

INFLUENCE OF OXYGEN NANOBUBBLES FOR ENRICHMENT OF DISSOLVED OXYGEN IN ULTRA PURE WATER

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

BY

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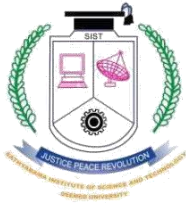
**DEPARTMENT OF MECHANICAL ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

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

**Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **POLU PRAJUVAL REDDY (39150098)** and **POTHAKAMURI VENKATA ABHI RITHVIK (39150097)** who carried out the project entitled "**INFLUENCE OF OXYGEN NANOBUBBLES FOR ENRICHMENT OF DISSOLVED OXYGEN IN ULTRA PURE WATER**" under our supervision from December 2022 to April 2023.

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DECLARATION

We **POLU PRAJUVAL REDDY (39150098)** and **POTHAKAMURI VENKATA ABHI RITHVIK (39150097)** hereby declare that the Project Report entitled **“INFLUENCE OF OXYGEN NANOBUBBLES FOR ENRICHMENT OF DISSOLVED OXYGEN IN ULTRA PURE WATER”** done by us under the guidance of **Dr.NIVIN JOY 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 in Mechanical Engineering.

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ABSTRACT

The nanobubbles (200 nm in diameter) exhibit a variety of unique qualities, including a prolonged life in liquids because of their extremely soluble nature and negatively charged surface area. Due to high internal pressures, in gases. Despite their widespread usage as diagnostic instruments and medicine delivery systems, no studies have examined their effects on the formation of human life. Utilizing nanoparticles

For four weeks, *Brassica campestris* was hydroponically grown in water with wind or freshwater nanoparticles. River fish and lake trout were raised for three and six weeks, respectively, in liquid containing air nanoparticles or regular liquid. Finally, five-week-old male DBA1/j mice reproduced properly in pastures that were within normal limits. For 12 weeks, she drank either submicron water or regular water. The accumulation of the nanoparticles and the quantity of dissolved oxygen were both typically steady for 70 days, but both changed dramatically after that the oxygen nanoparticles have risen. Air nanowater enhanced leaf height and length as compared to regular water Freshwater fish may weigh up to 10.2 kg in air saliva and 3.0 kg to 6.4 kg in regular water, respectively. In regular water, rainbow trout's total weight rose from 50.0 to 129.5 kg, but in nanofoam liquid, it fell from 50.0 to 148.0 kg. When oxygen-free nanomarbles are used, water length and weight both considerably increase first demonstrates the potential of oxygen and water nanobubbles as instruments for life growth.

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LIST OF ABBREVIATIONS

CaCO ₃	-	Calcium Carbonate
CU	-	Conductivity Units
DLS	-	Dynamic Light Scattering
DO	-	Dissolved Oxygen
EC	-	Electrical Conductivity
mg/L	-	milligrams per liter
MNB	-	Micro Nanobubbles
ppm	-	parts per million
Pt-Co	-	Platinum-Cobalt
PVA	-	Polyvinyl Alcohol
SEM	-	Scanning Electron Microscopy
TDS	-	Total Dissolved Solids
TEM	-	Transmission Electron Microscopy

CHAPTER 1

INTRODUCTION

Nanobubbles are minuscule air bubbles in liquids that have a diameter smaller than the line - of - sight and unique physical properties. While macroscopic particles multiply, climb to the surface quickly, and ultimately disintegrate on the level, they are stable in for a long time because the surface contains a repulsive force (zeta potential). Because the pressure of the nanoscale in the liquid is substantially higher than the ambient pressure, the breakdown of the vapours in the liquid is expedited. It has been reported that the remarkable gas solubility feature of nanoparticles is used to create the osmotic pressure of gaseous oxygen in water. Smaller bubble sizes are connected with repeated testing of more dioxide (PO₂) in water, showing that nano-balls have a greater PO₂ concentration in the water than tiny pebbles (10 to 50 m in diameter).

Because of their high oxygen solubility and numerous applications, small particles have been found to facilitate the oxidative stress of tissues with low oxygen content. Effective in medicine A recent test-tube study found that NaCl solution containing nano-oxygen effectively cured ischemia in pigs. Previous studies have shown that high oxygen concentrations promote both plant and animal development, suggesting that both air and oxygen levels may have an effect on plant growth. By changing the conditions that allow oxygen to exist. I figured that must be true. In reality, although it was only one study, a previous inquiry found that microbubbles promoted lettuce growth in contrast to macrobubbles. Yet, only plants displayed it; animals were not. Tiny nanobubbles' impact on the development of life has not been the subject of any published study.

The safety of utilising airborne nano-oxygen water and potential effects on the growth of plants, fish, and animals were examined in this study. Recently, the

use of MNB innovation in biological systems has garnered interest. It is believed that water containing MNB promotes plant growth.

Moreover, it is used in the aerobic shellfish rearing process. The addition of air microparticles improved the size and flavour of the culture medium. Male oxygen user an osteoblast culture system with enhanced aminotransferase activity and microbubbles produces increased osteoclast activity. Male oxygenation user an osteoblast culture system with enhanced aminotransferase activity and microbubbles produces increased osteoclast activity.

Nanobubbles are stable for a long period of time because the surface has a repulsive force (zeta potential), but macroscopic particles proliferate, rise to the surface fast, and then disintegrate on the level. The breakdown of the vapors in the liquid is accelerated by the fact that the increased pressure of the nanoscale in the liquid is significantly above the ambient pressure. The osmotic pressure of gaseous oxygen in water has been reported to use the nanoparticles' outstanding gas solubility characteristic. Higher dioxide (PO₂) applying multiple in water are correlated with smaller bubble diameters, indicating that nano-balls PO₂ concentrations in water are higher than tiny pebbles (10 to 50 m in diameter).

Small particles' high oxygen solubility has been shown to aid in the oxidation of impoverished tissues and they have a wide range of uses such as medicine. NaCl solution containing nano-oxygen efficiently treated hypoxia in pigs, according to a recent test-tube research. In regular water, rainbow trout's total weight rose from 50.0 to 129.5 kg, but in nanofoam liquid, it fell from 50.0 to 148.0 kg. According to earlier research, high oxygen concentrations encourage the growth of both plants and animals, indicating both air and oxygen nanoscale may have an impact on plant growth by altering the circumstances under which oxygen may survive. In fact, a prior investigation revealed that microbubbles encouraged lettuce growth in comparison to macro bubbles. This study looked at the safety of using airborne nano-oxygen water and how it can impact the development of plants, fish, and animals. Usage of micro nanobubbles (MNB) innovation in biological systems has recently attracted attention.

It is thought that MNB containing water encourages plant development. Additionally, it is employed in the aerobic raising of shellfish. The size and flavour of the culture media were enhanced by the inclusion of air micro particles. Oxygen Increased amino transfer activity in conjunction with microbubbles in an osteoblast culture system results in increased osteoclast activity. 2.1 times the fresh weight of lettuce micro seeded than micro grained lettuce in size comparable dissolved oxygen (DO) requirements (NBs) offer a Gas delivery technique that affects the structure or transmembrane proteins of membranes or cells. Both impacts have a profound impact on cellular function.

CHAPTER 2

LITERATURE SURVEY

Agrawal et al. (2005) Using nanopatterned surfaces with repeated patterns of polystyrene (hydrophobic domains) and poly(methyl methacrylate), the presence of nanobubbles, as observed using tapping-mode atomic force microscopy, is regulated (hydrophilic domains). We discover that the spatial dimensions of the hydrophobic domains on the nanopatterned surface must match the equilibrium structure of the nanobubbles in order for nanobubbles to exist in addition to influencing the level of surface hydrophobicity.

A.Athanasios et al. (2019) This chapter provides a basic outline of the history, development mechanisms, and potential uses of NBs. A historical problem from the first trials, where the origin of NBs was demonstrated, is explained in particular. The constraints with producing NB in bulk and at the interface, as well as information on their stability, are then discussed. Before reporting on the group of potential application fields, the attributes of NBs are also presented and addressed. The impact of the NBs on biological applications, when fresh, unpublished data are presented, has received some attention.

A.Amirfazli et al. (2004) Line tension is a notion that is widely understood and on firm basis. There is a perception in the literature that there isn't much agreement on the direction or degree of line tension. The existing uncertainty may have been exacerbated in part by improper comparisons of line tension values, particularly those between theoretical and experimental values. It's possible that a large range of reported line tension levels is due to the variety of systems tested rather than contradicting results. Differences across comparable approaches and systems, however, can occasionally be the result of one or more of the following: challenges with sample preparation, subpar experimental methodologies, non-equilibrium, conceptual and theoretical challenges, or mischaracterizations. It is

important to clearly establish the magnitude and sign of line tension as it may determine its relevance to technological applications such as microfluidic systems. This review has examined a wide range of recent and past studies on the subject of line tension.

Beng Hau tan et al. (2021) Although the traditional theory states that spherical gas bubbles cannot reach stable equilibrium, the discovery of stable nanoscopic gaseous domains in liquids, or nanobubbles, has drawn both scepticism and interest. Therefore they established the reality of these gaseous regions. They provide a critical analysis of current theoretical views on the stability of surface and bulk nanobubbles and explain how investigations support or refute these views. They wrap up by discussing open issues and suggesting future directions for the whole discipline.

Changsheng Chen, et al. (2020) Nanobubbles in this can only last for a few milliseconds before fading, while various experimental findings show that they may last for hours or even weeks in bulk solutions. There hasn't been a consensus reached despite the existence of several conjectures on the stability mechanism of bulk nanobubbles, including the contamination process, skin mechanism, and surface zeta potential mechanism. The argument over bulk nanobubbles' stability mechanisms has been heated since they have a lot of promise in a variety of applications and are pertinent to many open problems with implosion and polymerization.

Christopher F. Deacutis et al. (2015) For environmental regulatory purposes, the amount of oxygen present in water that is dissolved is calculated in mg/L or ml/L units, however it is often measured in moles for chemical and oceanographic investigations. The exchange of oxygen with the atmosphere at the seawater's surface accounts for the majority of dissolved oxygen in estuary waters. Nowadays, atmospheric oxygen makes up 23.1% of the atmosphere's mass and 20.9% of its volume. The maximum oxygen concentration at homeostasis with the environment relies on the oxygen pressure in the atmosphere as well as the water's temperature and salinity. Dissolved oxygen saturation falls as temperature and salinity rise, whereas atmospheric pressure increases.

C. Cottin-Bizonne et al. (2003) Here, they offer data demonstrating that hydration characteristics and surface roughness working together may significantly decrease drag of the fluid past boundaries. The use of surfaces with nanoscopic patterning is demonstrated to significantly enhance the fluid's sliding at channel borders. In the same vein as the anti - fouling effects that have been identified at macroscopic sizes, this phenomenon occurs in the region where the surface pattern is partially dewetted. Contrary to popular assumption, our findings demonstrate for the first time that surface roughness can actually reduce surface friction. They also provide the ability for the "nanobubbles" that have long been thought to contribute to interfacial slippage to be controlledly generated.

C.Rameshkumar et al. (2019) They focus specifically on the vacuum distillation production of nanobubbles in pure water. Any bubble with a diameter of less 200 nm is considered a nanobubble. The Atomic Force Microscope is used to measure the size of the nanobubbles. Also, the growth rate of seeds that are germinated with nanobubble water is compared to seeds that are germinated with regular water for species like Tulsi (Holy Basil), beans, and surattense night shade. The comparison is based on how long it took the seed to erupt from the earth, how long it took for the first leaf to bloom, and how long it took for the branches to form entirely. It also examines the situation when moss develops as a result of overwatering plants. However, mass formation was found to be very less when nanobubbled water was flooded during seed germination.

C.Rameshkumar et al. (2021) With the use of nanobubble technology, they offer exploratory study that aims to determine if it is possible to produce drinking water from tap water, regardless of its quality. The first step of our work reflects the production of NBs, and the second phase is the rationalization and reconfiguration of this NBs water to drinking water. The NBs were produced by hydrolysis in tap water, and characterisation experiments using atomic force microscopy and scanning electron microscopy supported this.

D.R. Evans et al. (2004) Scrutinized are the effects of surface-adsorbed nanoscale gas films, or nanobubbles, on the genesis of the hydrodynamic force and

theoretical depictions of this force. Instead of challenging the model's veracity, we look at how well the experimental findings that led to it performed.

Elisavet D.Michailidi et al. (2005). This chapter provides a basic summary of the history, generation processes/generators, and potential uses of NBs. A historical problem from the first trials, where the existence of NBs was demonstrated, is explained in particular. The challenges with producing NB in bulk and at the interface, as well as information on their stability, are then discussed. Before reporting on the group of potential application fields, the attributes of NBs are also presented and addressed. The impact of the NBs on biological applications, when fresh, unpublished data are presented, has received some attention.

G. Binning et al. (1982). The use of vacuum tomography for surface microscopy is shown for the first time. Atomic-scale surfaces have been captured in topographic images. Surfaces of CaIrSn_4 and Au are used as examples of characterized monoatomic steps and surface recreations.

H.K. Christenson et al. (2001) The force between surface tension in aqueous solutions is directly measured and evaluated. The outputs are provided in accordance with the technique used to create hydrophobic surfaces. The published data don't all fit into a single model, thus an effort is made to divide the measured interactions into three groups. The enormous heterogeneity in the measured interaction that occurs based on the kind of hydrophobic surface, frequently within each class, is highlighted. Compared to other hydrophobic surfaces, stable ones only exhibit a very close contact.

Limin Zhou, et al. (2021) Bulk nanobubbles, which can last for several hours or even days, are submicron sized gaseous domains that are disseminated in liquids. The study of BNBs has seen exceptional development recently, as have the applications. Nonetheless, traditional theories based on diffusion rate and Laplace pressure predicted that nanoscale gas bubbles in water should disintegrate within microseconds, providing a topical dilemma in current nanobubbles research. Moreover, the methodologies now in use make it difficult to effectively manufacture BNBs and establish their gaseous nature. In this study, we begin with a basic overview and a succinct history of nanobubble research before going through the

most recent developments in production and detection technologies. There are two potential formation methods, and the probability of each of the proposed theories on BNBs stability is discussed with some suggestions for future studies on bulk nanobubbles.

L. A. Melnik et al. (2019) They have analysis of scientific publications and normative documents concerning properties, fields of using and methods of producing ultrapure water was made. Features of determination of electrical conductivity of ultrapure water as the method of the primary control of its quality were considered. The most effective and spread methods of producing ultrapure water on an industrial basis were described as well requirements to the process of its distribution, storage and use, whose fulfillment rules out degradation of water quality.

Mohit Trivedi et al. (2022) The past several decades have seen a lot of interest in bulk liquid nanobubbles. These are gas-filled bubbles with a mean size between 100 and 200 nm. Exceptional lifespan, a high surface to volume concentration, a high mass transfer coefficient, a high Laplace pressure, and the capacity to produce reactive oxygen species are just a few of the distinctive characteristics of bulk nanobubbles. Nanobubbles have a wide range of uses in the fields of wastewater treatment, medicinal applications, food processing, and environmental sectors due to their distinctive features. Despite these numerous uses, fundamental knowledge of how to create nanobubbles and a special identification method to separate them from particles and nanodroplets are still in their immaturity.

Muidh Alheshibri et al. (2021) The unexpected stability, which opens up a wide variety of prospective applications where the dynamics between particles and nanobubbles are critical, is the source of the fundamental interest. Here, we assess the state of knowledge about systems that contain both nanoparticles and nanobubbles. Acknowledging these systems is crucial since nanoparticles and nanobubbles are frequently encountered together, particularly in situations where nanobubble applications are implicated. This involves looking at how nanoparticles originate from nanobubbles, how nanobubbles form from nanoparticles, and how

nanobubbles and nanoparticles interact. It is evident that further research is needed to properly understand these systems, particularly with regard to the issue of submicron-scale nanobubble-nanoparticle interactions and nanobubble spawning.

M.Behl et al. (2002) Using a nanoimprint photolithographic technology, functional semiconducting polymers have been directly patterned. The described room-temperature technique saves time since it does not require frequent temperature cycling. Moreover, the direct patterning method eliminates the requirement for additional processing steps (plasma treatment) to pattern the underlying semiconducting material.

P. Attard et al. (2002) AFM in tapping mode is used to directly image nanobubbles, the presence of which on hydrophobic surfaces submerged in water had previously been inferred from measurements of long-range attractions between such surfaces. The scientists discovered that the nanobubbles cover the surfaces in a crooked, intertwined, or tightly packed network whose shape is pH-dependent and whose lifetimes are at least of the order of hours. Its radius of curvature is from 100 to 300 nm, and their height is in the range of 30 nm. It appears that a solution that is aerosol gives rise to the nanobubbles.

P. Attard et al. (1996.) Ionic vertices and bonding effects are added to the six-vertex lattice model. The additional vertices reflect the pH of the water, and these represent the sources and sinks for hydrogen atoms. This 14-vertex lattice model with Bjerrum bond defects depicts an ice crystal and, maybe, structured water near to a surface in a way that is not implausible. Such surfaces alienate the surrounding molecules, severely limiting the available hydrogen bonding patterns. The flawed vertices and links screen the polarisation, causing a strong exponentially decaying attraction between two surfaces that are identical to one another.

P. Attard et al. (1996). Given that it is undesirable for water to come into touch with hydrophobic surfaces, they have a close relationship with bubbles. While water droplets on hydrophobic surfaces have a significant contact angle at the three-phase line by definition, one would anticipate that water bubbles would preferentially cling to hydrophobic surfaces. Microvascular evaporation of the water between two closely spaced droplets is another expected outcome. Given that Parker, Claesson,

and I recently proposed that the long-range attractions that have been detected may be caused by nanometric air bubbles bridging between two macroscopic hydrophobic surfaces, the link between bubbles and hydrophobic surfaces is of special interest.

R. Blossey et al. (2003) The idea of a contamination-free (or "no-clean") surface is soon to become a reality because to advances in our knowledge of and ability to create surfaces with controlled wetting qualities. There are now two methods for self-cleaning that function by removing debris through either film or droplet movement. The first consumer products for everyday use and for biotechnology applications are getting closer to being available on the market. The principles for creating such surfaces, the current state of our knowledge of the underlying mechanics, and some of their initial applications are all described in this progress report.

Stewart et al. (2006) Reliable information on the amount of dissolved oxygen in surface and ground waters is crucial for identifying changes in the environment's water resources brought on by both natural occurrences and human activity. Many aquatic creatures depend on dissolved oxygen to survive and thrive, and it is also used as a sign of how well surface-water bodies are doing. The Geological Survey guidelines and protocols for the four theories, photoluminescence, spectrometry, and evaluating the effect (Winkler)—used to measure dissolved oxygen concentrations are provided in this part of the National Field Manual. The National Field Manual's chapters are published independently and go through frequent revisions.

S. Granick et al. (2003) Although viscoelastic flow is well-known and practical, the underpinning physics is surprisingly nuanced and intricate. Recent models and tests demonstrate that when walls are moderate and low, the traditional presumption of "no slide at the border" might severely fail. The causes of this appear to entail manipulable interactions between the materials chemistry, particularly wettability and the existence of traces of contaminants, even dissolved gases. Examining microscopic details is necessary to determine whether boundary condition is acceptable for solving continuous equations.

CHAPTER 3

AIM AND SCOPE OF THE WORK

3.1 AIM

The aim of the present investigation is study the properties of dissolved oxygen in ultra pure water so that we can use this type of water where is there more enriched dissolved oxygen for different applications. To increase the dissolved oxygen we use oxygen nanobubbles by generating them using the generator and mix with the ultra pure water to see the change.

3.2 SCOPE

Future Applications for this research shows that the use of Oxygen Nano-bubbles has wide range of uses like if we see using oxygen nanobubbles we can provide better growth for aquatic life by altering the sea water and enriching the dissolved oxygen in sea water. Having done this we can say that life of aquatic plants and animals increase by 20%. A recent study shows that using Nano-bubbles we can do cultivation in a better way as water is used for cultivation of seeds so, if water which is enriched with dissolved oxygen by nano-bubbles is used then we can have 20% more cultivated crops.

CHAPTER 4

GENERATION, PROPERTIES AND METHODS

4.1 FUNDAMENTAL PROPERTIES OF MNBS

This incident report emphasises how beneficial nanobubbles are in regular tap water. Total dissolved solids (TDS), sulphate, chromium, phosphate, and nitrate concentrations were all high prior to the formation of nanobubbles. As the ability to produce nanobubbles increases, it has been demonstrated that the importance of water will rise. Three basic categories can frequently be used to classify water bubbles. The classical thermodynamic theory states that strapping and NB preservation are prevented by domain curve restraint For instance, the NBS's small bending radius results in faster death because the internal pressure is higher than the atmospheric pressure. The tension inside the NB for a 100 nm sweep is 1.5MPa at a pressure of 105 N / m² in water and a friction coefficient of 72mN m. The high operating pressure of the NB is thought to produce this occurrence because it does not equalise with the atmosphere, which causes the bubble to explode rather quickly The NBs were initially reported using AFM as brilliant, hard Particles on a solid, level surface (atomic force microscopy). Neutron interferometers, crystal-clear microbalance, and X-ray rempit are some of the most recent methods for NB localization

4.2 MNB GENERATION MECHANISM

On the outside of water-borne particles, MNBS are generated Different mechanisms are used to trigger MNB development based on internal or external influences Typically, gas is dissolved under pressure to form bubbles, and gas is then released when the bubble decompresses. This is regarded as a standard process. The primary pieces of equipment for this technique are a air tank, air

compressor, and water pump. An air compressor drives air into the dissociated gas canister, and a water pump provides a steady pressure that forces flowing water into the canister.

The dissolved gas tank produces a high-pressure hydrocarbon combination that supersaturates the gas and dissolves it, causing the gas to precipitate out of the water as He-MNB through quick decomposition. Due to fast decomposition, the gas precipitates as He-MNB out of the water. The gas dissolving tank and the needle of both the MNB generator are both washed with fresh water that is pumped from the acrylic tank. On the pump's suction side, air is blasted into the flowing water and expelled through the high pressure system. Because of the pressure decrease across the nozzle, water becomes air-supersaturated and transforms into the gaseous phase of He-MNB. There are several MNB generating techniques. When a homogenous liquid phase exists, NB often happens. Cavitation is often brought on by high pressure variations in moving liquids or the propagation of ultrasonic waves. Ultrasound can also cause NB.

4.3 TYPES OF METHODS

4.3.1 Venturi Type Generators

In a venturi alternator, air bubbles are produced as liquid and gas concurrently travel through a venturi tube. After pumping a pressurised liquid into the tube part, the pressure in the intake area drops and the flow of fluid in the cylindrical neck increases, leading to vortex.

4.3.2 Conventional Methods

Micro nanobubble and nanobubble generators generate air bubbles with average particle size > 200 nm by electrolysis, dissolving under pressure or by swirling the liquid in a mixing chamber and feeding the liquid through a single cut-off injector.

4.3.3 Bauer Method

The Bauer Nanobubble Generator is a patented high-tech device that uses a complex model of the cavity and the cutting surface to initiate controlled endothermic reactions to produce oxygen nanoparticles. Highly dense paramagnetic particles with average particle sizes from 50 to 100 nm. To create a chemical balance of ionic species in water.

4.3.4 Oxidation method

The technique of synthesizing oxygen nanobubble water, in accordance with the present invention, involves rapidly attenuating oxygen droplets possessing a diameter of 10 to 50 mm through excitation of the organism. The impedance in an aqueous solution containing oxygen microbubbles is 300 S/cm or greater when electrolytes like ferrous, manganese, calcite, sodium, mg, and other mineral ions are combined. This contradicts the repulsive force's capacity for diminishing bubbles. When the sphere compresses into a spherical microbubble, this electrostatic force increases the curvature of the object and repels any ions of the same sign that are present on the object's opposite surface. The tendency for the reduced oxygen microbubbles to contract begins to increase the smaller they are since their contraction is forced. Yet, this electrostatic interaction force becomes obvious when the bubble diameter is less than 500 nm.

The bubble stops becoming smaller, this electrostatic repulsive force operates sufficiently strongly when an element, such as ca, sodium, mg, ferrous, manganese, or other mineral ions, are immersed in an aqueous solution with a dielectric permittivity of 3 mS/cm or above. By balancing the repelling force and the shrinking force, bubbles maintain their stability. The relatively stable bubble diameter (nanobubble diameter) ranges from 50 to 500 nm, depending on the type and concentration of electrolyte ions. The peculiarity of oxygen nanobubbles is that the concentrated surface charge creates an incredibly strong electric field in addition to retaining oxygen in a compressed condition. The surrounding aqueous solution and the oxygen in the bubbles are both greatly impacted by this powerful electric field,

which also has an impact on bacterial activity, chemical reactivity, and other factors. The microbubble generator's water intake sucks in the container's aqueous solution, while an unknown input injects oxygen into the device to produce oxygen microbubbles.

Generated by the microbubble generator. As a result, the container contains oxygen microbubbles. The discharge generator is connected to the anode and cathode, which are housed in the container. In the onset, the aqueous solution's container contains oxygen microbubbles created by the microbubble generator. Then a mineral-based electrolyte made of calcium, iron, manganese, and other compounds is added. When the aqueous solution's electrical resistance reaches 3 mS/cm or higher, this electrolyte is added. The aqueous phase with oxygen microbubbles in the canister is discharged undersea using the discharge generator. To more consistently produce oxygen nanobubbles, the proportion of oxygen microbubbles in the container should optimally be 50% or higher of the optimum point. The voltage for underwater discharge should optimally be in the 2000–3000V range. By using underwater discharge and wave propagation agitation (corporeal stimulation), oxygen microbubbles in water are quickly reduced to nano-level bubbles. Because of the ions' quick reduction speed at this location, which prevents them from having time to diverge into the surrounding water, the ions become quickly concentrated as the bubbles shrink. Concentrated ions bubbles are encircled by a powerful, high electric field. Hydrogen and hypochlorite ions at the gas-liquid interface bond to electrolyte ions with opposing signs to surround the bubbles, creating an inorganic shell, in the presence of this strong electric field. The O₂ nanobubbles are persistently preserved in the aqueous solution without liquefying because this shell prevents the impulsive solubilization of oxygen in the bubbles in the aqueous solution. Also, since the generated oxygen nanobubble is a very small bubble that spans in size from 50 to 500 nm, it barely experiences buoyancy in water and virtually never ruptures on the water's surface like a conventional bubble would.

4.3.5 Test Methods Used for Water Quality Parameters

IS 3025 Part 4: 1983(Reaff.2017) — COLOUR

IS 3025 Part 5: 2018 — ODOUR

IS 3025 Part 10: 1984	—	TURBIDITY
IS 3025 Part 11: 1983(Reaff.2017)	—	pH at 25 celsius
IS 3025 Part 14: 2013(Reaff.2019)	—	Conductivity @ 25 celsius
IS 3025 Part 16: 1964(Reaff.2017)	—	Total Dissolved Solids
IS 3025 Part 21: 2009(Reaff.2019)	—	Total Hardness as CaCO ₃
IS 3025 Part 40: 1991(Reaff.2019)	—	Calcium as Ca
IS 3025 Part 46: 1994(Reaff.2019)	—	Magnesium as Mg
IS 3025 Part 32: 1988 (Reaff.2019)	—	Chloride as Cl
IS 3025 Part 23: 1986(Reaff.2019)	—	Total Alkalinity as CaCO ₃
IS 3025 Part 24: 1986(Reaff.2019)	—	Sulphate as SO ₄
IS 3025 Part 34: 1988(Reaff.2019)	—	Nitrate as NO ₃
IS 3025 Part 53: 2003(Reaff.2019)	—	Iron as Fe
APHA-23 Edn. 2017:4500 F,D	—	Fluoride as F

4.4 MATERIALS USED

4.4.1 Ultra Pure Water

A water filtration system utilising it was used to obtain ultrapure water with modules for activated carbon, ion exchange, and reverse osmosis. Ultrapure water that is free of any particles or air bubbles, according to nanoscale tracking analysis of results. The dissolved oxygen concentration in the super pure water ranged from 6 to 9 mg/L.

4.4.2 Oxygen Cylinders

A metal cylinder containing oxygen under pressure for a wide range of uses especially mostly we see the oxygen cylinders in hospitals for patients who need oxygen will be going through a surgical mask, not only in hospitals but also we use oxygen cylinders in industries and etc.

4.4.3 Nano-bubble Generator

In addition to reducing algae blooms and enhancing water clarity, nanobubble generators also increase dissolved oxygen levels, oxidise metals, and remove chemicals that give off a bad taste or odour from natural and drinking water sources.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 WATER QUALITY AND TEST PARAMETERS

5.1.1 Odour

Odour in water can be a concerning issue that can affect both the quality and safety of the water supply. There are various causes of odour in water, including natural sources such as algae or organic matter, as well as human activities such as wastewater discharge or industrial pollution. The presence of odour can be indicative of the presence of potentially harmful compounds such as bacteria, viruses, or chemicals, which can pose health risks to individuals who consume the water. Moreover, the unpleasant smell of water can also affect its taste, making it unpalatable and unsuitable for drinking or cooking purposes. The detection of odour in water can be challenging, as it often requires specialized equipment and trained professionals to accurately identify and determine its source. Once the source of odour has been identified, appropriate measures can be taken to treat and eliminate the odour, which can range from simple methods such as activated carbon filtration to more complex processes such as chemical treatment or ultraviolet disinfection. In conclusion, the presence of odour in water is a multifaceted issue that requires careful consideration and prompt action to ensure the safety and quality of our water supply.

5.1.2 Turbidity

Turbidity in water is a measure of the amount of suspended particles, such as clay, silt, and organic matter, that affect the clarity of the water. It is an important parameter for assessing the quality of water, as high levels of turbidity can

indicate the presence of pollutants and other contaminants that can pose health risks to humans and aquatic life.

Turbidity can be caused by a variety of factors, including soil erosion, agricultural runoff, industrial discharges, and natural sources such as algal blooms. The presence of turbidity can also affect the taste and odor of water, making it unpalatable and unsuitable for drinking and other uses. To measure turbidity, water samples are analyzed using a turbidimeter, which measures the amount of light scattered by the suspended particles.

There are several methods to reduce turbidity in water, including filtration through sand, gravel, or activated carbon, coagulation and flocculation, and sedimentation. These methods involve the removal or settling of the suspended particles, which improves the clarity and quality of the water. Additionally, addressing the underlying causes of turbidity, such as reducing soil erosion or controlling agricultural runoff, can prevent or minimize the occurrence of turbidity in the first place.

5.1.3 PH at 25°C

pH is a measure of the acidity or alkalinity of a solution and is an important parameter in assessing the quality of water. It is a logarithmic scale that ranges from 0 to 14, with a pH of 7 considered neutral. Values below 7 indicate acidity, while values above 7 indicate alkalinity. pH can be affected by a variety of factors, including dissolved minerals, organic matter, and chemical pollutants. The pH of water is also influenced by temperature, with colder water having a higher pH than warmer water. At a temperature of 25°C, the ideal pH range for drinking water is between 6.5 and 8.5. This range ensures that the water is not too acidic or alkaline and is safe for consumption. However, the optimal pH range can vary depending on the intended use of the water. For example, water used for swimming pools or industrial processes may require a different pH range to be effective. A pH level that is too low or too high can have adverse effects on the quality of water. Low pH levels can cause corrosion of pipes and fixtures, leading to the release of heavy metals such as lead and copper into the water supply.

High pH levels can cause scale buildup in pipes and fixtures, reducing water flow and affecting water quality. Additionally, extreme pH levels can also affect aquatic life, causing harm to fish and other organisms. To maintain an appropriate pH level in water, treatment methods such as chemical adjustment or filtration may be required. Chemical adjustment involves the addition of substances such as lime or sulfuric acid to adjust the pH of water to the desired range.

5.1.4 Conductivity @ 25°C

Conductivity is a measure of the ability of water to conduct electricity and is an important parameter in assessing the quality of water. It is an indication of the presence of dissolved solids, such as salts and minerals, in water, which can affect its suitability for various uses. Conductivity is measured in units of electrical conductivity (EC) or conductivity units (CU), and is affected by temperature, with higher temperatures resulting in higher conductivity readings.

At a temperature of 25°C, the recommended range for conductivity in drinking water is between 50 and 800 $\mu\text{S}/\text{cm}$ (microsiemens per centimeter). High conductivity levels in water can indicate the presence of dissolved salts or minerals, which can affect the taste and odor of water and make it unsuitable for consumption. High conductivity levels can also cause corrosion of pipes and fixtures, leading to the release of metals such as lead and copper into the water supply. Conversely, low conductivity levels in water can indicate a lack of dissolved minerals, which can also affect water quality. This can lead to corrosion of pipes and fixtures, resulting in the release of metals and other pollutants into the water supply. To maintain appropriate conductivity levels in water, treatment methods such as reverse osmosis or ion exchange can be used to remove dissolved minerals and other impurities. Filtration through activated carbon or other materials can also be used to reduce conductivity levels in water. It is important to regularly test the conductivity of water to ensure that it remains within the recommended range and is safe for consumption and other uses.

5.1.5 Total dissolved solids

Total dissolved solids (TDS) is a measure of the total amount of inorganic and organic substances that are present in water in a dissolved form. This can include minerals, salts, metals, and organic compounds such as pesticides, fertilizers, and industrial chemicals. TDS is measured in parts per million (ppm) or milligrams per liter (mg/L) and is an important parameter in assessing the quality of water. The recommended TDS level for drinking water is below 500 ppm, as high levels of TDS can affect the taste and odor of water, and make it unsuitable for consumption. Additionally, high levels of TDS can also lead to corrosion of pipes and fixtures, and can increase the risk of scaling and buildup in water heaters and other appliances. Conversely, low levels of TDS can indicate a lack of dissolved minerals and may also affect water quality. TDS can be influenced by a variety of factors, including the source of water, the presence of dissolved minerals, and the use of agricultural or industrial chemicals. To maintain appropriate TDS levels in water, treatment methods such as reverse osmosis, distillation, or deionization can be used to remove dissolved minerals and other impurities. Filtration methods such as activated carbon can also be used to reduce the levels of organic compounds in water.

Regular testing of TDS levels is essential to ensure that water remains within the recommended range and is safe for consumption and other uses. TDS levels can vary over time, and changes in TDS levels can indicate changes in the quality of water.

5.1.6 Calcium Ca

Calcium is an essential mineral that is present in many foods and is important for the growth and maintenance of healthy bones and teeth. However, when calcium is present in high levels in water, it can cause scaling and buildup in pipes and fixtures, and can also affect the taste and appearance of water. Calcium in water is typically measured as Ca^{2+} and is expressed in milligrams per liter (mg/L) or parts per million (ppm). The recommended level of calcium in drinking water is below 75 mg/L, as higher levels can cause hardness and affect the taste of water. Hard water can also lead to scaling and buildup in pipes and fixtures, which can

reduce water flow and increase maintenance costs. In addition to affecting the taste and appearance of water, high levels of calcium can also have health implications. Calcium is an important mineral that is necessary for the body, but excess intake of calcium through water or supplements can increase the risk of kidney stones and other health problems. To reduce the levels of calcium in water, treatment methods such as ion exchange, reverse osmosis, or distillation can be used to remove the mineral. Filtration methods such as activated carbon can also be used to reduce the levels of other impurities in water. Regular testing of calcium levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses. Changes in calcium levels over time can also indicate changes in the quality of water, and further testing may be required to identify the source of the problem. In conclusion, calcium is an important mineral that is necessary for the body, but high levels of calcium in water can cause hardness, affect the taste and appearance of water, and have health implications. Treatment methods should be used to adjust calcium levels when necessary, and regular testing of calcium levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses.

5.1.7 Chloride Cl

Chloride (Cl⁻) is a naturally occurring anion that is present in many water sources, including rivers, lakes, and groundwater. Chloride levels in water are typically measured in milligrams per liter (mg/L) or parts per million (ppm) and can be an important indicator of water quality. Chloride in water can originate from a variety of sources, including natural sources such as rock formations, as well as human activities such as industrial processes, road salt application, and wastewater discharges. High levels of chloride in water can cause corrosion of pipes and fixtures, which can lead to water leaks and contamination.

Additionally, chloride can affect the taste and odor of water and can be harmful to aquatic life at high concentrations. The recommended level of chloride in drinking water is below 250 mg/L, as higher levels can affect the taste and odor of water and cause adverse health effects in sensitive populations such as infants, elderly, and people with certain medical conditions. Exposure to high levels of

chloride can cause gastrointestinal problems, such as nausea and vomiting, and can also affect kidney function. To reduce the levels of chloride in water, treatment methods such as reverse osmosis, distillation, or deionization can be used to remove the anion. Filtration methods such as activated carbon can also be used to reduce the levels of other impurities in water. Regular testing of chloride levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses.

5.1.8 Total Alkalinity CaCO_3

Total alkalinity is a measure of the ability of water to neutralize acids and is an important parameter in assessing the quality of water. Total alkalinity is typically expressed in milligrams per liter (mg/L) of calcium carbonate (CaCO_3), which is a common alkaline substance. The recommended level of total alkalinity in drinking water is between 80-120 mg/L, as levels outside of this range can affect the taste and odor of water and can also have health implications. Low levels of total alkalinity can make water more acidic and can lead to corrosion of pipes and fixtures, while high levels of total alkalinity can make water more alkaline and can cause scaling and buildup in pipes and appliances. Total alkalinity can be influenced by a variety of factors, including the source of water, dissolved minerals, and the use of chemicals. To maintain appropriate levels of total alkalinity in water, treatment methods such as lime softening, soda ash addition, or ion exchange can be used to adjust the pH levels of water and balance its alkalinity. Filtration methods such as activated carbon can also be used to reduce the levels of organic compounds in water, which can affect its alkalinity. Regular testing of total alkalinity levels is essential to ensure that water remains within the recommended range and is safe for consumption and other uses. Total alkalinity levels can vary over time, and changes in alkalinity levels can indicate changes in the quality of water. In some cases, changes in alkalinity levels may be an indication of contamination, and further testing may be required to identify the source of the problem.

In conclusion, total alkalinity is an important parameter in assessing the quality of water, and maintaining appropriate levels of alkalinity is crucial for ensuring the safety and suitability of water for various uses.

5.1.9 Sulphate (SO₄)

Sulfate (SO₄) is a common anion that is found in natural water sources and is also a byproduct of industrial processes. Sulfate levels in water can vary widely, depending on factors such as the source of water and the presence of industrial or agricultural activities. The recommended level of sulfate in drinking water is below 250 mg/L, as higher levels can have negative effects on the taste and odor of water. High levels of sulfate can also cause diarrhea, dehydration, and other health problems in some individuals, particularly those with certain medical conditions. Sulfate can also cause scaling and buildup in pipes and fixtures, which can reduce water flow and increase maintenance costs. Additionally, high levels of sulfate can react with certain metals to form sulfide compounds, which can have negative effects on water quality and can cause corrosion of pipes and fixtures. To reduce sulfate levels in water, treatment methods such as ion exchange, reverse osmosis, or distillation can be used to remove the anion. Filtration methods such as activated carbon can also be used to reduce the levels of other impurities in water. Regular testing of sulfate levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses. Changes in sulfate levels over time can also indicate changes in the quality of water, and further testing may be required to identify the source of the problem. In conclusion, sulfate is a common anion that can be found in natural water sources and can also be a byproduct of industrial processes. High levels of sulfate in water can have negative effects on the taste and odor of water, can cause health problems, and can cause scaling and buildup in pipes and fixtures. Treatment methods should be used to adjust sulfate levels when necessary, and regular testing of sulfate levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses.

5.1.10 Nitrate (NO₃)

Nitrate (NO₃) is a naturally occurring compound that is present in soil and water, and is also a byproduct of human activities such as agriculture and sewage treatment. Nitrate in water is measured in milligrams per liter (mg/L) or parts per million (ppm), and is an important parameter in assessing the quality of water.

While low levels of nitrate in water are generally not harmful, high levels can be a cause for concern, particularly for infants and young children. Nitrate can be converted into nitrite in the body, which can interfere with the ability of red blood cells to transport oxygen, a condition known as methemoglobinemia, or "blue baby" syndrome.

The recommended level of nitrate in drinking water is below 10 mg/L, and levels above this can indicate a potential health risk. Treatment methods such as reverse osmosis or distillation can be used to remove nitrate from water, and regular testing is important to ensure that levels remain within the recommended range. Nitrate levels in water can be influenced by a variety of factors, including the type of soil and the use of agricultural chemicals such as fertilizers and pesticides. In some cases, elevated nitrate levels may also indicate the presence of sewage contamination, and further testing may be required to identify the source of the problem. In conclusion, nitrate is an important parameter in assessing the quality of water, and high levels can be a cause for concern, particularly for infants and young children. Treatment methods should be used to adjust nitrate levels when necessary, and regular testing of nitrate levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses. Nitrate levels can be influenced by a variety of factors, and changes in levels over time can indicate changes in the quality of water, and further testing may be required to identify the source of the problem.

5.1.11 Iron (Fe)

Iron is a naturally occurring element that can be found in rocks and soil, and when water comes into contact with these sources, it can dissolve the iron and cause it to be present in the water. The amount of iron in water can vary depending

on the source, and while small amounts of iron in water are not harmful, high levels of iron in water can cause a range of issues. Drinking water with high levels of iron can cause a metallic taste and can stain teeth and clothing. Additionally, iron in water can promote the growth of bacteria and other microorganisms, leading to discoloration and an unpleasant odor. Iron in water can also have negative effects on plumbing and household appliances. Iron can accumulate in pipes and fixtures, causing blockages and reducing water flow. It can also cause corrosion in plumbing and appliances, shortening their lifespan and leading to costly repairs or replacements. There are several treatment options for iron in water, including filtration, chemical treatment, and ion exchange. Filtration involves passing water through a physical barrier, such as a mesh or screen, to remove impurities like iron. Chemical treatment involves adding a chemical to the water that will react with the iron and cause it to precipitate out, allowing it to be removed from the water. Ion exchange involves passing the water through a resin that exchanges ions with the water, removing the iron and replacing it with a more desirable ion, such as sodium.

5.1.12 Fluoride (F)

Fluoride is a naturally occurring mineral that is often added to drinking water in small amounts to help prevent tooth decay. The recommended level of fluoride in drinking water is between 0.7 and 1.2 milligrams per liter (mg/L), as higher levels can cause dental fluorosis, a condition that affects the appearance of teeth. Fluoride in water is typically measured as F⁻ and is expressed in milligrams per liter (mg/L) or parts per million (ppm). While fluoride is an important mineral that can benefit dental health, excessive intake of fluoride through water or other sources can cause health problems such as skeletal fluorosis, a condition that affects the bones. To regulate the levels of fluoride in water, treatment methods such as reverse osmosis, distillation, or activated alumina can be used to remove the mineral. However, it is important to note that removing fluoride from water entirely may not be necessary or desirable, as low levels of fluoride can still provide benefits for dental health. Regular testing of fluoride levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses. Changes in fluoride levels over time can also indicate changes in the quality of water, and further testing may be required to identify the source of the problem. In

conclusion, fluoride is an important mineral that can benefit dental health, but excessive intake of fluoride through water or other sources can cause health problems. The recommended level of fluoride in drinking water is between 0.7 and 1.2 milligrams per liter (mg/L), and treatment methods should be used to adjust fluoride levels when necessary. Regular testing of fluoride levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses.

5.1.13 Colour

Colour in water refers to the visual appearance of water, which can range from clear and colourless to various shades of yellow, brown, or green. The colour of water can be affected by a variety of factors, including natural substances such as decaying plant matter or algae, as well as human activities such as agriculture, mining, or industrial processes. Colour in water is typically measured using a spectrophotometer and is expressed in units of Hazen (also known as APHA units) or platinum-cobalt (Pt-Co) units.

The recommended level of colour in drinking water is below 15 Hazen units or 30 Pt-Co units, as higher levels can affect the taste and appearance of water, and can also indicate the presence of organic matter or other impurities. High levels of colour in water can also affect the efficiency of treatment processes such as disinfection, as organic matter can react with disinfectants and form harmful disinfection by products.

Treatment methods such as coagulation, flocculation, sedimentation, and filtration can be used to remove suspended particles and organic matter. Advanced treatment methods such as oxidation, membrane filtration, and activated carbon can also be used to further reduce the levels of colour and other impurities in water. Regular testing of colour levels in water is essential to ensure that it remains within the recommended range and is safe for consumption and other uses. Changes in colour levels over time can also indicate changes in the quality of water, and further testing may be required to identify the source of the problem. In conclusion, colour in water is an important parameter in assessing the quality of water, and maintaining

appropriate colour levels is crucial for ensuring the safety and suitability of water for various uses.

5.1.14 Total Hardness as CaCO_3

Total hardness is a measure of the amount of calcium and magnesium ions that are present in water in the form of salts. It is typically expressed as the equivalent concentration of calcium carbonate (CaCO_3) and is measured in milligrams per liter (mg/L) or parts per million (ppm). Total hardness is an important parameter in assessing the quality of water, as high levels of hardness can cause scaling and buildup in pipes and fixtures, and can also affect the taste and appearance of water. Total hardness in water can be influenced by a variety of factors, including the source of water, the geology of the surrounding area, and the use of agricultural or industrial chemicals. The recommended level of total hardness in drinking water is below 300 mg/L, as higher levels can cause scaling and affect the taste of water. Hard water can also increase the risk of skin irritation and can make it difficult to lather soap and shampoo. To reduce the levels of hardness in water, treatment methods such as ion exchange, reverse osmosis, or distillation can be used to remove the calcium and magnesium ions. Filtration methods such as activated carbon can also be used to reduce the levels of other impurities in water. Regular testing of total hardness levels is essential to ensure that water remains within the recommended range and is safe for consumption and other uses. Changes in total hardness levels over time can also indicate changes in the quality of water, and further testing may be required to identify the source of the problem.

In conclusion, total hardness is an important parameter in assessing the quality of water, and maintaining appropriate levels is crucial for ensuring the safety and suitability of water for various uses. Total hardness can be affected by a variety of factors, including the source of water, the geology of the surrounding area, and the use of chemicals.

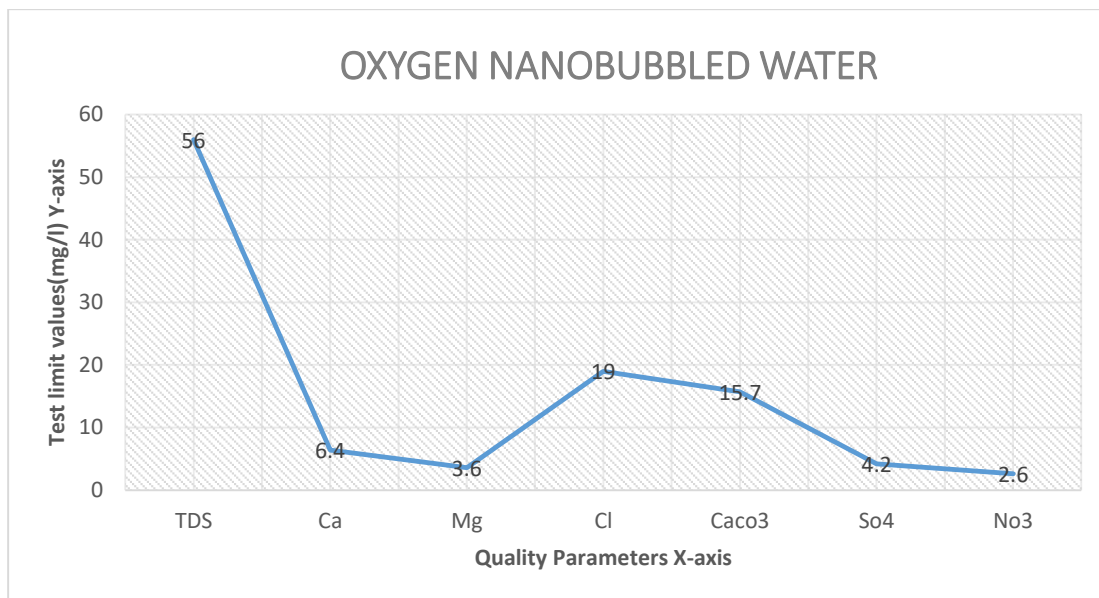


Fig. 5.1: Graph for quality test limits for oxygen nanobubbled water

The above graph depicts the important parameters of water quality for oxygen nanobubbled water. The first one is TDS i.e total dissolved solids having a value of 55mg/l, the next parameter we have is calcium having a value of 6.4 mg/l. magnesium plays a vital role in quality parameters the value for magnesium is around 3.6mg/l. chlorine is having a value of 19mg/l, Calcium carbonate which is used to neutralize the acids in water having a value of 15.7mg/l. Next comes the sulphate and nitrate which comes around 4.2mg/l and 2.6mg/l.

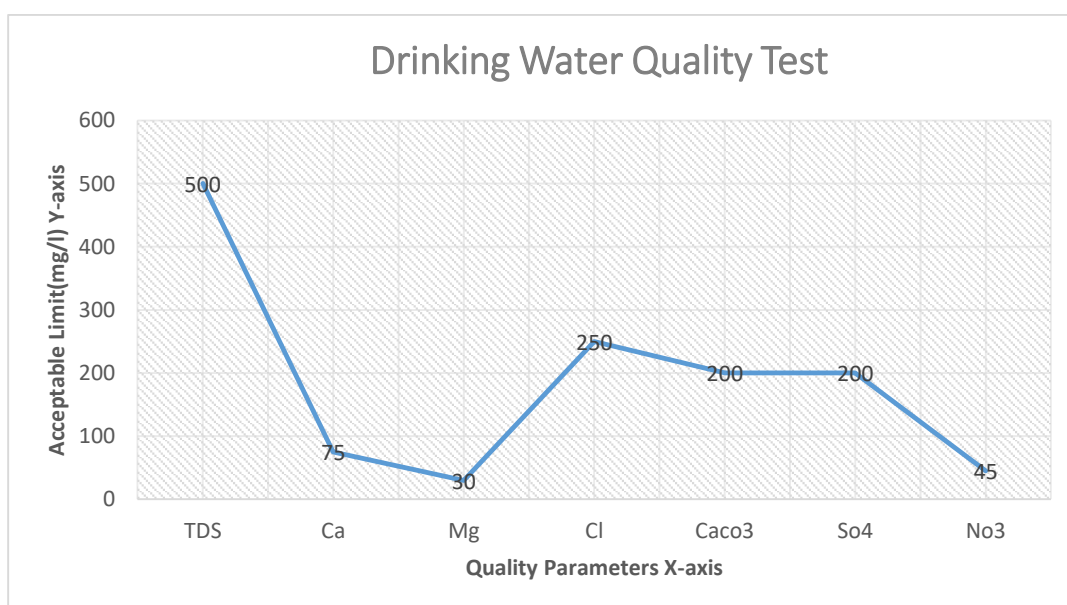


Fig. 5.2: Graph for quality test limits of drinking water

The above graph depicts the important parameters of water quality for drinking water. The first one is TDS i.e total dissolved solids having a value of 500mg/l, the next parameter we have is calcium having a value of 75 mg/l. magnesium plays a vital role in quality parameters the value for magnesium is around 30mg/l. chlorine is having a value of 250mg/l, Calcium carbonate which is used to neutralize the acids in water having a value of 200mg/l. Next comes the sulphate and nitrate which comes around 200mg/l and 45mg/l.

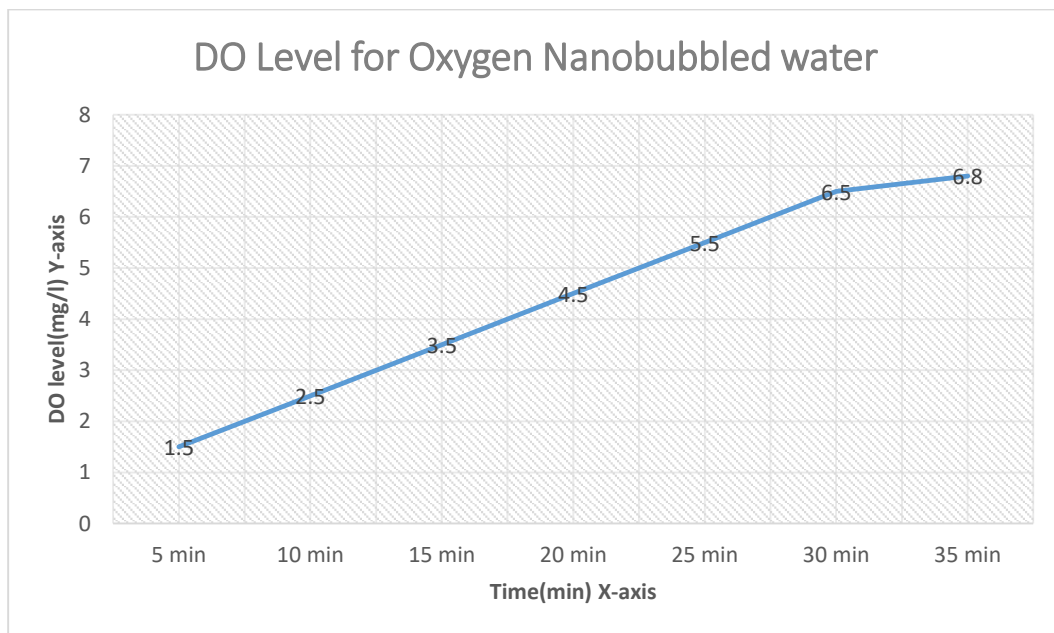


Fig. 5.3: Graph depicting the DO level in oxygen nanobubbled water

The above graph depicts the Dissolved oxygen level for oxygen nanobubbled water. As per Indian Standards drinking water should have a value of 6.5-8mg/l. And our Oxygen nanobubbled water is having a value of 6.8mg/l which is quite closer the drinking water value so, this water can be treated for drinking purpose.



Fig. 5.4: Generation of oxygen nanobubbles using micro-nanobubble generator

5.2 DYNAMIC LIGHT SCATTERING (DLS)

Dynamic Light Scattering (DLS) is a non-invasive method for measuring the size distribution of nanoparticles in solution. This technique is useful for characterizing oxygen nano bubbles, which have many potential applications in medicine and industry. In this paper, we describe the use of DLS to measure the size distribution of oxygen nano bubbles and compare the results to other characterization techniques. Our findings indicate that DLS is a powerful method for measuring the size of oxygen nano bubbles and can be used to optimize the synthesis and application of these particles.

One promising type of nanoparticle is the oxygen nano bubble, which is a small bubble of oxygen gas surrounded by a shell of surfactant molecules. These bubbles can be synthesized using various methods, such as ultrasound or chemical reduction, and have been shown to have properties that make them useful in a range of applications. However, to fully understand and optimize the synthesis and application of oxygen nano bubbles, it is important to accurately characterize their size distribution.

This technique measures the fluctuations in light scattering caused by the Brownian motion of particles in solution. By analyzing these fluctuations, DLS can

determine the size distribution of particles in solution. DLS is particularly useful for characterizing the size distribution of small nanoparticles, such as oxygen nano bubbles.

In this study, we synthesized oxygen nano bubbles using a chemical reduction method. The oxygen gas was reduced using sodium borohydride and the surfactant used was polyvinyl alcohol (PVA). The size distribution of the resulting oxygen nano bubbles was characterized using DLS, as well as other characterization techniques such as transmission electron microscopy (TEM) and scanning electron microscopy (SEM). For the DLS measurements, the oxygen nano bubbles were suspended in deionized water and placed in a DLS instrument (Malvern Zetasizer Nano ZS). The size distribution was calculated using the software provided by the instrument.

Oxygen nano bubbles are tiny bubbles of oxygen gas with a size ranging from 1 nm to 100 nm. These bubbles are produced by various methods such as ultrasonication, electrolysis, and photochemical reactions. Oxygen nano bubbles are widely used in various fields such as medicine, wastewater treatment, and agriculture due to their unique properties such as high oxygen solubility and stability. The size and stability of oxygen nano bubbles are crucial factors that determine their effectiveness in various applications. Therefore, it is important to measure the size and stability of oxygen nano bubbles accurately.

Dissolved oxygen (DO) is an important parameter to monitor in various fields, including wastewater treatment, aquaculture, and food and beverage processing. Traditional methods for measuring DO involve taking grab samples and performing chemical analyses, which can be time-consuming and expensive. In recent years, the development of a new technique, the DLS test for oxygen nano bubbles, has emerged as a promising method for measuring dissolved oxygen. This paper provides an overview of the DLS test for oxygen nano bubbles, including its principles, advantages, and limitations. Furthermore, the paper discusses recent research progress in the application of the DLS test for oxygen nano bubbles. In recent years, the use of oxygen nano bubbles has gained significant attention in various fields such as medicine, wastewater treatment, and agriculture. The size

and stability of oxygen nano bubbles are crucial factors that determine their effectiveness in various applications. This research paper discusses the use of Differential Light Scattering (DLS) test for measuring the size and stability of oxygen nano bubbles. The results obtained from the DLS test can be used to optimize the production process of oxygen nano bubbles and improve their efficacy in various applications.

In this study, oxygen nano bubbles were produced by ultrasonication of deionized water containing oxygen gas. The produced oxygen nano bubbles were then subjected to DLS test using a Zetasizer Nano instrument (Malvern Panalytical Ltd.). The DLS test was performed at room temperature, and the scattering angle was set at 90 degrees. The size and stability of oxygen nano bubbles were measured at different time intervals.

Recently, a novel method called the DLS test for oxygen nano bubbles has emerged as a promising technique for measuring DO. This method is based on the principle of dynamic light scattering (DLS), which is commonly used to measure the size and concentration of colloidal particles in solution. In this paper, we review the principles, advantages, and limitations of the DLS test for oxygen nano bubbles, as well as recent research progress in its application.

One of the main advantages of the DLS test for oxygen nano bubbles is that it is a rapid and non-invasive method for measuring DO. Unlike traditional methods that require grab samples, the DLS test can be performed in real-time, providing continuous monitoring of DO levels. Additionally, the DLS test is highly sensitive and can detect low levels of DO, which is especially important in applications where maintaining low oxygen concentrations is critical.

One limitation of the DLS test for oxygen nano bubbles is that it requires the addition of hydrogen peroxide to the sample, which can introduce potential measurement errors. Additionally, the stability of the oxygen nano bubbles can be affected by factors such as temperature, pH, and salinity, which can impact the accuracy of DO measurements.

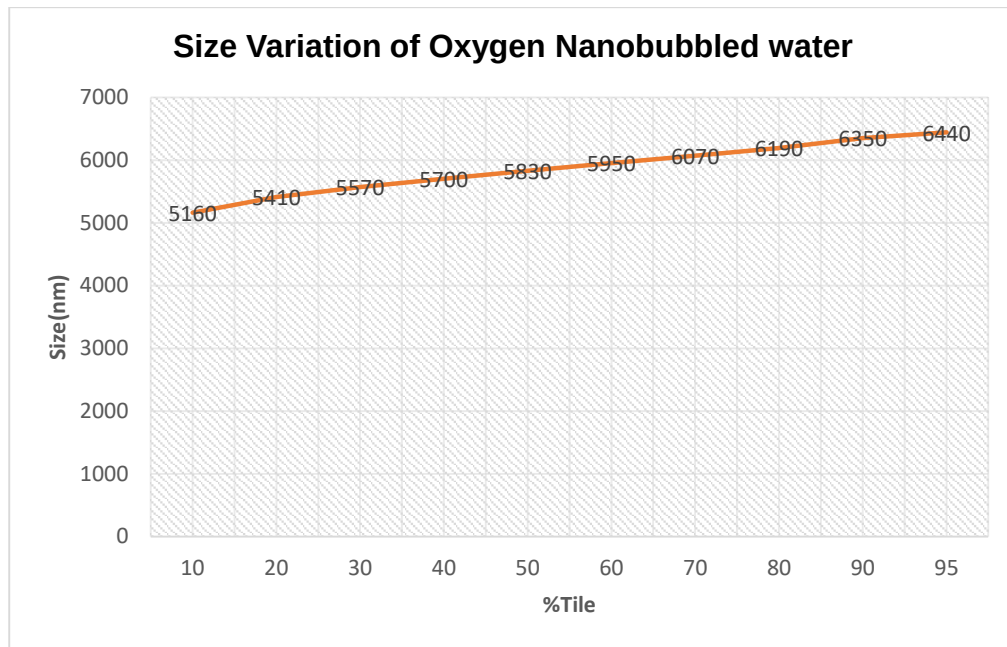


Fig. 5.5: Graph depicting the size of oxygen nanobubbles

The above graph shows the variation of oxygen nanobubble size under different light scattering we can see that at 10% tile the size of the nanobubble is around 5160nm and at 95% tile is 6440nm, the average size of the nanobubble is around 5867nm.

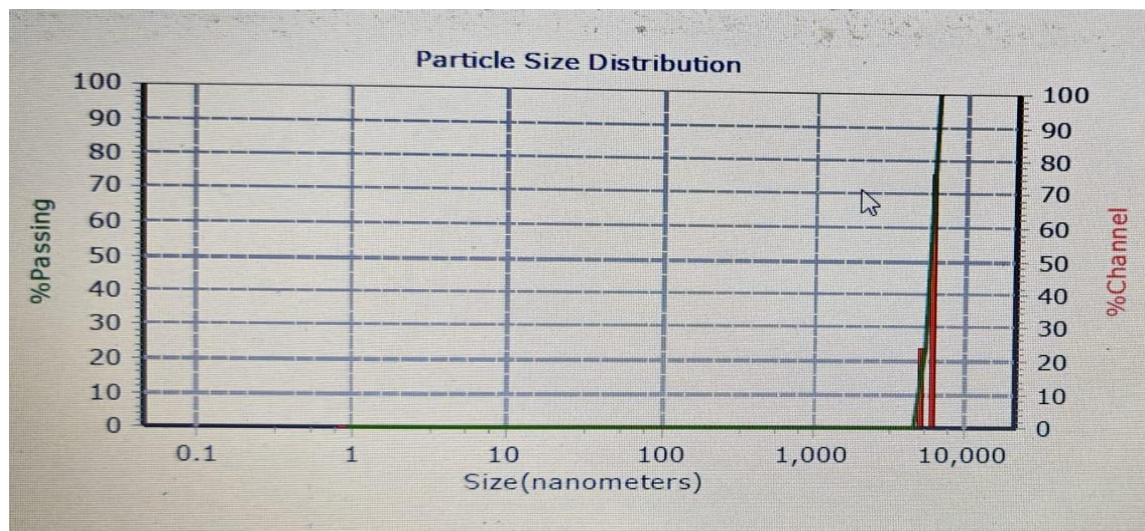


Fig.5.6: Graph depicting the particle size distribution of oxygen nanobubbles

5.3 RESULTS

Test Parameters	Test Methods	Test Results	Limits As per IS 10500 : 2012 (Reaff.2018) with Amendment No. 4	
			Acceptable Limit (Max)	Permissible Limit in the absence of alternate source (Max)
Discipline: Chemical				
Group: Water				
Colour	IS 3025 Part 4:1983(Reaff.2017)	Less than1 Hazen	5	15
Odour	IS 3025 Part 5:2018	Agreeable	Agreeable	Agreeable
Turbidity (NTU)	IS 3025 Part 10:1984(Reaff.2017)	Less than 0.5 NTU	1	5 NTU
pH at 25°C	IS 3025 Part 11:1983(Reaff.2017)	6.56	6.5 – 8.5	No Relaxation
Conductivity @ 25°C	IS 3025 Part 14:2013(Reaff.2019)	101 µmhos/cm	—	—
Total Dissolved Solids	IS 3025 Part 16:1984(Reaff.2017)	56 mg/l	500 mg/l	2000 mg/l
Total Hardness as CaCO ₃	IS 3025 Part 21:2009(Reaff.2019)	31 mg/l	200 mg/l	600 mg/l
Calcium as Ca	IS 3025 Part 40:1991(Reaff.2019)	6.4 mg/l	75 mg/l	200 mg/l
Magnesium as Mg	IS 3025 Part 46:1994(Reaff.2019)	3.6 mg/l	30 mg/l	100 mg/l
Chloride as Cl	IS 3025 Part 32:1988(Reaff.2019)	19 mg/l	250 mg/l	1000 mg/l
Total Alkalinity as CaCO ₃	IS 3025 Part 23:1986(Reaff.2019)	15.7 mg/l	200 mg/l	600 mg/l
Sulphate as SO ₄	IS 3025 Part 24:1986(Reaff.2019)	4.2 mg/l	200 mg/l	400 mg/l
Nitrate as NO ₃	IS 3025 Part 34:1988(Reaff.2019)	2.6 mg/l	45 mg/l	No Relaxation
Iron as Fe	IS 3025 Part 53:2003(Reaff.2019)	BDL(DL: 0.01 mg/l)	1.0 mg/l	No Relaxation
Fluoride as F	APHA-23 rd Edn. 2017:4500 F,D	BDL(DL: 0.1 mg/l)	1.0 mg/l	1.5 mg/l
Discipline: Biological				
Group: Water				
Escherichia coli	IS 15185 : 2016(Reaff.2021)	Absent/100ml	Shall not be detectable in any 100ml sample	
Total Coliform		Present/100ml	—	
Note : The above water sample Complies with Acceptable limits of drinking water specification as per IS 10500:2012 with respect to above parameters tested. BDL : Below Detection Limit, DL: Detection Limit.				

Fig. 5.7: Above table represents the Quality test for Oxygen Nanobubbled water

Table: 5.1 Below table shows the amount of DO Present in the Oxygen Nanobubbled Water

Test Parameters	Test Methods	Test Results	Limits as per IS 10500:2012 (REAFF.2018) with Amendment No.4
Dissolved Oxygen (Do)	IS 3025 PART 58 (1989-2006)	6.8 mg/l	6.5-8 mg/l

Table 5.2 Below table shows the size variation of oxygen nanobubbles

% TILE	SIZE(nm)
10	5160
20	5410
30	5570
40	5700
50	5830
60	5950
70	6070
80	6190
90	6350
95	6440

CHAPTER 6

CONCLUSION

Nanobubbles may be used for many different things. B. Drinking water and wastewater treatment, including decontamination of groundwater, sediment, and soil, biomedical engineering, and industrial uses including food, aquaculture, and agriculture. Treatment of drinking water and wastewater is one of nanobubbles' finest uses. They were created recently because of their capacity to produce extremely reactive free radicals (Agarwal et al., 2011). Hu and Xia (2018) showed that purifying groundwater with ozone nano- and microbubbles is feasible.

Meegoda (2017) suggested a brand-new method for disinfecting sediments utilising ultrasonic waves and ozone nanobubbles. In order to deliver cost-effective, ecologically friendly on-site treatment of silt in a reasonable timeframe at a low overall cost, he employs three cutting-edge technologies: ultrasound, ozone, and nanobubbles. Nanobubbles aid in the ozone gas's dissolution in water (Meegoda and Batagoda, 2016; Meegoda et al., 2017). Their air sparging efforts served as the impetus for using nanobubbles (Hu et al., 2010, 2011, 2014). Nanobubbles have a wide range of biological uses. One of them is the delivery of cancer drugs, in which the body is filled with nanobubbles that can recognise malignant cells. The carcinoma is destroyed when the bubbles approach tumour cells and burst them (NHI, 2017). Also, during emergency procedures, oxygen nanobubbles are delivered straight into the circulation, giving choking patients an extra 15 minutes to reach the hospital. While transient, this enables higher survival rates (Narayan, 2017). Nanobubbles have a wide range of industrial applications. Reactive oxygen species may be produced by nanobubbles, which promotes seed germination.

The germination rate is increased as a result of this rise in reactive oxygen species, which is similar to the impact of H₂O₂ addition (Liu et al., 2015).

Sport drinks and sparkling water also include it. Water may be able to hold onto gas longer by adding nanobubbles (Bauer Nanobubbles, 2017). In paint, nanobubbles are also utilised. The use of nanobubbles causes the paint to dry more quickly and to be moisture. Additionally, there is an increase in brightness due to nanobubbles (Bauer, 2014). It is also used as artificial flotation in water. This is achieved by altering the ionic equilibrium of dissolved ions in solution and the net charge on the particle surface (Moleaer, 2017a).

As was already indicated, nanobubbles have a wide range of uses, but the reasons for their long-term stability are only partially understood. As a result, this laboratory study was created as a thorough analysis of nanobubbles based on four distinct gases, and the size distribution and zeta of the bubbles were then studied at various salinity levels, pH values, and temperatures was further examined to learn more about the potential characteristics of nanobubbles in water systems. To make inferences regarding bubble stability that were meaningful, the measurement findings were examined.

In order to investigate the stability of nanobubbles, we examined the bubble size and zeta potential of multi-gas bubbles in various solution settings. Bubble size is a crucial factor in the categorization of bubbles. The charge on the bubble surface is another crucial aspect of nanobubbles. This is so that the stability of colloidal systems may be discussed using the concept of charge. As the potential of colloidal systems may be represented in terms of zeta potential, zeta potential measurements have been used to explain the stability of bubbles.

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ANNEXURE

Types of tests done for the sample

1. Water Quality test
2. Dynamic light scattering test (DLS)