeter

A venturi meter typically consists of a converging section, a throat, and a diverging section. The converging section narrows down the pipe, causing the velocity of the fluid to increase and the pressure to decrease. At the throat, the pipe narrows down to its smallest cross-sectional area, where the velocity of the fluid is at its maximum and the pressure is at its minimum. The diverging section then widens the pipe, causing the velocity to decrease and the pressure to increase back to its original value.

To measure the flow rate of the fluid, the venturi meter is typically installed in the pipe and a pressure difference is measured between the upstream and downstream sections of the meter. This pressure difference is directly proportional to the square of the fluid velocity, and hence the flow rate can be determined using the venturi meter equation.

Venturi meters are widely used in industries such as oil and gas, water treatment, and chemical processing to measure the flow rate of fluids accurately and reliably.

3.2 METHODOLOGY



3.2.1 FUNDAMENTAL PROPERTIES OF MICRO NANOBUBBLE

This report highlights the benefits of using nanobubbles in tap water to improve its quality. The presence of nanobubbles resulted in lower concentrations of various contaminants such as total dissolved solids (TSS), total dissolved solids (TDS), sulphite, chromium, phosphate, and nitrate. However, there are still debates about the abilities and existence of nanobubbles in solutions under specific conditions. According to classical thermodynamics theory, the narrow curvature of nanobubbles limits their survival and stability as the high pressure inside does not balance with the surrounding air, causing them to rupture quickly. Advanced techniques such as atomic force microscopy, X-ray reflectivity, neutron reflectometry, and quartz clear microbalance have been used to locate and describe nanobubbles. Nanobubbles are known for their resilience, superior contact angle, and longer lifetime in liquids, distinguishing them from other materials.

3.2.2 MNB GENERATION PROCESS

Nanobubbles are formed by regulating water pressure to create a pattern of separating vapor and delivering it while reducing pressure, using a combination of water inject, air compressor, and air tank. This process results in regular bubbles of water in a watertight container containing a dissolved substance. Nanobubbles have been found to be effective in improving the quality of drinking water, with lower levels of turbidity, viscosity, pH, TDS, and TSS compared to water without nanobubbles. The hydrophobic particles used to create nanobubbles are only present on the surface. The formation of nanobubbles can be attributed to various internal and external factors. Water is circulated in a transparent, colored container through a vaporization-condensation system and a nozzle that generates microbubbles. Air is introduced into the flowing water on the intake side and removed using an agitation method. An air compressor pushes air into the stopped flow container, while the water supply adjusts the pressure to propel the flowing water into the dissolved vapor container. The agitation of the gas-water mixture in the annular vapor container creates a supersaturated gas that rapidly condenses and disappears, causing the microbubbles to accelerate due to the sudden decompression of water in the microbubble generator nozzle.

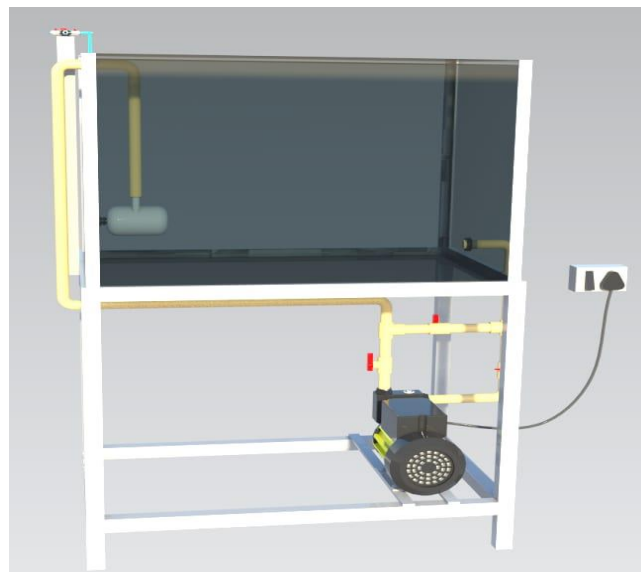


Fig:3.6: Nanobubble Generation Tank

3.2.3 AERATION PROCESS

Aeration involves injecting or penetrating oxygen into a liquid and is a crucial aspect of water treatment, as oxygen is essential for biological reactions in substrates and aquatic organisms. Various studies have focused on the impact of aeration methods on wastewater treatment, biological water, and groundwater recovery, with the aim of enhancing the effectiveness of the numerous factors that influence mass transfer rates.

To address the inefficiency of aeration systems, aerobic systems that rely on dissolved oxygen have been developed, but they require significant maintenance expenses and power input, making the amount of oxygen transferred during mass transfer crucial. Researchers have tried to optimize the design of traditional bubbles and aerators to improve oxygen transfer, but there has been no systematic study of high mass transfer bubbles. In this study, the gas-liquid mass transfer rate parameters of stirred-tank reactors using microbubbles for aeration were analyzed, and it was found that microbubble aeration is better suited for bioreactors. The impact of microbubble aeration on the mesophilic filamentous fungus *Trichoderma*, which relies on the limited rate of oxygen mass transmission, was also examined. It was observed that using microbubble aeration resulted in higher dissolved oxygen levels compared to lower agitation rates. The concentration of cellular mass also increased rapidly during the fast growth phase, going from 0.1 to 0.18 g/LH, which is a significant increase when compared to the normal bubbling seen during the stationary phase.

Results showed that synthetically aerated NB treatment plants achieved almost double the oxygen consumption and volume transfer rates as those attained with normal air bubbles. When compared to traditional systems, the NB-aerated units' organic waste production degrading time was less than half as long. Last but not least, the NB aerated unit's decay and growth rates were likewise substantially faster than those of the traditional system. Further experimental research in this field are required as a result of these features.

3.2.4 MNB APPLICATION IN WATER TREATMENT

A critical component of water treatment is aeration, which involves the injection or penetration of oxygen into a liquid. This process is essential for facilitating biological reactions in substrates and supporting the survival of aquatic organisms. Researchers have conducted many studies to investigate the impact of aeration methods on various aspects of water treatment, such as wastewater treatment, biological water, and groundwater recovery. These studies aim to improve the efficiency of the numerous factors that affect mass transfer rates, which can be a limiting factor in achieving optimal water treatment outcomes.

Recent research has shown that the use of MNBs has significant potential in several key areas of water management. For example, in wastewater treatment, MNBs can increase the capacity of processing plants, extend their operating period, and reduce associated costs. Additionally, MNBs are effective at removing water contaminants, thus enhancing water quality.

In agriculture, the use of MNB-treated water can improve soil conditions by promoting the growth of aerobic microorganisms, leading to enhanced plant growth and nutrient uptake. MNBs can also reduce CH₄ emissions and arsenic solubility in flooded soils. Moreover, MNBs are utilized in hydroponic systems to sanitize irrigation water and enhance plant growth.

MNBs have diverse applications in the medical field, including the identification of malignancies in human tissue using ultrasound imaging, cancer treatment, dental care, and malaria detection. Additionally, MNBs can be used in genetics research for drug, oxygen, and gene delivery.

In the energy industry, MNBs can be employed in mechanical biological cleaners to separate oil and carbon from water, allowing for cost-effective water reuse.

Furthermore, magneto-nematic bimorphs can be utilized to generate solar steam energy via nanobubble generation, providing a clean and efficient source of energy.

CHAPTER 4

INVESTIGATION OF PROPERTIES OF NANOBUBBLES

4.1 GAS WATER CIRCULATION METHOD

The gas-water circulation approach produces a flow of very small bubbles in water, ranging from micro- to nanoscale. The method involves pumping water into a nozzle with an off-center position to induce a swirling motion. As a result, a vacuum is created at the nozzle's outlet, where the desired gas is injected at a precisely controlled rate. As the gas is introduced into the swirling water via the vacuum, it emerges from the nozzle as a blend of micro- and nanobubbles.

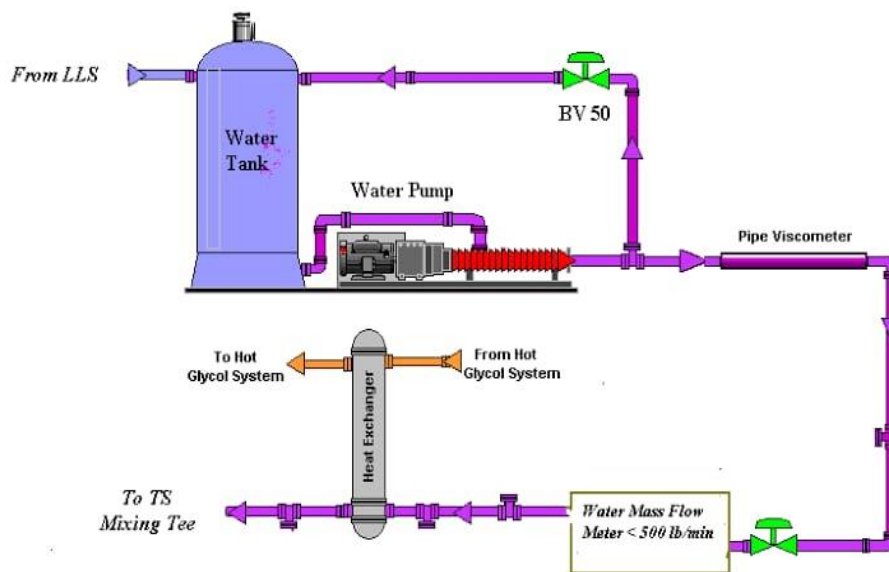


Fig:4.1: Water Circulation System

4.2 OSTWALD VISCOSITY METHOD

The Ostwald viscosity method is utilized to ascertain the viscosity of a Newtonian fluid. In this approach, the liquid is allowed to flow due to gravity through a capillary tube, and the time taken by the liquid to pass through the two demarcated points, A and B, is recorded. To calculate the viscosity of the

unknown liquid, the flow time of the liquid being tested is compared to the flow time of a liquid with a known viscosity. This enables the calculation of the viscosity of the unknown liquid under test.

η_1 can be determine using following equation.

$$\eta_1 = \rho_1 t_1 / \rho_2 t_2 \times \eta_2$$

ρ_1 = Density of unknown liquid

t_1 = Time of flow of unknown liquid

ρ_2 = Density of standard liquid

t_2 = Time of flow of standard liquid

η_2 = Viscosity of standard liquid.

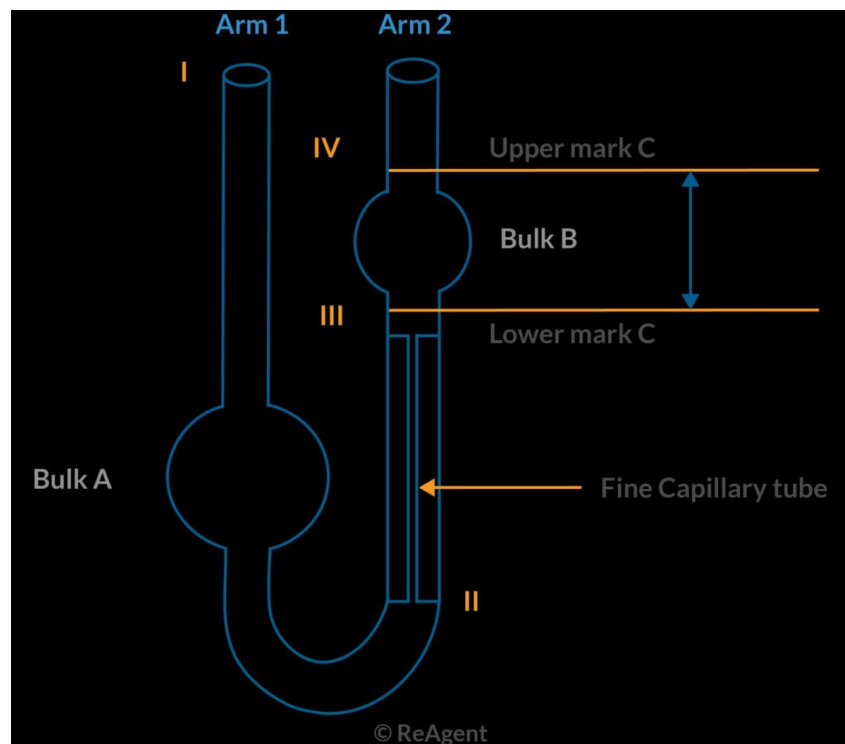


Fig:4.2: Schematic Diagram Of Viscometer

4.3 DENSITY MEASUREMENT

Density bottles are primarily utilized for measuring the density of moderately viscous liquids. Unlike volumetric flasks, they are not considered volumetric instruments, but rather calibrated "to contain," indicating that they are designed to hold a fixed volume of liquid.



Fig:4.3: Density Measurement

4.4 HEATING AND COOLING

An experiment was conducted to investigate the behavior of nanobubbles when subjected to heat, using a hot plate method. The hot plate utilized in this experiment had a power capacity of 1000 watts and operated on 230 volts of alternating current. Two samples were prepared in Borosil glass beakers, one containing nanobubbles and the other without, both with a volume of 60 milliliters. The samples were heated at a constant temperature using the medium mode setting on the hot plate. Temperature readings were taken with a mercury-in-glass thermometer, and the initial and final temperatures were

recorded, along with the time taken to heat and cool the samples. This experiment was conducted under controlled conditions to examine the thermal properties of nanobubbles.

4.5 LASER BEAM METHOD

The analysis of scattered light intensity provides a means of distinguishing between microbubbles and nanobubbles. Microbubbles have a lower refractive index than water, whereas the refractive index of nanobubbles, which are approximately 60 nanometers in size, is higher than that of water. This variation in refractive index results in a natural variation in the intensity of scattered light, which can be leveraged to differentiate between these two types of bubbles. In the presence of nanobubbles, a laser beam that is passed through water causes the beam width to decrease and converge into a point due to the constant horizontal motion and high internal pressure of the nanobubbles in the aqueous solution. In contrast, a laser beam that is passed through normal water maintains a constant width. The convergence of the laser beam in the presence of nanobubbles is a clear indication of their existence in the water and serves as additional experimental evidence for their presence.

The laser beam method refers to the use of a highly concentrated and focused beam of light (laser) to perform a wide range of tasks in various fields such as medicine, manufacturing, and communication.

In manufacturing, lasers can be used to cut or weld materials with high precision and accuracy. In medicine, they can be used for surgical procedures or to treat conditions like eye disorders. In communication, lasers can transmit data over long distances through fiber optic cables.

The laser beam method is highly precise and efficient, making it a valuable tool

in many

industries. However, it also requires specialized equipment and training to use safely and effectively.

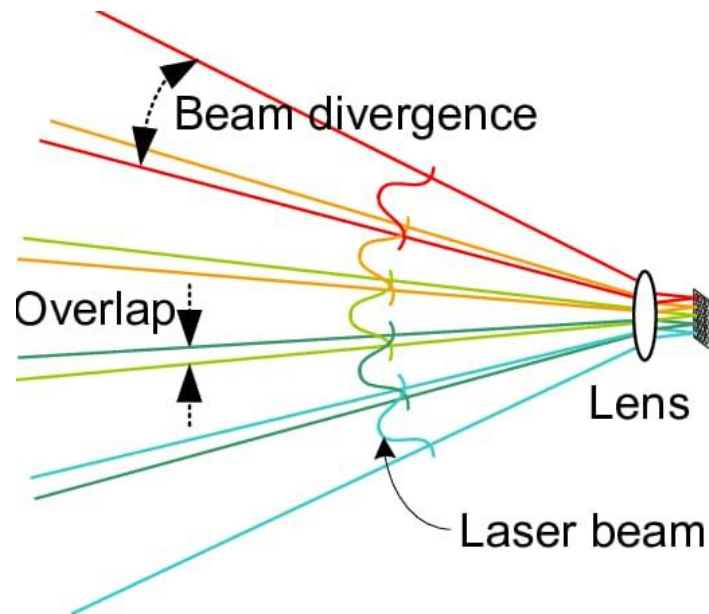


Fig:4.4:Laser Beam Method

CHAPTER 5

PROPERTIES OF NANOBUBBLE

5.1 Density

Density, a fundamental property of matter, quantifies the mass of a material per unit volume. The unit of measurement for density is grams per cubic centimeter, which indicates the weight of a substance relative to the space it occupies. For liquids, density is an essential indicator of their weight in relation to the volume they occupy. If two liquids have similar volumes or amounts, the one that weighs more has a higher density. Furthermore, if a substance is less dense than water, it will float when gently placed on the surface of water because it cannot displace an equal amount of water owing to its lower density.

To determine the mass of a sample accurately, the mass of the specific gravity bottle containing the sample (m_s) is measured and then subtracted from the mass of the empty specific gravity bottle (m_e). This calculation provides a precise measurement of the mass of the sample being weighed.

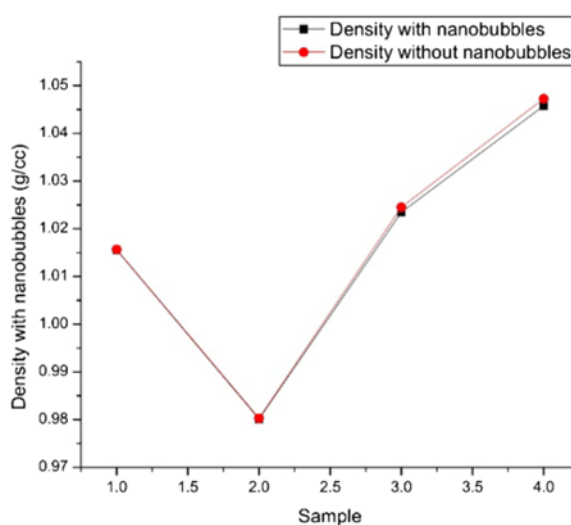


Fig:5.1:Graph Comparing Density

5.2 Viscosity

The physical attribute of kinematic viscosity is crucial when evaluating the optimal combustion efficiency of biodiesel in diesel engines, as it determines how the fuel burns within the engine. Biodiesel's kinematic viscosity is affected by various factors, including temperature, the number of double bonds, and the carbon atom count, which alter the fuel's molecular structure and, in turn, impact its combustion behavior within the engine. Therefore, understanding the kinematic viscosity of biodiesel is essential to ensure its efficient and effective combustion in diesel engines.

$$\text{Viscosity} = \text{Time in seconds} \times 0.014 \text{ (diameter)}$$

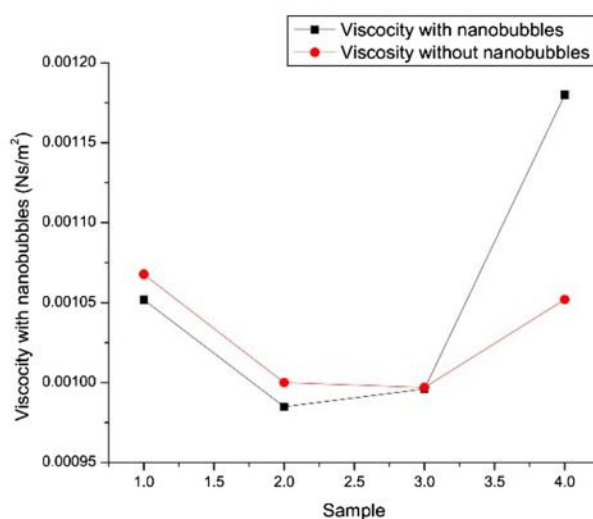


Fig:5.2: Graph Comparing Viscosity

5.3 pH (POTENTIAL HYDROGEN)

The pH scale is a logarithmic numerical measurement of the concentration of hydrogen ions (H^+) in a water-soluble substance, which serves as an indicator of its acidity or alkalinity. The pH scale ranges from 1 to 14, where a neutral pH of 7 denotes equal concentration of H^+ and hydroxide ions (OH^-) present in the substance. The pH values below 7 correspond to acidic substances, with the lower the number, the stronger the acidity. Conversely, pH values above 7 indicate alkalinity, where higher numbers indicate a greater level of alkalinity.

5.4 TOTAL SUSPENDED SOLIDS

Total suspended solids (TSS) are defined as solids in water that can be trapped by a filter. To measure TSS, the water sample is filtered through a pre-weighed filter. The residue retained on the filter is dried in an oven at 103–105°C until the weight of the filter no longer changes. In water sources, a significant proportion of TSS comprises of inorganic materials, although TSS levels may also be influenced by the presence of organic matter such as algae and bacteria. TSS is a broad term that refers to any suspended particulate matter, including sediment, sand, and plankton. The decay of organic matter can introduce suspended organic particles into water sources. While some sedimentation may occur, some TSS particles remain suspended within the water column or at the water surface. The level of TSS affects the clarity of water, and higher TSS content leads to decreased clarity. Therefore, monitoring and managing TSS levels in water sources are critical to maintaining water quality. Total suspended solids (TSS) refer to the concentration of solid particles present in water that are not dissolved and can be trapped by a filter. TSS is an essential parameter used to measure the level of water pollution caused by sedimentation, erosion, or human activities such as industrial or agricultural discharge. TSS can affect water quality and aquatic life by reducing light penetration and oxygen levels, which can cause harm to fish and other aquatic organisms. High TSS levels can also clog water treatment facilities and increase operational costs. Therefore, it is essential to monitor TSS levels in water bodies to ensure their safe use and to protect the environment. Several methods are available to measure TSS, including gravimetric analysis, optical methods, and turbidity measurements. However, each method has its limitations and requires appropriate calibration and quality control measures to ensure accurate and reliable results. In conclusion, TSS is an essential parameter that affects water quality and aquatic life, and it must be monitored and managed to ensure safe and sustainable use of water resources. Regular monitoring and appropriate management practices can help prevent the adverse impacts of high TSS levels on human health and the environment.

5.5 TOTAL DISSOLVED SOLIDS

Dissolved solids" refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts, principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates and some small amounts of organic matter that are dissolved in water. Total dissolved solids (TDS) refer to the sum of all inorganic and organic substances that are present in water in a dissolved form. TDS can have significant effects on water quality, and it is important to understand its impact on water resources. One of the critical factors affecting water quality is the level of TDS present in it. TDS can be introduced into water sources from natural sources like weathering of rocks or from anthropogenic sources like wastewater discharge, agricultural runoff, or industrial effluents. High levels of TDS can impact the taste, odor, and color of water, making it undesirable for consumption. It can also cause health problems and damage to aquatic ecosystems. Therefore, it is essential to monitor TDS levels in water bodies to ensure their safe use and to protect the environment. Various methods are available to measure TDS, including gravimetric analysis, conductivity measurements, and optical methods. However, these methods require appropriate calibration and quality control measures to ensure accurate and reliable results. In conclusion, TDS is a critical parameter that affects water quality and must be monitored and managed to ensure safe and sustainable use of water resources. Regular monitoring and appropriate management practices can help prevent the adverse impacts of high TDS levels on human health and the environment

CHAPTER 6

RESULT AND DISCUSSION

MNB is a promising technology that has gained substantial traction during the past 10 years in a variety of industries. This review paper emphasises the current level of knowledge and the context around MNB's usage in a number of water treatment applications, including flotation technology and disinfectants, among others. Separation and stability have not been tested to see whether they conform to scientific standards (classical thermodynamic principles). Despite a number of advances and the hypothesised explanations for the long-term stability of NBs, the experimental data cannot be explained. The project also aims to conduct more investigations into performance approaches, bubble size and growth under diverse physical and chemical circumstances, bubble generating techniques, and automated optimization.

TOTAL DISSOLVED SOLIDS

Today, the water treatment facilities discharge dangerous substances into the drinking water that we receive. Consequently, the natural minerals in the water are eliminated. In this situation, appropriate filtration techniques must be employed to eliminate impurities and render the water safe for consumption. The primary pollutant remaining in the water following the typical filtration process is known as total dissolved solids (TDS), which encompasses contaminants that exceed 2 microns in size. Fine filters are typically effective in removing particles that are 0.45 microns in size and originate from a variety of sources.

Table 6.1: TABLE DESCRIBING TDS

SAMPLE	TDS	
	With Nanobubble	Without Nanobubble
1	840 mg/L	1000 mg/L

The Total Dissolved Solids (TDS) level of the sample before undergoing nanobubble treatment was measured to be 1000mg/l, while after being subjected to the nanobubble treatment, the TDS level was found to have significantly reduced to 840mg/l. This noticeable change in TDS clearly indicates the effectiveness of the nanobubble treatment in removing dissolved solids from the sample.

TOTAL SUSPENDED SOLIDS

Total suspended solids (TSS) refer to solids in water that can be captured by a filter. To determine the TSS level, a water sample is filtered using a pre-weighed filter, and the remaining residue is dried at 103-105°C until the filter's weight becomes constant. The difference in weight before and after filtration is used to calculate the TSS concentration.

In contrast, turbidity is a measurement of the amount of suspended particles in a liquid, determined by the degree to which these particles scatter light. The unit used for measuring turbidity can vary depending on factors such as the wavelength of the light source and the angle at which it is incident. Nephelometric turbidity units (NTU) are a commonly used unit of measurement for turbidity, based on white light with a wavelength range of 400-680 nm and a 90° incident angle. Measuring total suspended solids (TSS) is essential for ensuring Efficient treatment of wastewater is crucial for protecting environmental health. As wastewater usually contains a significant amount of suspended organic and inorganic matter, it is essential to remove them before discharging into the environment through various methods like screening, filtration, or settling/flotation. Failure to remove Total Suspended Solids (TSS) can lead to decreased water quality in the receiving environment by absorbing light and causing an increase in water temperature and decreased oxygen levels. This can harm aquatic life, highlighting the importance of regulating TSS effluent levels in wastewater treatment plants that discharge into the environment. High TSS concentrations can also affect UV disinfection by blocking or scattering UV light, which is used for pathogen disinfection. This may require higher intensity for adequate disinfection, leading to increased energy costs.

Table 6.2: TABLE DESCRIBING TSS

SAMPLE	TSS	
	<i>With Nanobubble</i>	<i>Without Nanobubble</i>
1	2400 mg/L	5000 mg/L

The Total Suspended Solids (TSS) level in the sample prior to the nanobubble treatment was measured to be 5000mg/l, whereas after undergoing the nanobubble treatment, the TSS level was significantly reduced to 2400mg/l. This substantial reduction in TSS demonstrates the efficacy of the nanobubble treatment in removing suspended solids from the sample. Thus, the observed change in TSS clearly indicates the positive impact of the nanobubble treatment on the quality of the sample.

POTENTIAL OF HYDROGEN (PH)

The pH scale is used to determine the acidity or alkalinity of a substance or solution, and ranges from 0 to 14. . A pH level of 7 denotes a neutral state, whereas pH levels lower than 7 indicate acidity, and pH levels higher than 7 indicate alkalinity Proper pH balance is crucial for optimal physiological function in bodily fluids. The pH scale is logarithmic, meaning that it is inversely proportional. The pH of a solution refers to the amount of hydrogen ions present, and solutions with a pH below 7 are considered acidic, while those with a pH above 7 are considered alkaline

at a temperature of 25. Concentrated strong acids have the potential to exhibit a pH level below 0, while concentrated strong bases have the ability to reach a pH level higher than 14. pH is typically measured using a pH meter or color-changing indicator, with standard solutions used to establish the pH scale. pH measurements have a wide range of applications, including fields such as chemistry, medicine, agronomy, and water treatment.

Table 6.3: TABLE DESCRIBING PH

SAMPLE	PH	
	<i>With Nanobubble</i>	<i>Without Nanobubble</i>
1	7	7.4

The pH level of the sample prior to nanobubble treatment was measured to be 7.4, whereas after undergoing the nanobubble treatment, the pH level was observed to

have decreased to 7. This significant decrease in pH demonstrates the effectiveness of the nanobubble treatment in altering the pH level of the sample. Thus, the observed change in pH clearly indicates the ability of the nanobubble treatment to modify the chemical composition of the sample.

TURBIDITY

The level of clarity or transparency of water is referred to as turbidity, and it is influenced by suspended particles such as silt, sewage, plankton, and algae. These particles scatter and absorb light rays, resulting in turbidity. An increase in turbidity leads to water appearing cloudier and denser due to a higher concentration of particles. To measure turbidity, Nephelometric Turbidity Units (NTU) or Formazin Nephelometric Units (FNU) are typically employed, with NTU measurements obtained through white light at a 90-degree detection angle according to EPA Method 180 guidelines. Nephelometers or turbidimeters can detect the intensity of light scattered at a 90-degree angle as it passes through a water sample. Turbidity can be influenced by multiple factors, including sediment erosion, resuspended sediments, waste discharge, phytoplankton, algae growth, and urban runoff. The World Health Organization recommends that drinking water should have a turbidity level below 1 NTU, and levels should not surpass 5 NTU.

Not just aesthetically unappealing but can also increase the cost of water treatment and impact the effectiveness of disinfection for drinking purposes. Additionally, suspended particles can facilitate the attachment of toxic organic compounds, heavy metals, and pesticides, making it crucial to eliminate turbidity from water.

Table 6.4: TABLE DESCRIBING TURBIDITY

SAMPLE	TURBIDITY	
	<i>With Nanobubbles</i>	<i>Without Nanobubbles</i>
1	3.3 NTU	8.9 NTU

The turbidity level of the sample before the nanobubble treatment was measured to be 8.4 NTU, while after undergoing the nanobubble treatment, the turbidity level was significantly reduced to 3.3 NTU. This substantial reduction in turbidity indicates the efficacy of the nanobubble treatment in removing suspended particles and colloids

from the sample. Thus, the observed change in turbidity clearly highlights the positive impact of the nanobubble treatment on the clarity of the sample.

CHAPTER 7

CONCLUSION

The electrolysis method can produce nanobubbles, which range in size from 60 to 80 nanometers, in various types of water solutions, such as tap water, distilled water, slurry water, and sea water. These nanobubbles exhibit a mineral floatation property that can be beneficial for wastewater treatment processes. When present in slurry and seawater, nanobubbles were found to cause a higher percentage reduction of density, with values of 0.102% and 0.142%, respectively.

Studying the properties and behavior of nanobubbles is crucial for their application in various industries. Consequently, a sequence of laboratory experiments was carried out to examine their conduct. The use of MNB technology has gained significant momentum in several industries over the past decade. The primary aim of this journal is to concentrate on the present level for comprehension and the utilization of MNBs in diverse water treatment applications such as disinfectants and flotation technology. among others. Despite significant advances, the separation and stability of MNBs have yet to be tested against classical thermodynamic principles. Additionally, experimental data cannot be explained, despite proposed explanations to ensure the enduring steadiness or durability of nanobubbles. The project's objective is to carry out additional inquiries into various aspects, including performance methods, bubble size and expansion in diverse physical and chemical circumstances, techniques for bubble generation techniques and automatic inflation.

REFERENCES

- [1] Agarwal, A. Ng, W. j. Liu, Y. Principle and applications of microbubble and nanobubble technology for water treatment.
- [2] Ahmed N. Jameson G. 1985. The effect of bubble size on the rate of flotation of fine particles. *International Journal of Mineral Processing* 14 (3), 195–215.
- [3] Attard P. 2013 The stability of nanobubbles. *European Physical Journal Special Topics* 223 (5), 893–914. <https://link.springer.com/article/10.1140/epjst/e2013-01817-0>
- [4] Azevedo A. Etchepare R. Calgarato S. Rubio J. 2016. Aqueous dispersions of nanobubbles: generation, properties and features. *Minerals Engineering* 94, 29–37.
- [5] Batagoda J. H. Hewage S. D. A. Meegoda J. N. 2019. Nano-ozone bubbles for drinking water treatment. *Journal of Environmental Engineering and Science* 14 (2), 57–66.
- [6] Dockko S. Han M. Y. 2004. Fundamental characteristics of bubbles and ramifications for the flotation process. *Water. Science & Technology* 50 (12), 207–214.
- [7] An investigation of nanobubbles in aqueous solutions for various applications G. Senthilkumar· C. Rameshkumar. M. N. V. S. Nikhil· J. Navin Ram Kumar.

- [8] Demangeat J.-L. 2015 Gas nanobubbles and aqueous nanostructures: the crucial role of dynamization.
- [9] El-Zahaby A. M. El-Gendy A. S. 2016 Passive aeration of wastewater treated by an anaerobic process – a design approach.
- [10] Cho, S. H. Kim, J. Y. Chun, J. H. Kim, J.D. 2005 Ultrasonic formation of nano bubbles and their zeta-potentials in aqueous electrolyte and surfactant solutions. *Colloids and surfaces A* 269 (1-3), 28-34.
- [11] Ohgaki, Khanh, N.Q. Jorden, Y. Tsuji, A, Nakagawa, T. 2010 Physiochemical approach to Nano bubble solution. *Chemical Engineering science* 65(3), 1296-1300.
- [12] Parker, J.L. Claesson, P.M. Attard, P. 1994 Bubbles, cavities, and long range attraction between hydrophobic surfaces. *Journal of physical chemistry* 98(34), 8468-8480.
- [13] Ushikubo, F.Y. Furukawa, T. Nakagawa, R. Enari, M. Makino, Y. Kawagoe, Y. Shiina, T. Oshita, S. 2010. Evidence of the existence and stability of nano-bubbles in water. *Colloids and surfaces A: Physicochemical and engineering aspects* 361 (1-3), 31-37.
- [14] Wang, S. Liu., M. Dong, Y. 2013 Understanding the stability of surfaced nanobubbles. *Journal of Physics: condensed matter* 25(18), 184007.
- [15] Yoon, R.-H. 1993 Microbubbles flotation *Mineral Engineering* 6(6), 619-630.

- [16] Zhang, X.H. Maeda, N. Craig, V.S.j. 2006 Physical properties of nanobubbles on hydrophobic surfaces in water and aqueous solutions. *Langmuir* 22(11), 5025-5035.
- [17] Bredwell, M.D. Worden , R.M. 1998 Mass transfer properties of Microbubbles. 1. Experimental studies. *Biotechnology progress* 14(1), 31-38.
- [18] Cavalli, R. Bisazza, A. glustetto, P. civra, A. lembo, D. trotta, G. guiot, C. trotta, M.2009 preparation and characterization of dextran nanobubbles for oxygen delivery. *International journal of pharmaceutics* 381 (2), 160-165.
- [19] De Rik, S.E. van der graff, J. H. J.M den Blanken, J.G 1994 Bubble size in floatation thickening. *Water research* 28(2), 465-473.
- [20] Lou, S.T. Ouyang, Z.Q. zhang,, Y. Li, X.j. Hu, J. Li, M. Q. Yang, F. J. 2000 Nanobubbles on solid surface imaged by atomic force microscopy. *Journal of vacuum science and Technology B* 18(5), 2573-2575.
- [21] Agarwal, A. Ng, W. j. Liu, Y. Principle and applications of microbubble and nanobubble technology for water treatment.
- [22] Ahmed N. Jameson G. 1985. The effect of bubble size on the rate of flotation of fine particles. *International Journal of Mineral Processing* 14 (3), 195–215.

- [23] Attard P. 2013 The stability of nanobubbles. *European Physical Journal Special Topics* 223 (5), 893–914.
- [24] Azevedo A. Etchepare R. Calgarato S. Rubio J. 2016. Aqueous dispersions of nanobubbles: generation, properties and features. *Minerals Engineering* 94, 29–37. b
- [25] Batagoda J. H. Hewage S. D. A. Meegoda J. N. 2019. Nano-ozone bubbles for drinking water treatment. *Journal of Environmental Engineering and Science* 14 (2), 57–66.
- [26] Dockko S. Han M. Y. 2004. Fundamental characteristics of bubbles and ramifications for the flotation process. *Water. Science & Technology* 50 (12), 207–214.
- [27] An investigation of nanobubbles in aqueous solutions for various applications G. Senthilkumar· C. Rameshkumar. M. N. V. S. Nikhil· J. Navin Ram Kumar.
- [28] Demangeat J.-L. 2015 Gas nanobubbles and aqueous nanostructures: the crucial role of dynamization.
- [29] El-Zahaby A. M. El-Gendy A. S. 2016 Passive aeration of wastewater treated by an anaerobic process – a design approach.
- [30] Cho, S. H. Kim, J. Y. Chun, J. H. Kim, J.D. 2005 Ultrasonic formation of nano bubbles and their zeta-potentials in aqueous electrolyte and surfactant solutions. *Colloids and surfaces A* 269 (1-3), 28-34.

