

IMPROVING WATER QUALITY USING ELECTRO-COAGULATION PROCESS TO REDUCE WATER WASTAGE DURING NANO-BUBBLE GENERATION

Submitted in partial fulfilment 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

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of Gaddey Varshini (Reg.No.39150042) and Kirankumar.B (Reg.No.39150067) who carried out the project entitled “**Improving water quality using electro-coagulation process to reduce water wastage during nano-bubble generation**” under our supervision from June 2022 to April 2023.

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DECLARATION

We Gaddey Varshini (Reg.No.39150042) and Kirankumar.B (Reg.No.39150067) hereby declare that the Project Report entitled “**Improving water quality using Electro-coagulation process to reduce water wastage during nano-bubble generation**” done by us under the guidance **Dr M. ANISH M.E., Ph.D.** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ABSTRACT

Some of the most difficult wastewater treatment problems can be successfully overcome by employing nanobubble technology. Nanobubbles are neutrally buoyant, which makes them float in a liquid for days without rising to the surface. Nanobubble technology manages to overcome various treatment issues by employing deep oxygen delivery, oxidation, efficient gas transfer and surfactant removal. Wastewater that has undergone nano-bubble treatment has to go through a reverse osmosis process as well to obtain water that is completely devoid of impurities. This method results in a lot of water wastage. The paper mainly focuses on how to overcome this problem of water wastage and to provide water of superior quality. The main aim is to eliminate the RO equipment completely and instead introduce an electro-coagulation set-up prior to the nano-bubble treatment process. This proposal not only reduces water wastage but also increases the quality of water and is relatively economical. Electro-coagulation in general is a treatment process where electrical current is used to treat and flocculate pollutants without the use of additional coagulants, in this process the coagulant is provided by the electrodes. Water samples are collected for NB+RO and EC+NB treatment processes and these collected samples are put through a series of water quality tests to finally prove which out of the two methods is the better alternative.

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LIST OF ABBREVIATIONS

TSS – Total Dissolved Solids

TDS – Total Suspended Solids

EC – Electrical Conductivity

NB – Nano Bubble

RO – Reverse Osmosis

EC – Electro Coagulation

pH- Potential of Hydrogen

DC- Direct Current

ECF- Electro-Coagulation Filtration

EO- Electrooxidation

EF- Electro-Flotation

COD- Chemical Oxygen Demand

MNB- Micro Nano Bubble

DI- Deionization

NTU- Nephelometric Turbidity unit

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO ELECTRO-COAGULATION:

Researchers' attention has recently been drawn to wastewater treatment methods in the context of the world's sensible use of energy resources to protect them [5]. Techniques for treating wastewater involve a variety of biological, physio-chemical, and electrochemical processes. To treat and flocculate impurities without the use of chemical coagulants, electrocoagulation – electro filtration (ECF) technology applies an electric field to an electrolysis reactor that is flowing through a stream of contaminated solution (often wastewater) [16]. When compared to standard flocculation-coagulation, electrocoagulation has the benefit of eliminating the smallest colloidal particles; such as charged particles, since they are more likely to be coagulated and destabilized due to the electric field that promotes their motion. Furthermore, electrocoagulation-flotation can reduce waste output from wastewater treatment as well as the time required for treatment [36]. Electrocoagulation is a water treatment process that has been used for a long time to remove a variety of impurities. Due to its simplicity, low operating costs, readily available equipment, and environmental friendliness, electrocoagulation is a potential approach for removing contaminants from wastewater. However, little scientific attention has been paid to it [32]. The mechanisms of EC are not fully understood, and the factors influencing the efficient removal of ionic species from wastewater, in particular heavy metal ions, oil wastes, foodstuffs, polymeric wastes, suspended particles, phenolic wastes, arsenic, textiles, and dyes, have received very little attention [6].

1.2 BACKGROUND TO ELECTRO-COAGULATION PROCESS:

Vik et al.[39] introduced EC in London in 1889, when a sewage treatment plant was setup and electrochemical treatment was employed by mixing domestic sewage with saline (sea)water. To treat ship bilge water, A. E. Dietrich originally patented the electrocoagulation technique in 1906. J.T. Harries was given a patent in the US in 1909 for electrolysis-based wastewater treatment employing sacrificial aluminum as well as iron anodes. After that, numerous water and wastewater uses in various settings followed. Electrocoagulation has re-emerged as a viable system at a time

when environmental restrictions are putting enormous pressure on businesses to find creative methods to comply.

1.3 ELECTRO-COAGULATION PROCESS:

Due to its excellent contaminant removal effectiveness, electro-coagulation has become one of the most promising processes attracting attention from researchers nowadays. It is used to treat both water and wastewater. When electricity is delivered during the electrocoagulation process, oxidation happens on the sacrificial anode and reduction occurs on the cathode in the aqueous solution. Due to their availability and inexpensive cost, Al and Fe electrode materials are the most widely used. Coagulants/precipitates like iron and aluminum hydroxides are generated in-situ throughout the process, they are non-toxic and have a high pollutant removal efficiency [34]. In the electrocoagulation process, electrode material, area, solution pH, current density, and treatment duration all play crucial roles, although electrolyte presence and electrode distance can also have an impact. [25]. When current is passed through the Electro-coagulation cell, the internal electrodes polarize differently on each face, hence the name bipolar electrodes [12]. Several studies have been published that compare the pollutant removal effectiveness and operating costs of monopolar and bipolar designs. The monopolar connection systems have undergone successful testing in the textile industry for the treatment of effluent from launderettes, oil, and water. For the treatment of fluoride water, bipolar system has been tested [9]. Aqueous colloidal particles coagulate during the electrocoagulation process when an electric current is applied to them. Contaminants that are suspended, emulsified, or dissolved are destabilized during this procedure. Electric current is used to create gas bubbles and coagulating agent on electrodes in an electrochemical cell throughout the procedure [7]. At the cathode, hydrogen is produced, and the bubbles aid in additional pollution removal. Filtration makes it simple to get rid of these flocs since they are stable, have less bound water, and are larger in size [8]. By producing oxygen and hydrogen gas bubbles on the anode and cathode electrodes during water electrolysis, respectively, the electro-flotation technique eliminates contaminants from water

[19]. When pollutants stick to the bubbles, they rise to the surface and are regularly scraped off. The removal efficiency of a bubble is determined by its size; the smaller the bubble, the more effective the process [26].

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION:

Freshwater resources have really been decreasing over the past few years, necessitating water treatment and recycling. Desalination is a crucial procedure to address the issue of freshwater scarcity because seawater makes up and over 98 percentage of the water that is available on Earth. Desalination is the process of removing salts and minerals from utilized water. Water that has been contaminated can be treated using several methods, including thermal distillation, reverse osmosis, adsorption, flotation, nanofiltration, electrochemical, electrocoagulation (EC), electrodeposition, electrooxidation (EO), and electro-flotation (EF). However, most of the techniques mentioned have some significant downsides.

RO has been the dominating technique in many nations over the last three decades, because of its low energy cost. At 40% retrieval, RO can operate at around 3.0 kWh/m^3 for saline water desalination. However, the existence of chlorine in saline water destroys the polyamide membrane, and replacing the membrane is an expensive process [24]. Adsorption and nanofiltration technologies are not always enough for reaching discharge limitations [7]. While the electrodeposition technique necessitates a lengthy treatment reaction time. Thus, one of the best options for desalinating water and treating wastewater in general is to use the electrocoagulation (EC) process. [11].

2.2 ELECTRO-COAGULATION:

Electrocoagulation is just an electrochemically driven method that produces coagulant substances in situ by electro-dissolving sacrificial anodes, which are typically comprised of aluminum or iron [4]. An electrolytic cell made of Plexiglas, an anode, cathode and glass are the essential components of an EC reactor. The cathode and anode are both made of metal plates, with the anode serving as a "sacrificial electrode." The electrodes are often built from the same or dissimilar materials, such as iron (Fe), aluminum (Al), or a combination of iron and aluminum [27]. The EC technique, which uses a simple instrument and produces a small quantity of sludge, has been effectively used to remove salts and impurities from

saline water. This approach stands out for its simplicity, safety, sensitivity, controllability, adaptability, automation potential, and environmental friendliness.

Merzouk et al. [22] investigated that, Electrocoagulation has been used successfully to cleanse wastewater from a variety of activities, including electroplating, laundry, latex manufacture, restaurants, and slaughterhouses. Meanwhile, arsenic, phosphate, sulphide, sulphate, sulfite, boron, fluoride, nitrate, and chromate species have been widely removed using EC procedures. Electrocoagulation has been used to study the treatment of dye-containing textile wastewaters. These experiments show that COD, color, turbidity, and dissolved solids can be significantly reduced under varied operating conditions.

Nandi et.al [28] tested that Electrocoagulation has been identified as a promising approach for eliminating arsenic, fluoride, iron, chromium, and hardness from drinking water, among other things. This is certainly a motivator for further research into dye removal from sewage using the EC technique.

Drako et al. [10] found that in executing the electrolysis in such an electro-coagulator with aluminum electrodes and a subsequent isolation of a created sediment of aluminum hydroxide. The pH range 6.0-6.1, up to which the subsurface water is acidified, is estimated since alkalization of such fluorine-containing water being processed occurs throughout the electrolysis process, up to pH 6.4-6.6.

Hu et al. [14] observed that in solutions lacking co-existing anions, de-fluoridation performance in the ECF system was over 100%. Shen et al. [31] revealed that a combination of electrocoagulation and electro-flotation processes was successfully used to treat fluoride-containing wastewater.

2.3 WATER TREATMENT USING NANO-BUBBLE GENERATOR:

Micro and nanobubbles have become a practical method for water filtration. MNBs are small bubbles with dimensions of a few nanometers to a few micrometers and they have several distinctive physical characteristics that make them ideal for treating water [17]. They can efficiently transport mass between the gas and liquid phases for instance, thanks to their special ability to have a wide surface area, which aids in the chemical reaction ³. MNBs are typically used in the water treatment techniques such as electro-flotation and dissolved air floatation [35]. Due to the

recent increase in MNB bioactivity, the use of such techniques for the decontamination of domestic and industrial water treatment is now widely accepted. [18]. Considering its viability as a sustainable technique for water treatment, research on MNBs for water-related applications has greatly risen in recent years [23]. Ordinary or macro-bubbles, microbubbles (MBs), and nanobubbles are the three main forms of water bubbles that can be distinguished (NBs). Macro bubbles have a diameter that ranges from 100 μ m to 2 mm. These bubbles burst to the liquid's surface swiftly before collapsing. Despite having a diameter ranging from 1 μ m to 100 μ m, micro-bubbles are less than macro bubbles, NBs are incredibly tiny gas bubbles that stand out from other bubbles due to a variety of peculiar physical characteristics. In general, the diameter range of NBs is 1 μ m [2]. For instance, NBs dissolve quickly because of the tiny radius of curvature, which increases internal pressure compared to external pressure [15]. The fundamental explanation for this phenomenon is because the high internal pressure stored in NB never balances with the atmosphere, that could necessarily result in bubbles bursting within a very short period [21]. One of NBs' distinctive characteristics is their greater durability, which results in a greater contact angle and a longer duration spent in liquids [13]. Zeta potential is just a physical property that is used to quantify the strength of the electrostatic attraction or repulsion between particles and bubbles. It is a crucial characteristic that governs how long MNB survives in a colloidal environment [20]. NBs are primarily dependent on hydrogen bonding at water-gas interface, they have a kinetically stable, impermeable surface, making them more diffusive resistant [37]. This mass transfer efficiency is determined by the size distribution of the bubbles, rising velocity, gas-liquid coalescence, hydrodynamics, and break up surface to volume ratio, as well as physical parameters [3]. With this technique, the apparatus is primarily made up of a pump, an air compressor, and an air tank. The water pump applies a certain pressure to transfer the flowing water to the tank containing the dissolved gas, while the air compressor pumps air into the tank. The gas is supersaturated and dissolved in the increased oxygen mixing condition that is created in the dissolved gas tank, after which the gas is precipitate out of the water in the form of MNBs by abrupt decompression [33]. Water is pumped via a gas dissolution tank, an MNB producing nozzle, and a transparent acrylic tank. On the pump's suction side, air is introduced into the flowing water and dispersed by a high-pressure system. The pressure is then reduced at the nozzle, which causes the

water to become supersaturated with air and generate a gaseous phase of MNB [9]. Whenever a homogeneous liquid phase changes phase because of an abrupt pressure decreases below a critical point, or cavitation, NBs frequently occur [38]. Typically, the passage of ultrasonic waves or fluctuations in high-pressure in a flowing fluid cause cavitation [9]. NBs are frequently produced using the Venturi-type generator and a hydrodynamic cavitation mechanism [1]. Due to an increase in air density, bubble size decreases as pressure rises; nevertheless, the diameter of MBs remains constant at pressures beyond 3.5 atm [29]. Studies investigated the effects of electrolyte solutions containing NaCl and frothers (chemical additives), together with impeller velocity and airflow rate, on saltwater in terms of its chemical characteristics [30]. Micro-nano bubbles have gained more and more interest in recent years due to their distinctive properties. Up until now, research has been done on the generation of MNBs using electrolysis, the production of bubbles that displace air, and the creation of bubbles that generate the air. Widespread applications of MNBs generators include mineral buoyancy, water treatment, lowering ship resistance, medicine injection, and thermal jet printing.

2.4 SUMMARY OF LITERATURE REVIEW:

A set of literature reviews were referred, and a valid course of action was determined and used in the current research work. The arrived conclusions are:

- Electro-coagulation process is more cost efficient and compatible for the treatment of wastewater from any kinds of source.
- From the reviews, it is possible to reduce the TDS of the water using EC process.
- By employing EC process for the treatment of water along with NB technology, water wastage will positively be reduced.

CHAPTER 3

AIM AND SCOPE

3.1 AIM:

- To perform various water quality tests on water samples other than the samples that went through NB+RO and EC+NB process.
- To fabricate an Electro-coagulation set-up to reduce the TDS of water thereby improving its quality before entering the Nano-bubble generation unit.
- To reduce the quantity of wastewater that comes out of the Nano-bubble generation unit.
- To perform various water quality tests on NB+RO and EC+NB process treated water samples.
- To compare the test results of water samples from a Nano-bubble generation unit with an Electro-coagulation set-up and Nano-bubble generation unit with RO.
- To arrive at a conclusion as to if the electro-coagulation process is a better alternative for reduce TDS and the amount of wastewater produced during nano-bubble process.

3.2 SCOPE:

Nano-bubbles have gained a noticeable amount of attention over the past few years. They have proved to be effective in treating wastewater but with this come a few draw backs such as water wastage during the treatment process and requirement for RO equipment post treatment, to further reduce TDS and allow the water to be consumed. To overcome such issues, we have introduced the electro-coagulation process to pre-treat water to reduce water wastage and TDS notably before it enters the nano-bubble set-up with the hope to eliminate the requirement for an RO, thereby making wastewater treatment more effective and economical.

CHAPTER 4

MATERIALS AND METHODS

The process is classified into six phases;

- Collecting water samples from the source.
- Fabrication of Electro-coagulation set-up
- Purification of water using EC set-up.
- Transferring the purified water into the nano-bubble generator.
- Collecting the water from the nano-bubble generator and testing the collected water.
- Comparing the results with NB+RO treatment process

4.1 MATERIALS:

- Water samples
- Electro-coagulation unit and its subsidiary materials
- Aluminum electrodes
- Nano-bubble generator set-up and its subsidiary materials
- RO
- Filter
- Various chemicals and equipment necessary for water quality tests

4.2 REDUCTION OF TDS USING ELECTROCOAGULATION:

TDS is an abbreviation of total dissolved solids, which indicates the overall concentration of dissolved compounds in water. TDS is composed of inorganic salts and a trace of biological elements. Generally, 50-150 ppm level of TDS is suitable and recommended for the drinking water. The higher the level of TDS, the more it'll affect the taste of water negatively. TDS level above 1000 ppm is unsafe and dangerous to drink it. So, to reduce the TDS there are several methods to follow such as, reverse osmosis (RO), distillation, deionization system (DI), Electro-coagulation process (EC). Among these, electro-coagulation process is best for the reduction of TDS from the water.

The electro-coagulation process is carried out from the EC equipment which comprises of electrodes. The best electrode for the removal of TDS is aluminum. By arranging the electrode parallelly the connections are made to it. The number of electrodes used is 7 which is arranged as 4 monopolar and 3 bipolar. The 4 monopolar electrodes are connected to the DC supply, 2 plates as anode and other 2 as cathode. The remaining 3 bipolar electrodes will act as a sacrificial electrode.

The collected water sample is poured into the EC unit and the current of 2 to 6 amp is supplied to the electrodes. When the current is passed through the electrodes, they will start losing electrons and react eventually with the water. The bipolar electrodes sacrifice itself by dissolving in the water and reacting with the TDS in the water and ultimately the sediments settle at the bottom of the tank. This process has a running time of 80 mins through which the water can get purified. After the running time the water is filtered from the EC unit and supplied to the Nanobubble set-up.

4.3 EXPERIMENTAL SET-UP:

The figure 4.1 – 4.5 shows the experimental setup of the electro-coagulation process used for this study. The TDS reduction of the water sample was performed in a batch reactor made of a glass. The water is tested for TDS, TSS and other parameters. The equipment size used here is of width 25 cm, depth of 25 cm and length of 51 cm. The volume of water used here is 15L for each run. For the electrodes aluminum is used in this study. Seven aluminum plates with an arrangement of 3 bipolar and 4 monopolar and the monopolar will act as both anode and cathode, where the bipolar electrodes will act as an inner electrode. The electrode dimension for both anode and cathode were 22×22 cm² and thickness of 0.1 mm, with 1 cm distance between the electrodes. The surface area of the electrode is 484 cm² ($22 \text{ cm} \times 22 \text{ cm}$). Table 4.1 shows the dimensions and materials used. The electrodes are connected to a DC supply. The electrodes are immersed completely in the water sample. The reaction takes place when electric current is passed through the electrodes. The DC power supply is supplying electricity of 0-40 V and 0-6 A. The running time for this process is of 80 mins for each run. After every single run, the electrodes are washed using distilled water before every subsequent run.

TABLE 4.1: MATERIALS AND DIMENSIONS

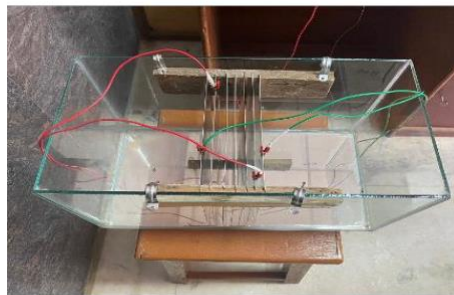
s.no	Materials	Dimensions and Specifications
1	Glass tank	51 cm × 25 cm × 25 cm (l × b × h)
2	Aluminum electrodes (7 plates)	22 × 22 ² , 0.1 mm (thickness)
4	Surface area of the electrodes	484 ² (22 cm × 22 cm)
3	DC power supply	0-40 V, 0-6 A
4	Volume of water	30 L (2 runs)
5	Nano bubble generator	1 (for 30L)
6	RO	1 (for 30L)



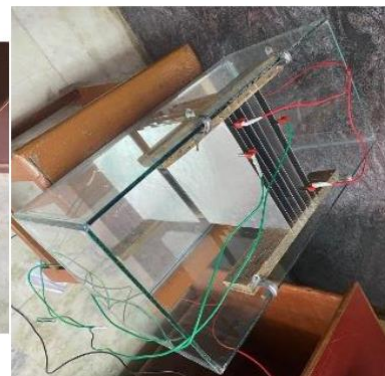
FIG 4.1: ELECTRODES



FIG 4.2: DC METER



(a)

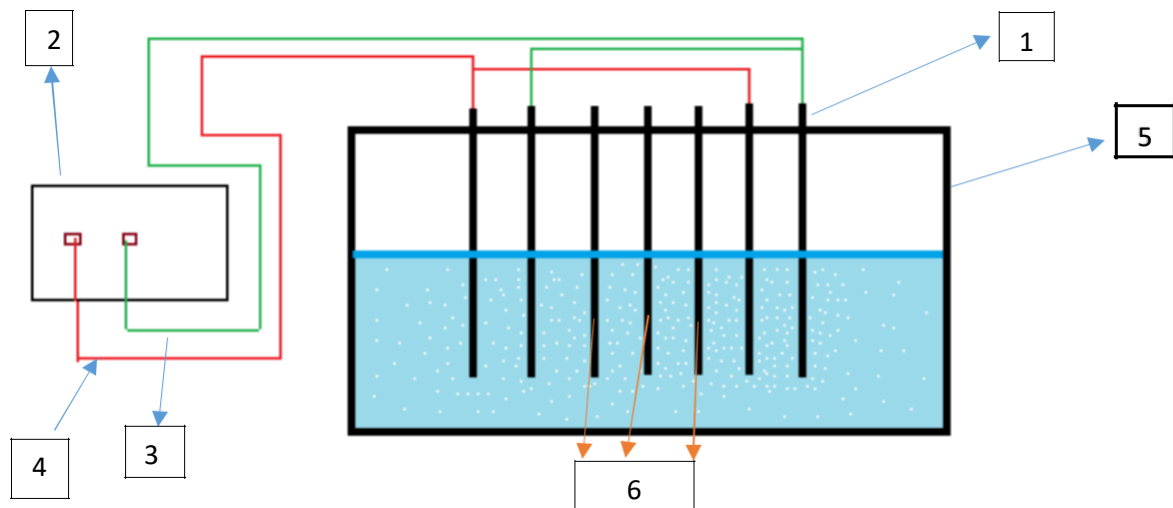


(b)

FIG 4.3 (A & B): ELECTROCOAGULATION SET-UP



FIG 4.4: OVERALL SET-UP WITH CONNECTIONS



1 – Monopolar Electrodes

3 – Negative terminal

2 – DC meter

5 – Glass tank

4 – Positive terminal

6 – Bipolar electrodes

FIG 4.5: SCHEMATIC LAYOUT OF EC SET UP

4.4 PROCESS:

- The water samples are collected, and the quality is tested using standard procedures.
- Then transfer the sample to the electrocoagulation set up which is prepared.
- Then switch on the DC supply and set the current and voltage to 0-6 A and 0-40 V respectively.
- After fixing the current and voltage the anode and cathode which is connected to the monopolar electrodes will be active by electric supply.
- Due to the polarization of the monopolar electrodes the bipolar electrodes sacrifice itself to form the sediments.
- This equipment runs for 80 mins with 15L for each run.
- After the process, the water is filtered using a filter and the sample is collected for the quality testing.
- Then the filtered water is transferred to the nano-bubble generator.
- Then the nano-bubble generator is turned on and the generator runs for a run time of 25-30 mins.
- The water is then collected from the nano-bubble generator and the samples are taken for the testing.
- Electro-coagulation is used here as a pre-purification process which is shown in below fig 4.7 and 4.8.
- The same procedure is carried out with the nano-bubble + RO process.
- The samples are collected from the source and the water is transferred to the nano-bubble generator and after the run time of 25 – 30 mins the water is collected and tested as shown in fig 4.6.
- Then the water is transferred to the RO unit and process is carried.
- In RO process, the amount of water transferred will be not equal to the amount of filtered water received whereas in electro-coagulation process the water transferred will be approximately equal to the water received.
- Then the water is collected from the RO unit and is tested.
- In this process RO acts as a post purifier in nano-bubble application for drinking water which is shown in the below fig 4.9 and 4.10.

- The pre-purification and post-purification results are compared and analyzed in this study and the fig 4.11 delivers the schematic view of this process.



FIG 4.6: WATER SAMPLES COLLECTION

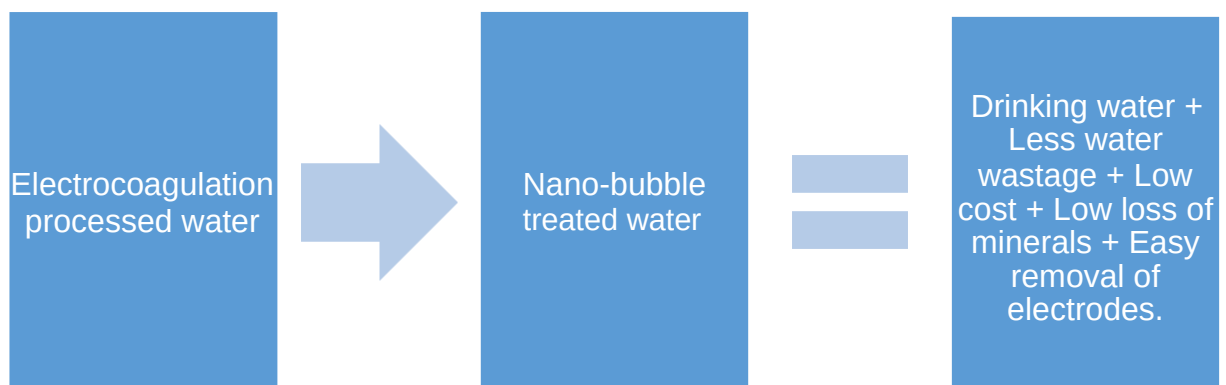


FIG 4.7: PRE-PURIFICATION LAYOUT



(A)

(B)

FIG 4.8(A & B): EC WITH NANO BUBBLE GENERATOR

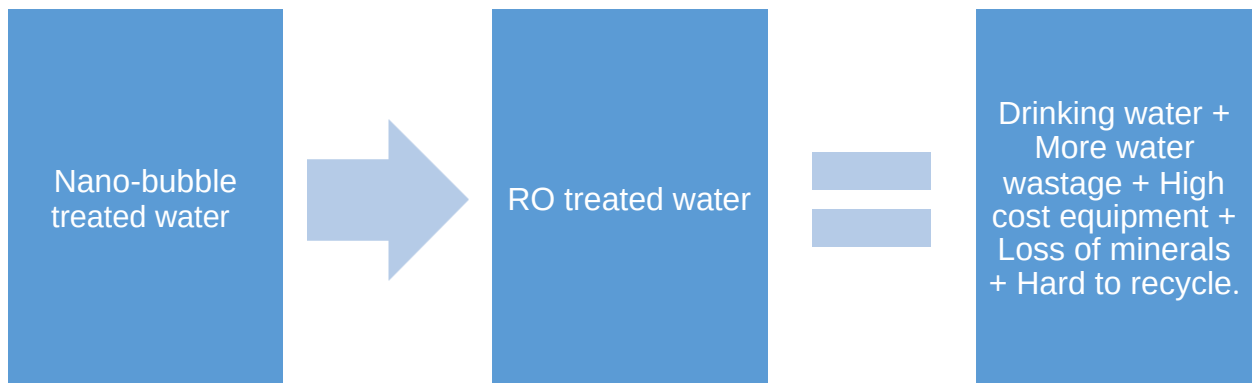
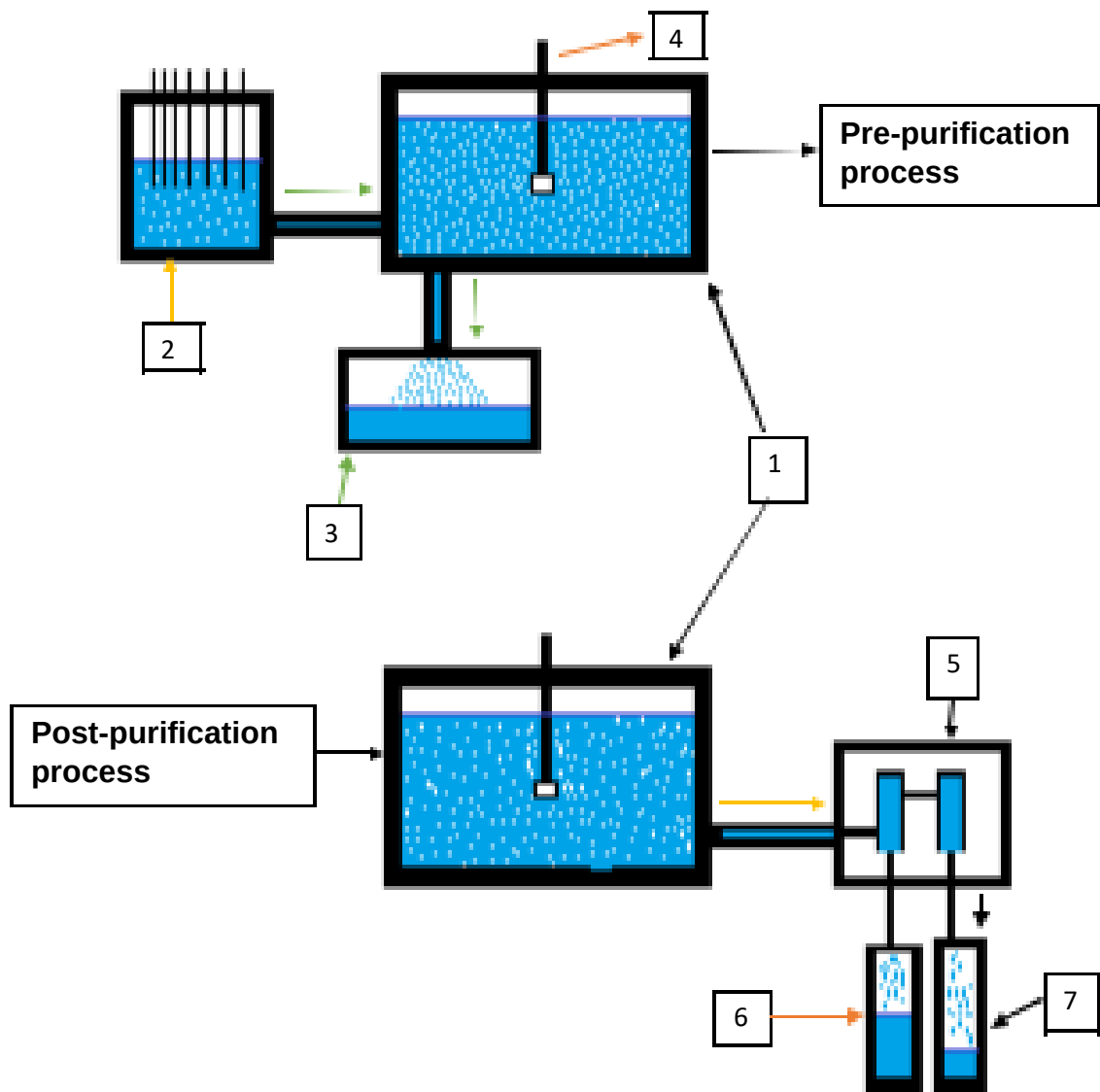


FIG 4.9: POST-PURIFICATION LAYOUT



FIG 4.10: NANO BUBBLE GENERATOR WITH RO UNIT



1 – Nano bubble generator
 2 – EC set-up
 3 – Purified nano bubble water
 4 – Air supply

5 – RO purifier
 6 – Wastewater output
 7 – Purified RO water

FIG 4.11: SCHEMATIC VIEW OF PRE AND POST PURIFICATION PROCESS

4.5 WATER QUALITY TESTING'S:

4.5.1 TDS (MG/L):

TDS is an abbreviation of total dissolved solids, which indicates the overall concentration of dissolving compounds in water and the unit for TDS is Mg/L. To test the TDS value of water, a clear dry glass beaker is weighed and noted, then 100ml of water sample is taken and poured in the dry beaker, then the beaker should be kept in the hot air Oven for 103°C for 24 hours. after the 24 hours of time, take the beaker out of the oven and let it cool and attain the room temperature. After cooling down the beaker weigh the beaker and the weight. After weighing substitute, the values in the formula mentioned below to get the value of TDS. The alternative way for the measurement of TDS is shown in the fig 4.12. Equation 1 shows the procedure for calculating the TDS of water.

$$\text{Dissolved solids, TDS (mg/l)} = \frac{\text{mg of solids in the beaker}}{(\text{Volume of sample}) \times 1000} \quad (1)$$



FIG 4.12: TDS METER

4.5.2 TSS (MG/L):

TSS is an abbreviation of total suspended solids in the water with a unit of Mg/L. To find the TSS in the water, a 100ml of water sample is filtered using a filter paper which is initially weighed before filtration. After filtering the water dry the filter paper in the oven, which is shown in fig 4.13, at 103°C - 105°C for 1 hour. After an hour take the filter paper out of the oven and let it cool for sometimes. When the dry paper settles to room temperature weigh the paper and note the reading. Finally, to calculate the TSS in water follow the below formula mentioned in equation 2,

$$\text{Total suspended solids (mg/l)} = \frac{\text{mg of solids in the filter paper}}{(\text{Volume of sample}) \times 100} \quad (2)$$



FIG 4.13: TSS FILTER WITH HOT AIR OWEN

4.5.3 HARDNESS (MG/L):

Defined as the calcium and magnesium levels of the water. In general water that has traveled through deposits forms hard water, the unit of hardness is said to be Mg/L. The hardness of water can be determined by the following steps: Prepare a 20 ml sample (V ml), add 20ml of distilled water to the 20ml of the sample in the Erlenmeyer flask to obtain 40ml. To achieve a pH of 10 ± 0.1 add 1 mL of ammonia buffer, then a drop or two of the indicators should be added and if the solution turns wine-red hardness is present. While vigorously shaking the sample, add EDTA titrant until the wine-red color faintly turns blue. The quantity of titrant that was added should be recorded (V1 ml). Separately boil a 50 ml sample in a different flask (To obtain the final volume of water, add distilled water) and perform all the above-mentioned steps for this sample again. Fig 4.14 shows the samples solutions of hardness. Equation 3 - 6 shows the procedure for calculating the various hardness of water.

$$\text{Total Hardness, mg/L as CaCO}_3 = \frac{V_1 \times N \times 100 \times 1000}{V} \quad (3)$$

V = Volume of the sample taken, ml

V1 = Volume of titrant used for sample, ml.

N = Normality of EDTA

$$\text{Total hardness of water mg/L} = \frac{\text{ml of EDTA used (un-boiled)} \times 10^3}{\text{ml of sample}} \quad (4)$$

$$\text{Permanent hardness of water mg/L} = \frac{\text{ml of EDTA used (boiled)} \times 10^3}{\text{ml of sample.}} \quad (5)$$

$$\text{Temporary hardness of water mg/L} = \text{Total hardness of water} - \text{Permanent hardness of water} \quad (6)$$

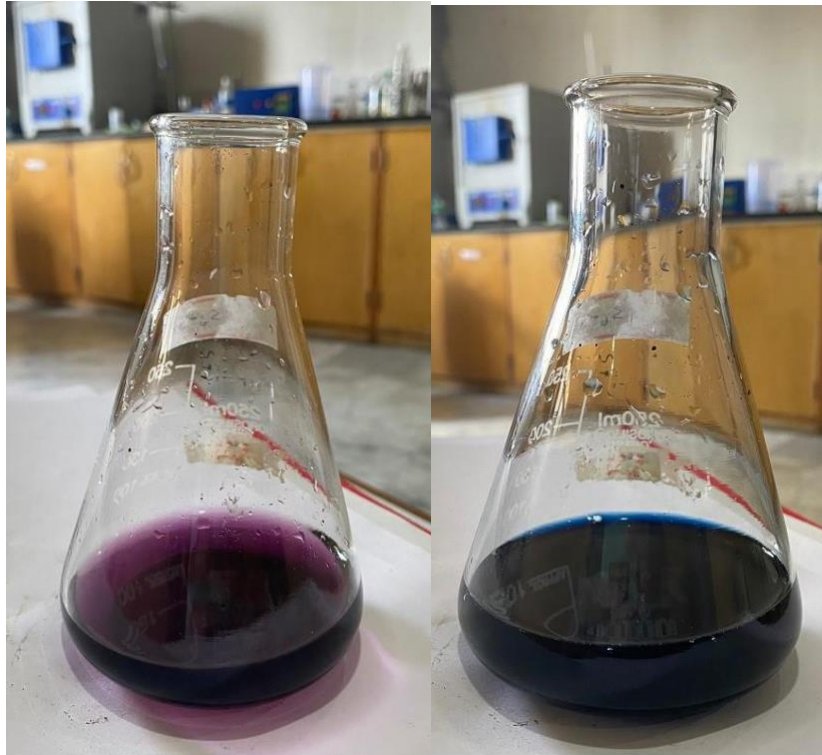


FIG 4.14: HARDNESS TEST

4.5.4 pH:

The pH of water indicates how acidic or basic water is. pH range is 0 to 14 with 7 representing neutrality. Acidity is indicated by pH values below 7, whereas basicity is shown by pH values above 7, water quality can be identified partially by its pH value. The pH of water is generally determined using either of the two methods- pH paper and pH meter but there are few other alternative ways to determine it which is shown in fig 4.15.

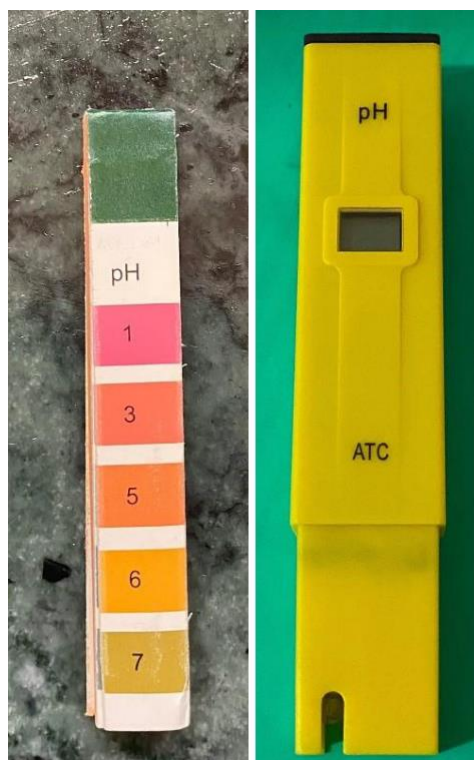


FIG 4.15: PH METER AND PAPER

4.5.5 CHLORIDE (MG/L):

In most natural waterways, chloride is a naturally occurring constituent that is typically present as a portion of salt (sodium chloride), or occasionally in mixture with potassium or calcium. the unit for chloride is Mg/L. For appropriate cell processes in plants and animals, chloride is required in acceptable levels on the other hand excessive chloride can cause corrosion as well as water taste issue. The following steps are used to determine chloride concentration in a water sample: Fill a conical flask with 25ml of water sample, put 2-3 drops of potassium chromate (K_2CrO_4) indicator until the color of the water sample obtains a light-yellow hue. Then add standard N/50 silver nitrate solution from the burette, then thoroughly shake. Titrate the solution till the light-yellow hue changes to a permanent brick-red (brownish red) color with white precipitate. Take note of how much silver nitrate was added. Finally calculate the concentration of chloride ions. Equation 7 shows the procedure for calculating the chloride in water.

$$\text{Chloride ion concentration (mg/l)} = \frac{(V_{SN} \times N_{SN} \times 35.45) \times 1000}{V_w} \quad (7)$$

Where;

V_{SN} = volume of titrant used

N_{SN} = normality of silver nitrate and

V_w = volume of water sample used (ml)

4.4.6 ALKALINITY (MG/L):

The alkalinity of water can be addressed as its ability/buffering capacity to neutralize bases and acids and to maintain a relatively constant pH level with a unit of Mg/L. Alkalinity of water can be determined using the following steps: First 50 mL of the sample should be pipetted into a fresh Erlenmeyer flask (V), then if any residual chlorine is detected, add one drop of sodium thiosulphate solution. Else when the pH is over 8.3, the solution turns pink when two drops of phenolphthalein indicator are added. Titrate in the burette until the color just vanishes when exposed to standard sulfuric acid (0.02N) and record the volume (V_1). After these two drops of methyl orange indicator are added and the color changes to yellow as shown in fig 4.16. Titrate again against acid until orange-yellow color is achieved. Record the overall volume (V_2). Using the formulae provided in the following table 4.2, the types of alkalinities contained in the samples are determined, and the data should be tabulated. Equation 8 and 9 shows the procedure for calculating the alkalinity of water.

TABLE 4.2: ALKALINITY RULE TABLE

Result of titration	Carbonate alkalinity as CaCO_3	Bicarbonate alkalinity as CaCO_3	Hydroxide alkalinity as CaCO_3
$P = 0$	0	T	0
$P < \frac{1}{2}T$	2P	$T - 2P$	0
$P = \frac{1}{2}T$	2P	0	0
$P > \frac{1}{2}T$	$2(T - P)$	0	$2P - T$
$P = T$	0	0	T

- Phenolphthalein alkalinity (P) as mg/L $\text{CaCO}_3 = \frac{V_1 \times 1000}{\text{mL of sample}}$ (8)

- Total alkalinity (T) as mg/L $\text{CaCO}_2 = \frac{V_2 \times 1000}{\text{mL of sample}}$ (9)



FIG 4.16: ALKALINITY TEST

4.5.7 TURBIDITY (NTU):

Turbidity is caused by particles that are soluble or suspended in water and scatter light, giving the appearance of cloudy or murky look, the unit of turbidity is NTU. Sediment, particularly silt and clay, fine inorganic and organic materials, soluble colored organic compounds and microscopic organisms are examples of particulate matter. A turbidity meter is used to find the turbid level of the water which is shown below in fig 4.17.

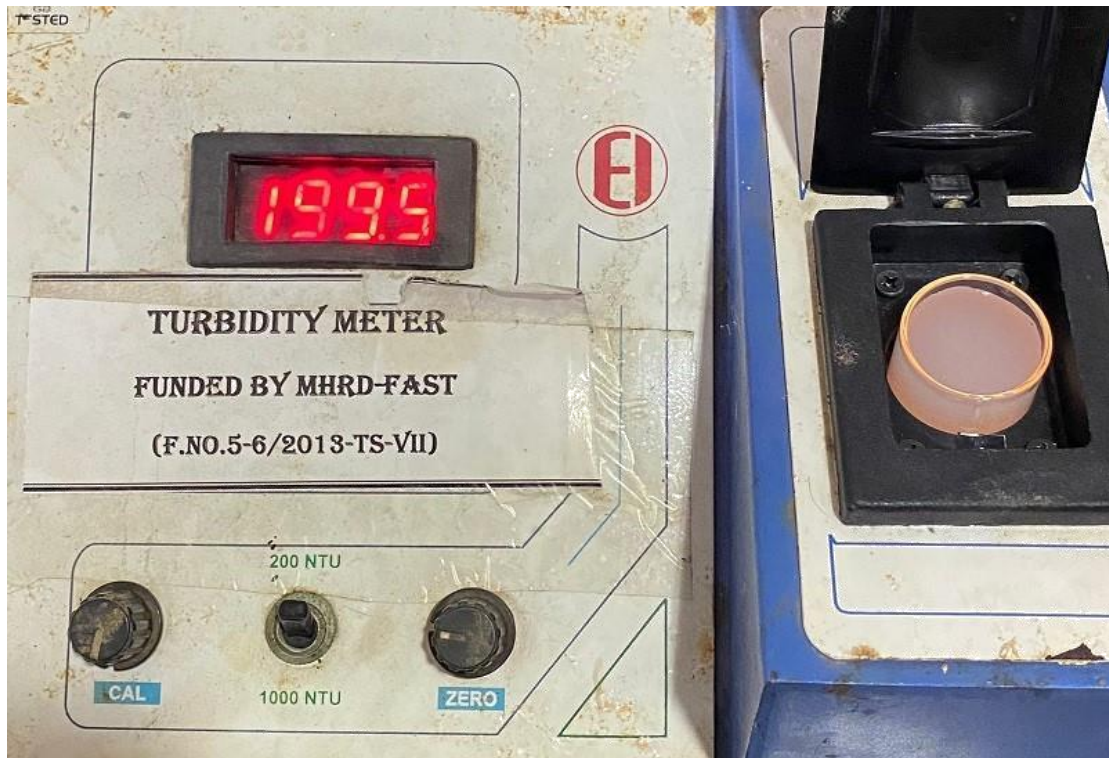


FIG 4.17: TURBIDITY METER

4.4.8 ELECTRICAL CONDUCTIVITY (S/M):

Pure water isn't a strong electrical conductor. Normal distilled water under equilibrium with atmospheric carbon dioxide seems to have a conductivity of around

$10 \times 10^{-1} \text{ S/m}$ (20 dS/m). Because electrical current is carried by ions in solution, conductivity increases as ion concentration increases. Low conductivity (between 0 and 200 S/cm) indicates pure or background conditions. Most major rivers have a normal background conductance (200 to 1000 S/cm). Conductivity outside of this range may indicate that water is unsuitable for some fish or bugs. To find the EC in water an EC meter is used which is shown below in fig 4.18.



FIG 4.18: ELECTRICAL CONDUCTIVITY METER

CHAPTER 5

RESULTS AND DISCUSSION

5.1 WATER TEST RESULTS:

TABLE 5.1: FINAL TEST RESULTS

s.no	Tests	Water sample	Water sample after nano- bubble process	Water sample after nano- bubble + RO	Water sample after electro- coagulation	Water sample after electro- coagulation+ nano-bubble process
1	TDS	514.3	419.3	99.6	225	126.3
2	TSS	3966.6	472.3	579	393.3	221.3
3	Hardness	Total = 466.6 Permanent=386.6 Temporary = 80	505.6 311 194.6	241 40.6 200.3	903.3 210 693.3	807.6 217.3 590.3
4	pH	9.9	9.1	9.5	7.7	7.4
5	Chloride	104.1	108.9	37	53.6	46.9
6	Alkalinity	Hydroxide= 0 Carbonate= 16 Bicarbonate=30.6	0 22.6 45.3	0 0 6	0 19.7 23	0 13.2 19
7	Turbidity	6.5	1.63	4.4	0.7	0.9
8	Electrical conductivity	1.31	1.06	61.97	0.87	1.08

The above table 5.1 completely summarizes the test results obtained after performing all of the following water quality experiments: Total dissolved solids, Total suspended solids, Hardness, Ph, Chloride, Alkalinity, Turbidity and Electrical conductivity of various water samples as mentioned: Un-treated, Nano-bubble treated, Nano-bubble and RO treated, Electro-coagulation treated and finally Electro-coagulation along with Nano-bubble treated water respectively.

In the case of TDS, it is clearly evident that the TDS of un-treated water is noticeably higher than that of the other samples, in addition to this it can be seen that the water sample that underwent Nano-bubble and RO treatment possesses the least TDS out of all the samples, but we cannot leave out the fact that the water sample that underwent Electro-coagulation and Nano-bubble treatment is also within the acceptable TDS range for drinking water. In the context of TSS, untreated water seems to possess the highest TSS test results but here unlike in TDS Electro-coagulation and nano-bubble treated water has the least TSS value in comparison to all the other samples from this we can conclude that this method is superior as compared to the other performed treatment methods in the case of reduction of TSS. When it comes to the total hardness of our various water samples quite unexpectedly Nano-bubble and RO treated water possessed the least total hardness while electro-coagulation treated water had the highest total hardness result followed by electro-coagulation and nano-bubble treated water sample. As for the Ph of water, untreated water had the highest ph value indicating its basic nature whereas electro-coagulation and nano-bubble treated water was the closest to neutrality as compared to all the other water samples. The results for chloride detection follow the same pattern as that of TDS results, that is nano-bubble and RO treated water possess the least amount of chloride followed by Electro-coagulation and nano-bubble treated water. When the overall alkalinity of the water sample is being discussed it can be seen from the table that Nano-bubble treated water has the highest alkalinity whereas nano-bubble and RO treated water has the least alkalinity followed by Nano-bubble and Electro-coagulation treated water. As for turbidity the sample that underwent Electro-coagulation alone has the least turbidity whereas the un-treated water sample has the highest turbidity. NB+RO treated water has the highest electrical conductivity and water that went through electrocoagulation alone has the least electrical conductivity.

5.2. PERFORMANCE GRAPHS AND COMPARISONS:

5.2.1 TDS:

TABLE 5.2: TDS TEST RESULTS

Sample no.	1	2	3
Water sample	500	469	574
Sample after NB	400	437	421
NB+RO	100	96	103
EC	220	243	212
EC+NB	122	136	121

To obtain the most accurate results for all our water quality tests we obtained and tested three different samples take on three different days for each type of sample that underwent a different treatment process. So due to this we had to perform each water quality test on fifteen individual samples.

The topic of discussion here is TDS, from the table 5.2 its quite evident that untreated water collectively has the highest TDS and quite clearly water samples that underwent the nano-bubble and RO treatment have the least TDS collectively, closely followed by the water samples that went under electro-coagulation and nano-bubble treatment.

In general, from the test results it can be concluded that Nano-bubble treatment alone doesn't reduce TDS to a great extent but quite contrary to this water samples that underwent electro-coagulation treatment alone show quite a noticeable amount of reduction in TDS when compared to the TDS value of un-treated water.

The permissible range of TDS for water to be considered drinkable is 50-150 mg/L. In fig 5.1, the line contains 5 break points indicating the TDS value for each kind of sample and fig 5.2 contains 3 bars which compares the TDS test results of raw water ,NB+RO treated water and EC+NB treated water. This pattern of test result representation is maintained for all the following water quality tests as well. From the graph it can be seen that both the NB+RO and EC+NB treatment processes are

within the acceptable range i.e 99.6 and 126.3 respectively, whereas the other three treatment processes are not. The TDS value for NB+RO is a little lower than that of EC+NB. In the NB+RO process the RO contains a two-way filtration system which thereby results in a little better TDS reduction when compared to the EC+NB process which only employs one- way filtration. Since there isn't a specific value for acceptable TDS content, it's rather a range hence both the above mentioned processes are acceptable. If other factors are considered then one process might have a upper hand over the other.

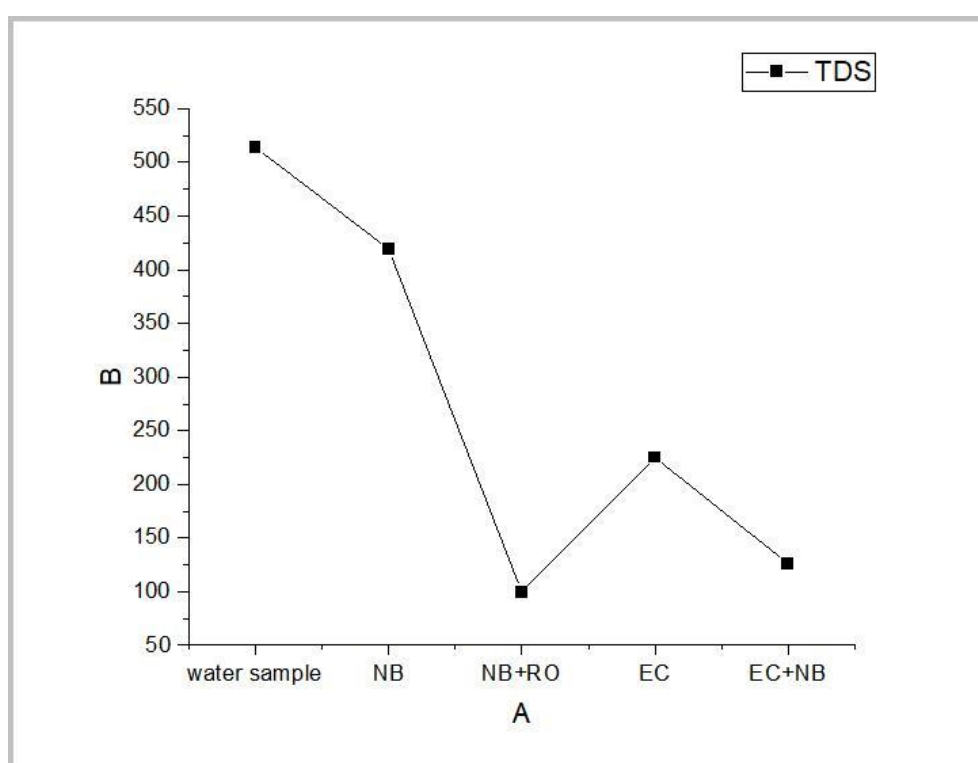


FIG 5.1: TDS GRAPH

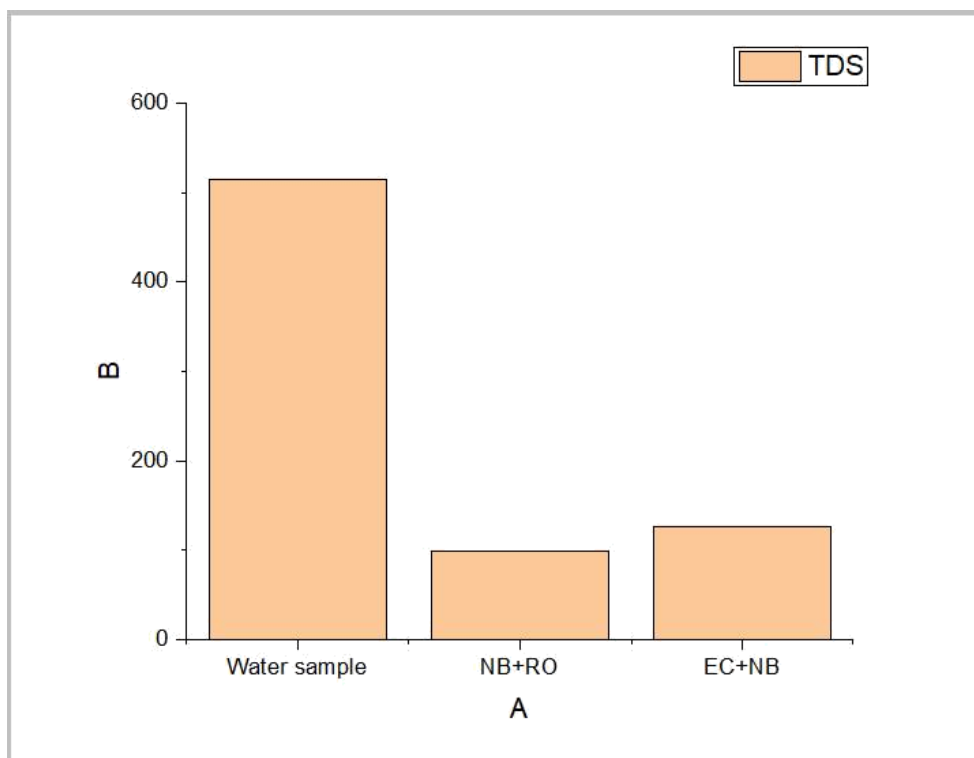


FIG 5.2: TDS COMPARISON CHART

5.2.2 TSS:

TABLE 5.3: TSS TEST RESULTS

Sample no.	1	2	3
Water sample	4100	4000	3800
Sample after NB	400	520	497
NB+RO	630	527	580
EC	400	383	397
EC+NB	200	216	248

As in the case of TSS, as expected untreated water sample have the highest TSS value overall, from the table 5.3. in general, all the other water samples have quite significantly a lesser TSS value but out of all these, the water sample that underwent electro-coagulation and nano-bubble treatment stands out by having the least TSS content as compared to all the other samples, closely followed by the water samples that underwent the nanobubble treatment and electro-coagulation treatment alone. It is quite evident from the test results that the treatment process

involving nanobubble and RO combined results to be the least efficient method in reducing the TSS content in a water sample as compared to the other methods.

The acceptable TSS value for drinking water is 100mg/L. As per the pictorial representation (i.e.) fig 5.3 and 5.4, the water which underwent EC+NB treatment process has achieved the TSS test result value (i.e.) 221.3 which is closest to the acceptable value as compared to the other samples, even if it isn't the exact acceptable value. A slight increase in TSS value can be noticed in the NB+RO test results as compared to NB. This is because proper reduction in TSS requires a multi-way filtration whereas NB+RO process involves only two-way filtration hence TSS seems to slightly increase.

In the case of TSS reduction EC+NB treatment process seems to be more efficient as compared to NB+RO treatment process and surprisingly NB treatment process resulted in a closer value (472) as compared to NB+RO (579), due to above mentioned reason.

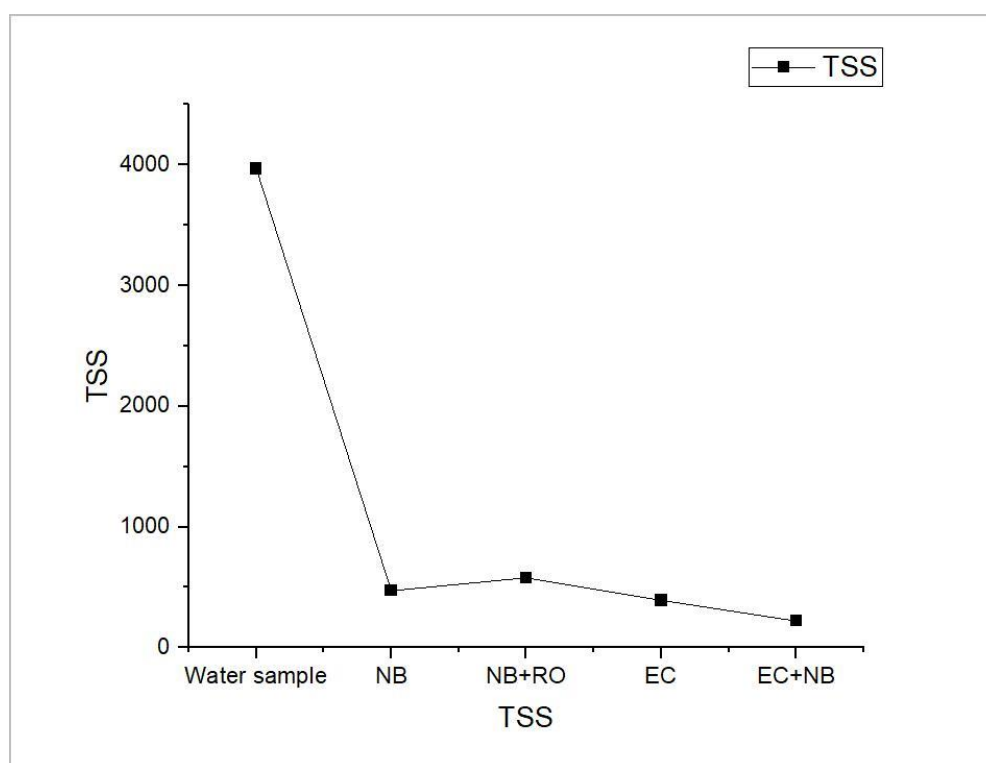


FIG 5.3: TSS GRAPH

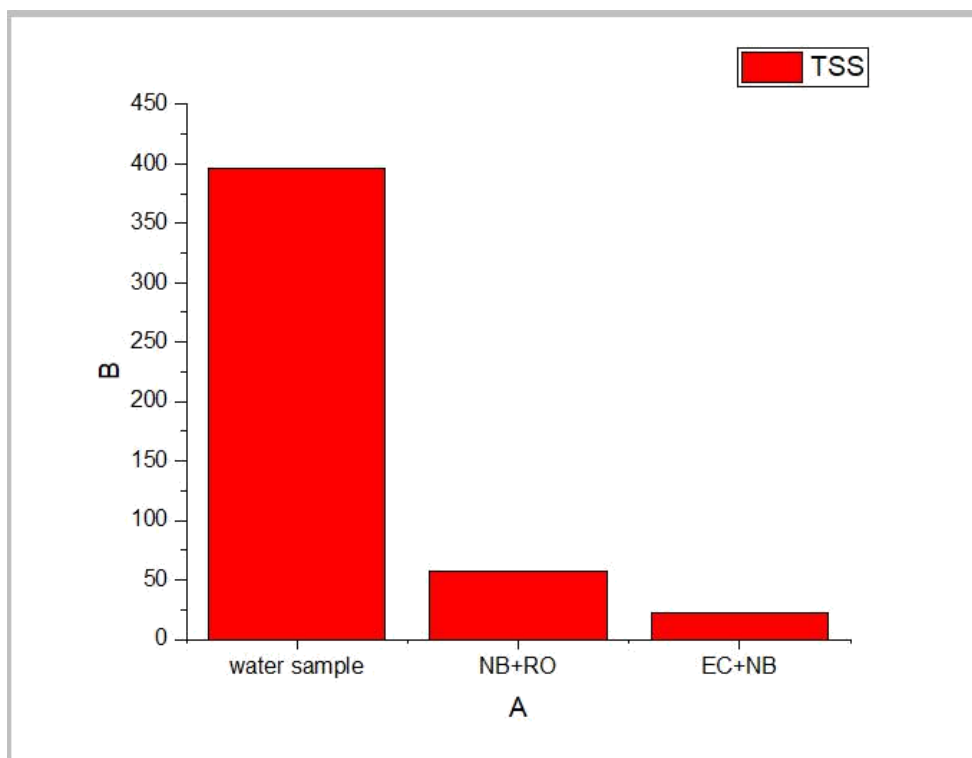


FIG 5.4: TSS COMPARISON CHART

5.2.3 HARDNESS:

TABLE 5.4: HARDNESS TEST RESULTS

Sample no.	1	2	3
Water sample	400	500	500
	360	400	400
	40	100	100
Sample after NB	500	537	480
	320	403	210
	180	134	270
NB+RO	200	280	243
	20	60	42
	180	220	201
EC	950	870	890
	180	210	240
	770	660	650
EC+NB	850	740	833
	200	240	212
	650	500	621

From the table 5.4 it can be seen clearly that the electrocoagulation fails to reduce the hardness of the water whereas the nanobubble with RO has reduced it to the required level.

As for the case of total hardness the acceptable value for drinking water is 200 mg/L. Quite unexpectedly EC+NB treatment seems to not be as effective as envisioned (i.e.) 806. Even EC process seems to be in-effective in reducing hardness of water due to the property of electrodes used. Electrodes used for the EC process are made of aluminium. It's a well-known fact that the hardness of water is caused due to the presence of calcium and magnesium. Aluminium has very less reactivity when it reacts with magnesium and calcium, it thereby overpowers the process eventually increasing hardness.

The sample which underwent NB+RO treatment resulted as 241 where the value is closest to the ideal hardness value. All the other treatment processes are way beyond the acceptable range and they fail to reduce the hardness of the water. So, we can conclude that NB+RO treatment process is the most effective when it comes to the reduction of hardness as compared to EC+NB treatment process which is shown graphically in figs 5.5 to 5.10. Temporary hardness and permanent hardness results also follow a similar trend as in total hardness.

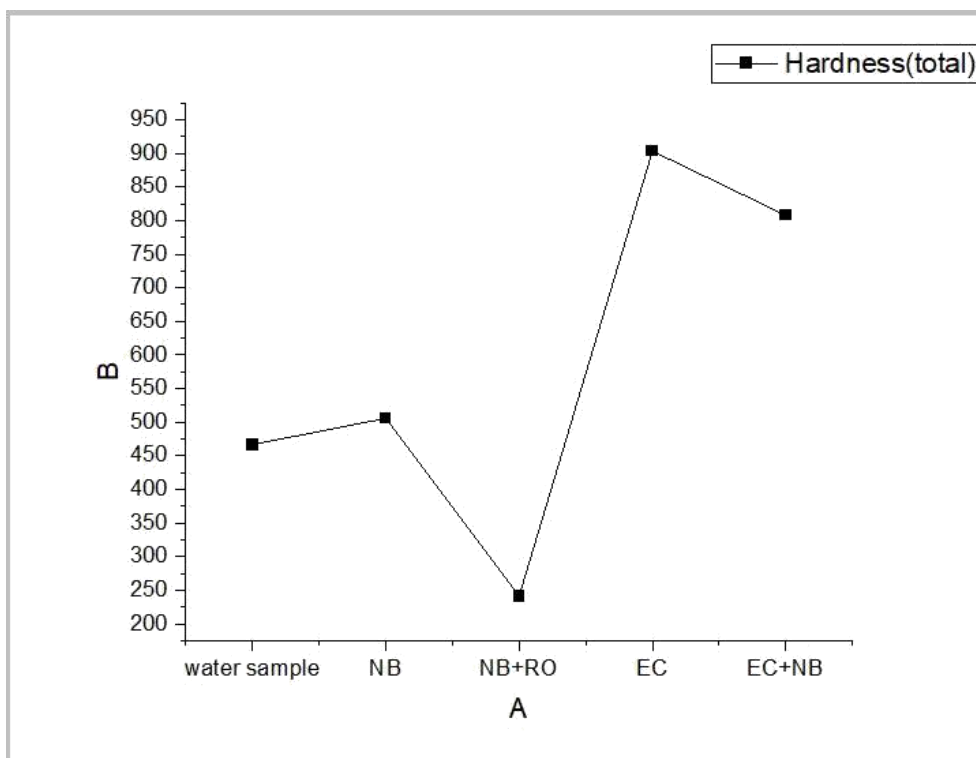


FIG 5.5: TOTAL HARDNESS GRAPH

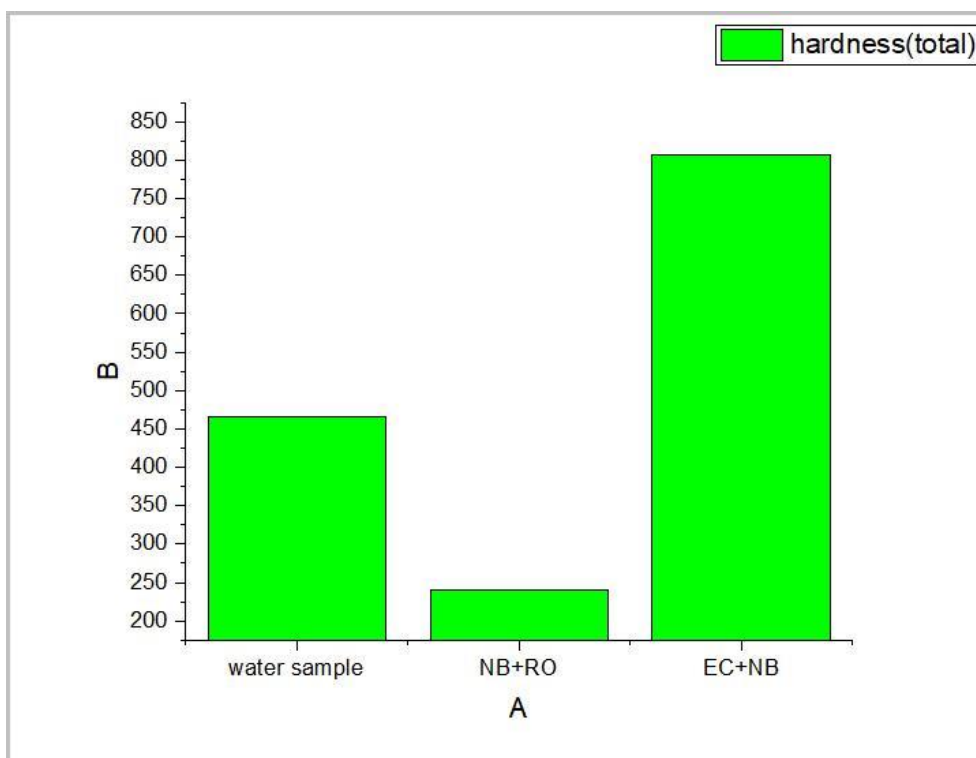


FIG 5.6: TOTAL HARDNESS COMPARISON CHART

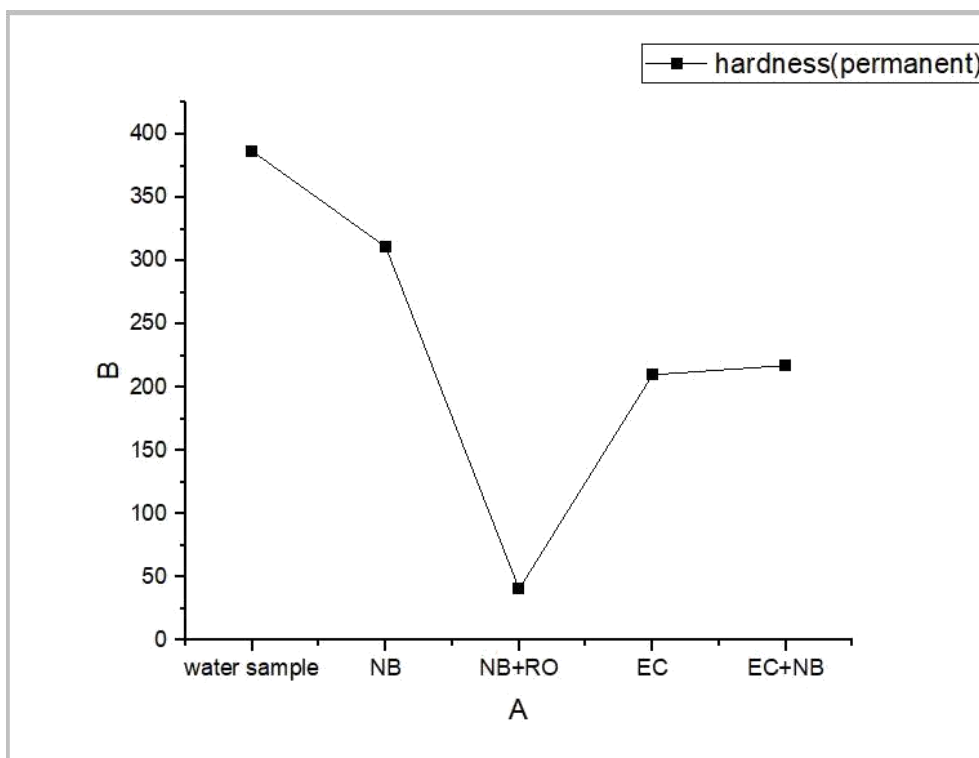


FIG 5.7: PERMANENT HARDNESS GRAPH

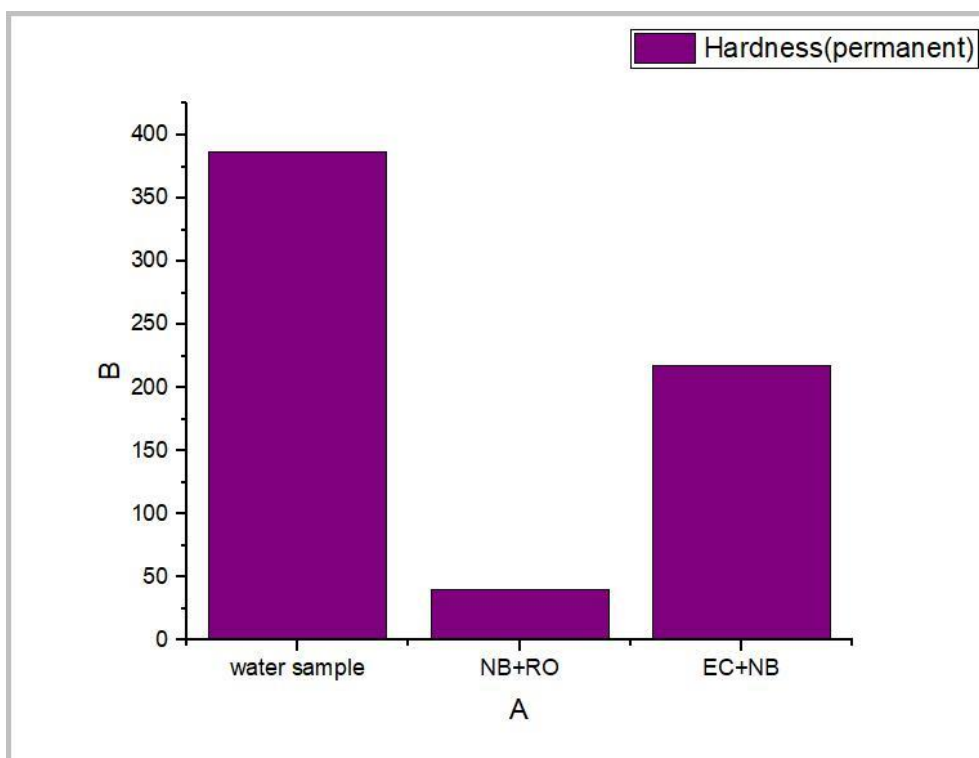


FIG 5.8: PERMANENT HARDNESS COMPARISON CHART

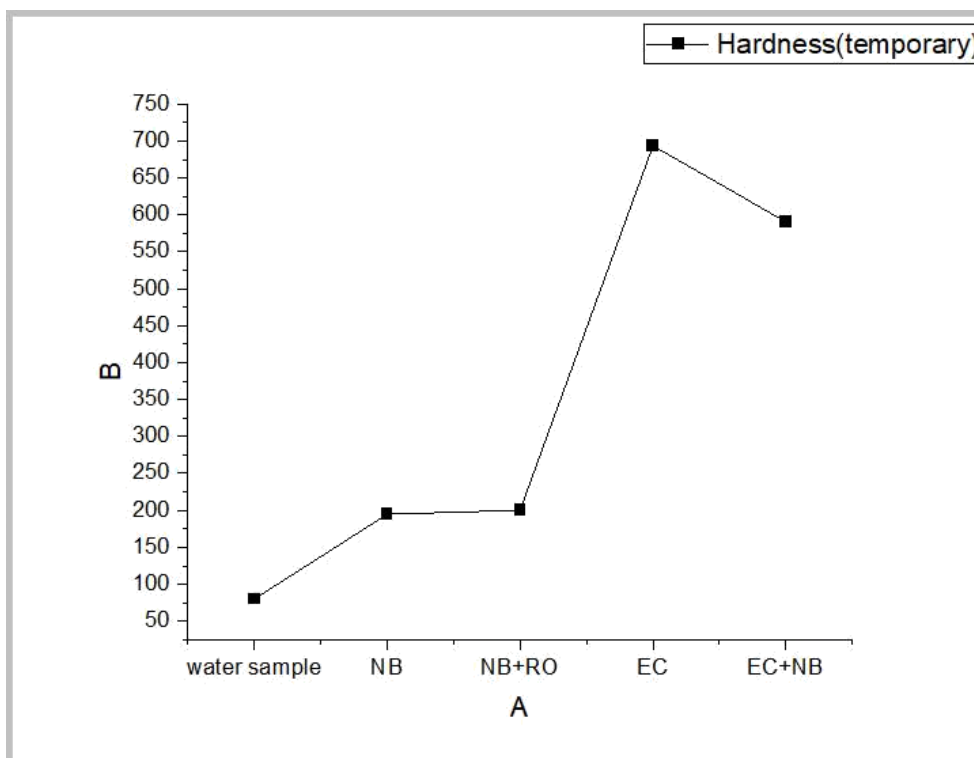


FIG 5.9: TEMPORARY HARDNESS GRAPH

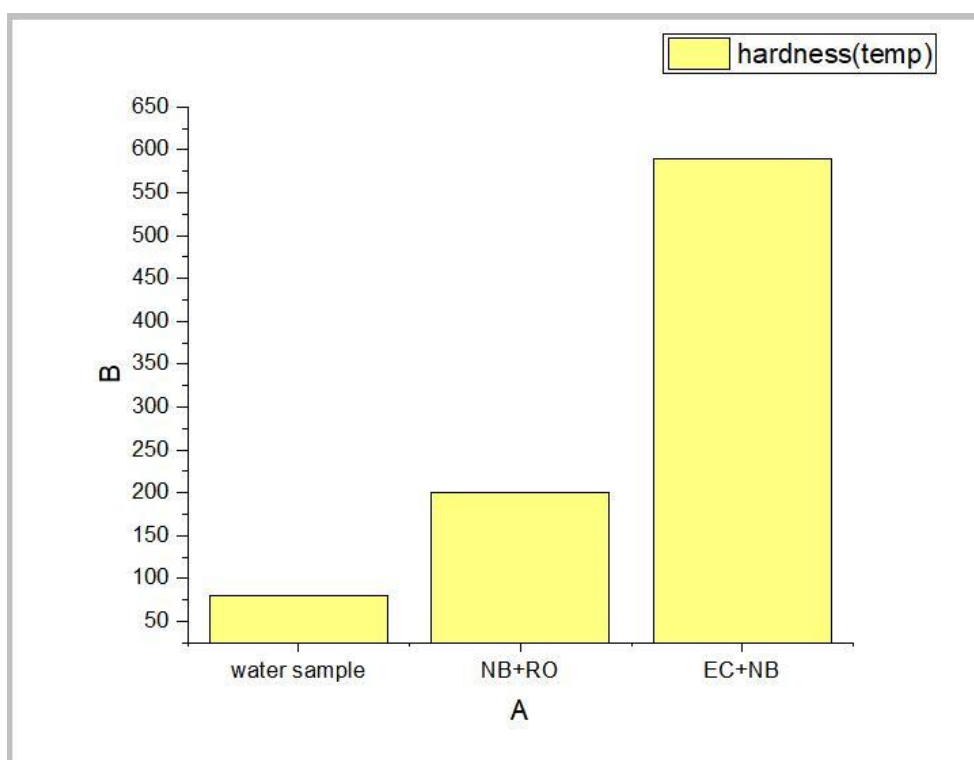


FIG 5.10: TEMPORARY HARDNESS COMPARISON CHART

5.2.4 pH:

TABLE 5.5: pH TEST RESULTS

Sample no.	1	2	3
Water sample	9.8	9.8	10.1
Sample after NB	9.6	9.2	8.7
NB+RO	9.8	9.3	9.4
EC	7.91	7.63	7.58
EC+NB	7.51	7.23	7.62

It is commonly known that the pH of water to be considered drinkable is 7, this value indicates that the water is neutral and does not possess any acidic or basic characteristics.

From the test results of table 5.5, for pH it can be quite clearly seen that neither of the methods proved to result in water with a perfect pH of 7 but the treatment method that could reach this value approximately was the electro-coagulation and nanobubble treatment method, followed by the electro-coagulation treatment method. The 2nd sample of the electro-coagulation and nano-bubble was the closest to attain a pH of 7 having the value of 7.23, which can be further reduced using other minor Ph alternation methods. All the other samples apart from the samples mentioned from the above two mentioned methods are far from the acceptable range, indicating that the water is hazardous to consume and is rather basic in nature.

Water to be considered safe for drinking should have a pH of around 7. Meaning that it is neutral and isn't acidic or basic in nature. The acceptable pH range for drinking water is between 6.5 and 8.5 but ideally it should be 7. From the figs 5.11 and 5.12, it can be concluded that water which underwent electro-coagulation and nano-bubble treatment has a value of 7.4 which is the closest pH value to the acceptable range and ideal pH value followed by the water that underwent electro-coagulation alone. Apart from these 2 treatment samples all the other samples have a pH way beyond the acceptable range. A slight increase in pH of NB+RO processed water when compared to NB processed water can be noticed this is

because in RO process the interference of oxygen alters the pH of water by 0.5. That also explains why NB+RO process yields water of higher pH than the water samples that went through EC and EC+NB processes. On the whole it can be concluded that in the case of pH electro-coagulation and nano-bubble treatment in unison proves to be the most efficient method.

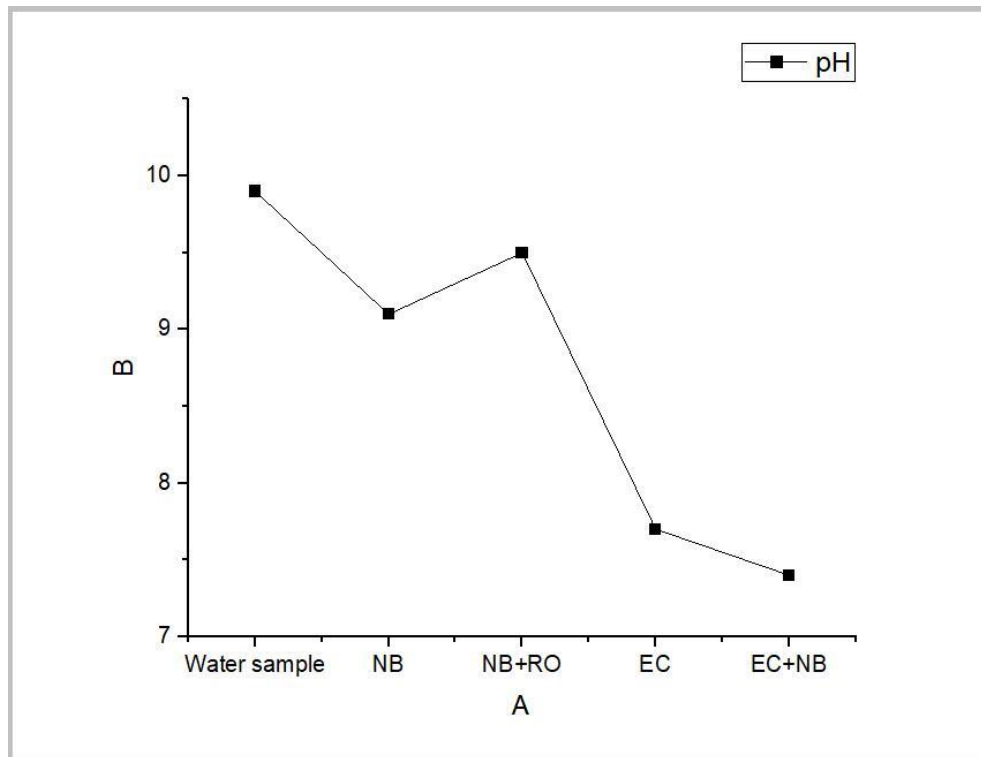


FIG 5.11: pH GRAPH

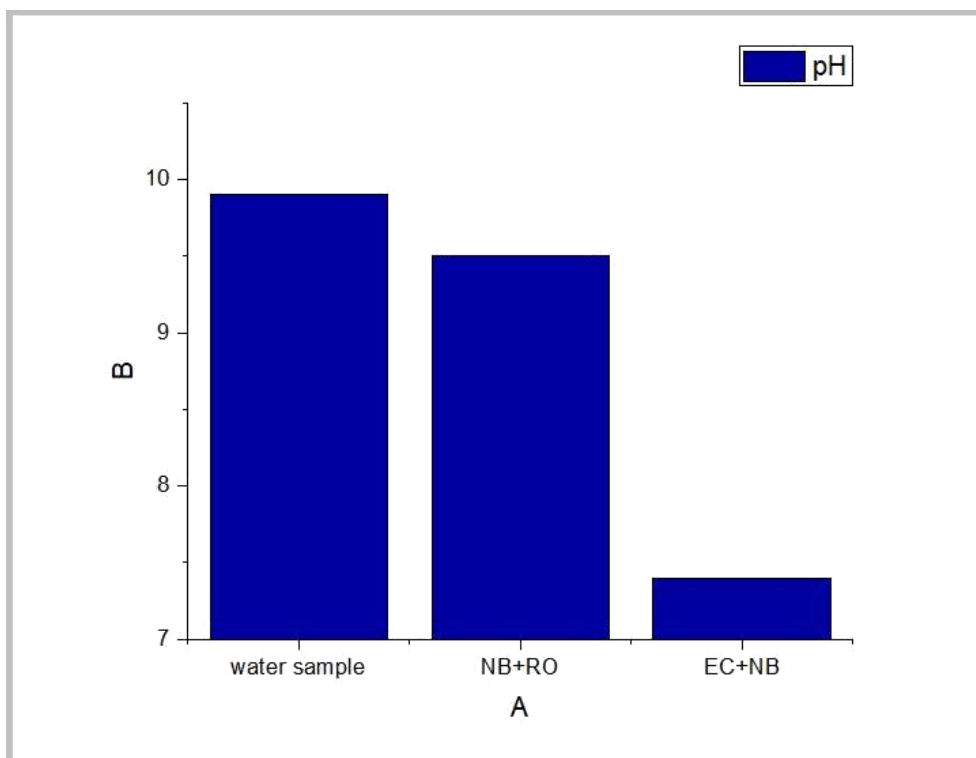


FIG 5.12: pH COMPARISON CHART

5.2.5 CHLORIDE:

TABLE 5.6: CHLORIDE TEST RESULTS

Sample no.	1	2	3
Water sample	134.9	71	106.5
Sample after NB	99.4	124.3	103.1
NB+RO	35.5	43.6	32.1
EC	49.7	58.2	53.1
EC+NB	42	51.43	47.4

The range of chloride content for a drinking water is said to be 50 – 250 mg/l. From the table 5.6 it is evident that the reduction of chloride content in the water when it undergoes electrocoagulation and nanobubble process is 46.6 which is pretty good. The process seems ideal because the reduction is within the acceptable range for chloride content present in drinking water. On the contrary it is evident that NB treated water has the highest chloride content. In the case of chloride reduction, the presence of dissolved oxygen projects a disadvantage. Oxygen and water don't

chemically react; hence the salinity of water increases and due to this the solubility of oxygen decreases thereby resulting in a higher chloride content.

Even though nano-bubble and RO reduced chloride content to a further lower level, it might not seem ideal because chloride content after treatment seems lower than the acceptable range for drinking water. The following figs 5.13 and 5.14 are a graphical representation of the test results. By interpreting these, it can be concluded that EC+NB is better when compared with the other processes.

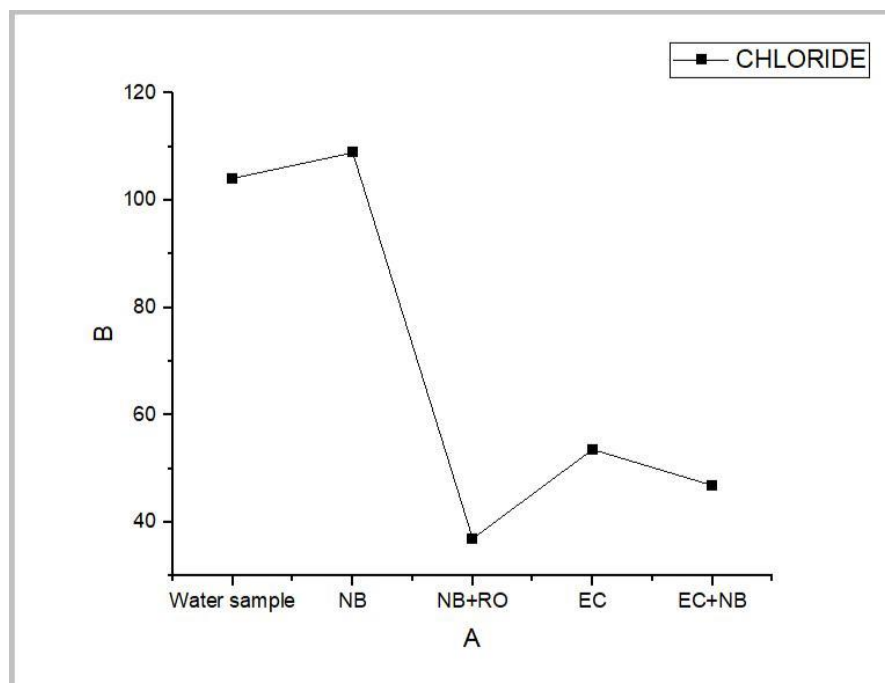


FIG 5.13: CHLORIDE GRAPH

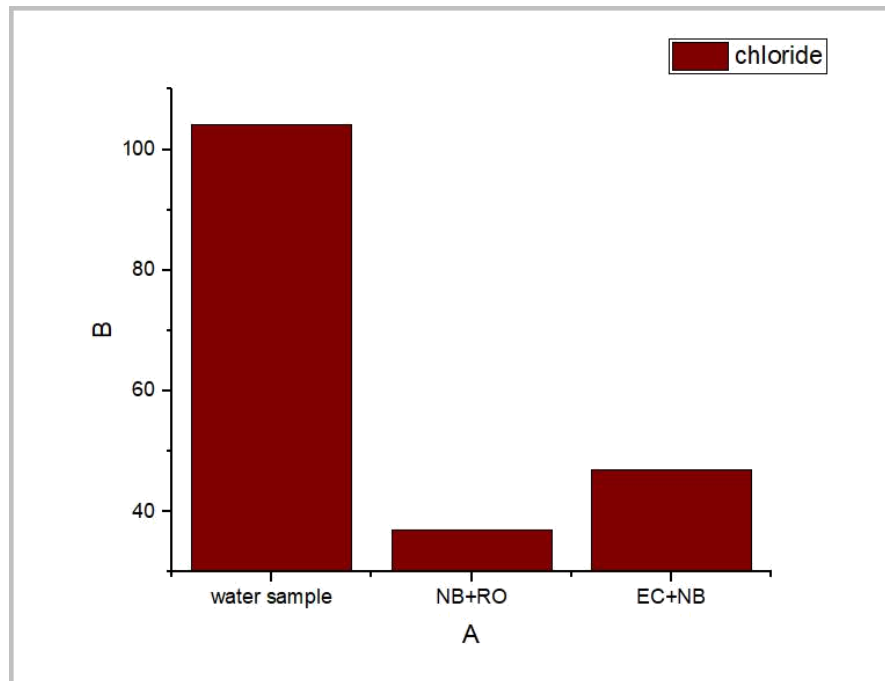


FIG 5.14: CHLORIDE COMPARISON CHART

5.2.6 ALKALINITY:

TABLE 5.7: ALKALINITY TEST RESULTS

Sample no.	1	2	3
Water sample	0	0	0
	20	20	8
	26	26	40
Sample after NB	0	0	0
	20	28	20
	40	56	40
NB+RO	0	0	0
	0	0	0
	6	6	6.1
EC	0	0	0
	20	17.2	18.6
	25.6	23	21.3
EC+NB	0	0	0
	15.2	12	14.8
	17	19	16.5

When alkalinity is the topic of discussion, from the table 5.7 for each sample in every type of treatment method there are three different values. The 1st value indicates the hydroxide concentration, the 2nd value indicates the carbonate concentration, and the 3rd value indicates the bi-carbonate concentration. All these values help to understand the basicity of the water sample. The more the basicity of the water the lower is the chance for it to be acceptable for being consumed.

In general, all the water samples have no hydroxide concentration at all, but as for the case of carbonate concentration the water sample that underwent nanobubble and RO treatment has the least value, it rather stands at 0 indicating that it has no carbonate content at all, quite closely followed by the water samples that underwent the Electro-coagulation and nano-bubble treatment process which has a considerable amount of alkalinity as compared to the latter mentioned process.

Bi-carbonate results follow the same trend as the carbonate results and in general there seems to be no difference between the test values of untreated water and the water sample that went through electro-coagulation. Quite un-expectedly the bi-carbonate concentration for the water samples that went through nano-bubble treatment alone seem to be very high.

Figs 5.15 – 5.18 are graphical representations that indicates the alkalinity test results of various samples that underwent different water treatment processes.

The alkalinity of NB treated water is higher than that of untreated water, this is because the more the chloride content in water the higher the alkalinity. This can be crosschecked with the chloride test results; it follows a similar pattern. The acceptable alkalinity content that can be present in drinking water is from 0-75 for carbonate and 5-25 for bicarbonate. From the graph it is evident that water samples that didn't undergo any treatment, nano-bubble treatment and electro-coagulation treatment alone are within the acceptable ranges which. Water that went through Nano-bubble along with RO treatment and water that went through electro-coagulation and nano-bubble treatment reduced chloride content way below the acceptable range which are 0 and 6 respectively. From this it can be concluded that both these processes aren't advisable in the case of alkalinity.

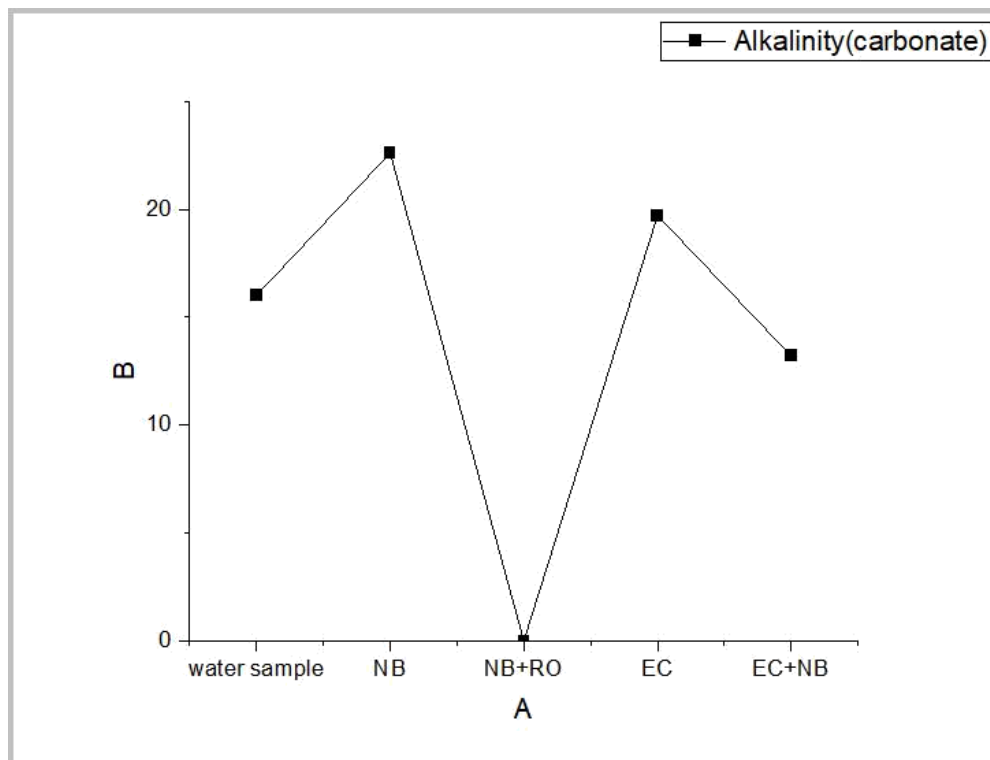


FIG 5.15: CARBONATE GRAPH

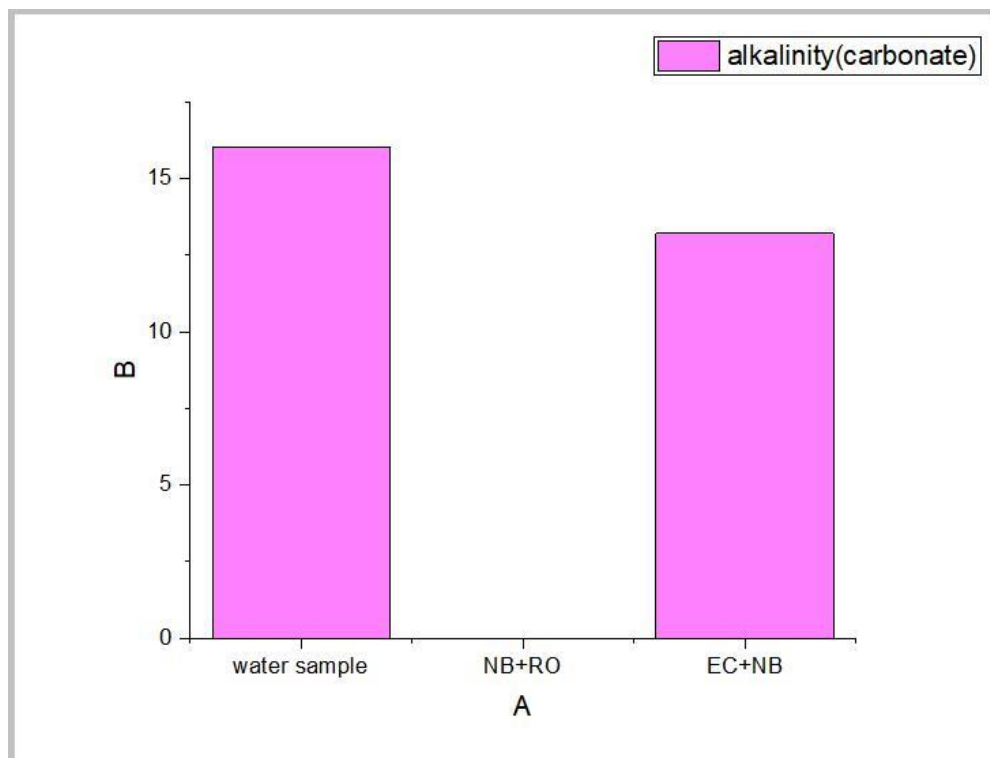


FIG 5.16: CARBONATE COMPARISON CHART

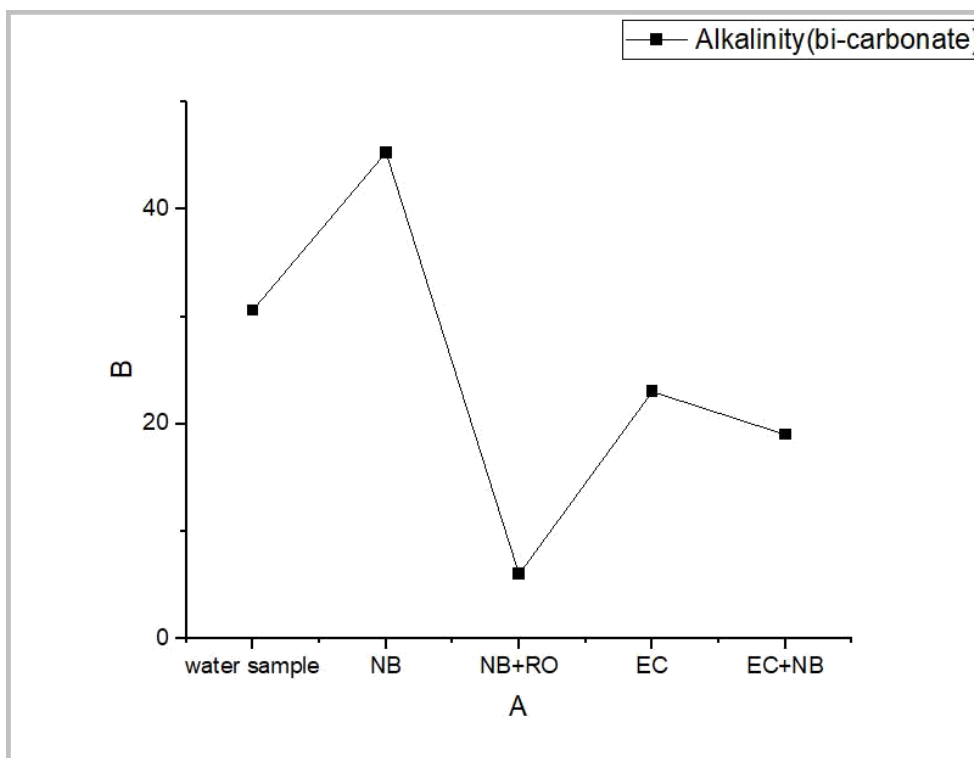


FIG 5.17: BI-CARBONATE GRAPH

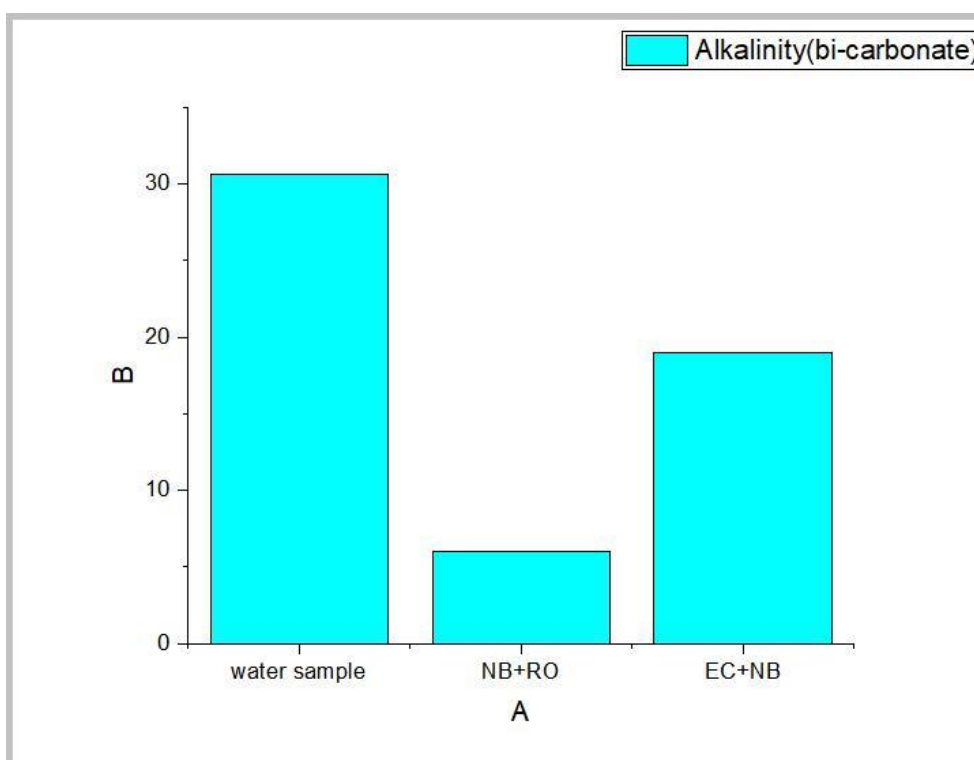


FIG 5.18: BI-CARBONATE COMPARISON CHART

5.2.7 TURBIDITY:

TABLE 5.8: TURBIDITY TEST RESULTS

Sample no.	1	2	3
Water sample	6.7	6.1	6.7
Sample after NB	1.7	1.9	1.3
NB+RO	4.3	4.9	4.1
EC	0.3	1.2	0.7
EC+NB	1.2	0.8	0.9

From the table 5.8 it is quite evident that untreated water collectively has more turbidity and water samples that underwent the nano-bubble and RO treatment have a reduction in the turbidity of the water but not to the required level, the water samples that went under electro-coagulation and nano-bubble treatment has enormous reduction in the turbidity of the water which is more suitable.

In general, from the test results it can be concluded that Nano-bubble treatment alone doesn't reduce the turbidity to a great extent but in addition to this water samples that underwent both electro-coagulation and nano-bubble treatment show quite a great amount of reduction in turbidity.

The acceptable turbidity value for drinking water is between 0.2 and 1 NTU. From the figures 5.19 and 5.20 it is pretty evident that the water samples that underwent electro-coagulation treatment alone and electro-coagulation in unison with nano-bubble treatment exhibit turbidity values within the acceptable range (i.e.) 0.7 and 0.9 respectively. For the other samples turbidity values are way beyond the desired range and cannot be accepted. Two un-expected phenomena can be noticed from the test results. One being the fact that NB+RO treated water has higher turbidity than NB processed water. This is because of two factors, 1-dissolved oxygen is inversely proportional to turbidity hence in NB process continuous dissolved oxygen

is supplied ultimately decreasing turbidity. 2-In NB+RO process it is known that RO is unable to reduce TSS, an increase in TSS increases turbidity and that is why NB+RO processed water has higher turbidity. The second phenomena are a slight increase in turbidity value of EC+NB treated water as compared to that of EC. This is because the sediments formed during the EC process is then again transferred to the NB where the sediments float on top as froth and it is removed by a filter, but the filter which is used is not that fine to reduce the turbidity of water, so due to this the EC+NB has slightly higher turbidity value than EC process.

Overall, it can be concluded that the above two mentioned treatment processes are the most effective in the case of maintaining proper turbidity values of water.

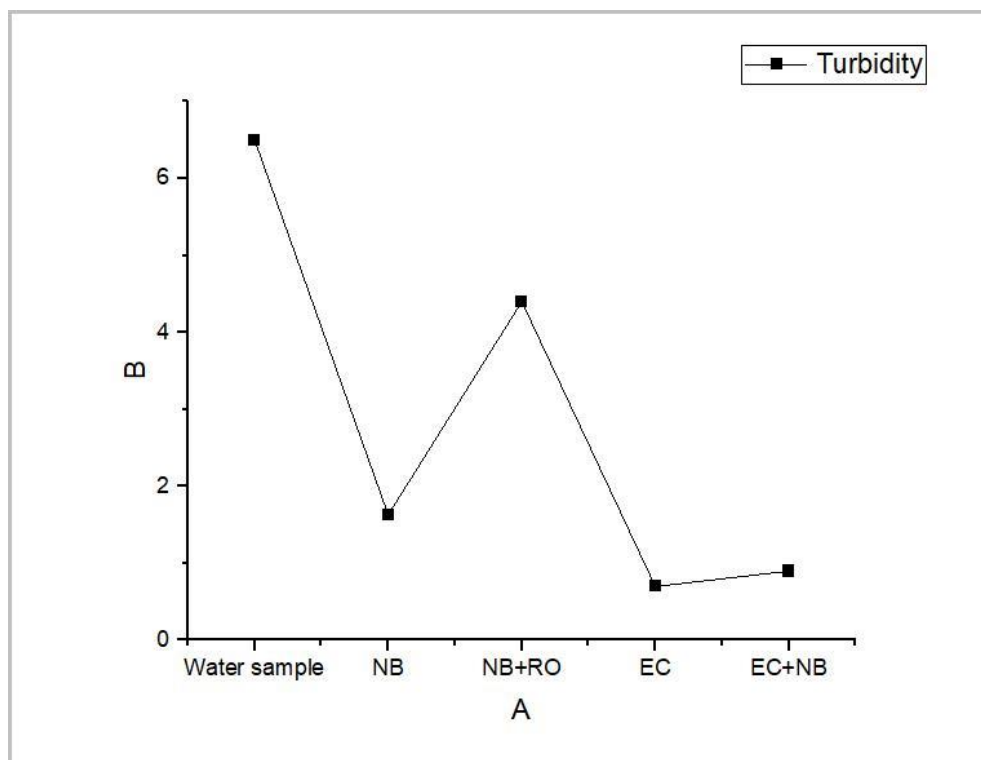


FIG 5.19: TURBIDITY GRAPH

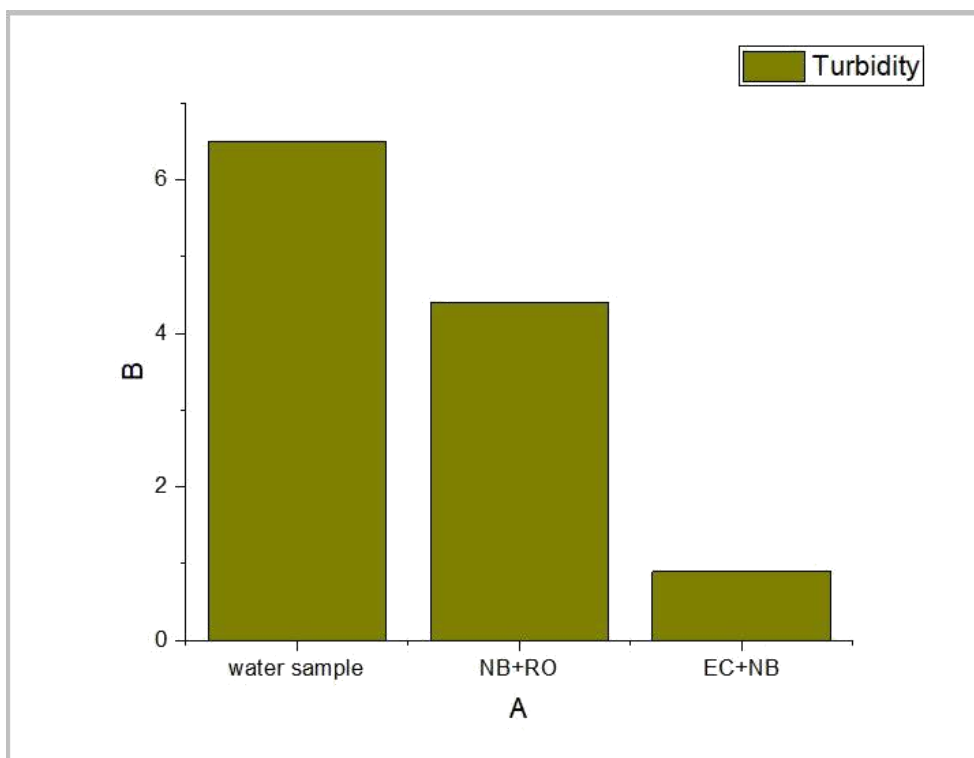


FIG 5.20: TURBIDITY COMPARISON CHART

5.2.8 ELECTRICAL CONDUCTIVITY:

TABLE 5.9: ELECTRICAL CONDUCTIVITY TEST RESULTS

Sample no.	1	2	3
Water sample	1.33	1.24	1.37
Sample after NB	1.7	1.9	1.3
NB+RO	64	59.3	62.6
EC	0.83	0.87	0.93
EC+NB	1.04	1.12	1.09

From the electrical conductivity table 5.9 containing the results of various water samples it is evident that the water samples that under-went the nano-bubble and RO process, seem to have the highest electrical conductivity overall. NB+RO treated water exhibits a higher electrical conductivity because in the RO system the suspended solids and chloride present in water, deposits ions (which are charged

particles). Due to this deposition electrical conductivity increases. This can be crossed checked with the test results pattern of TSS and chloride.

The water samples that underwent no treatment at all, just nanobubble treatment and electro-coagulation and nano-bubble treatment follow a similar trend in the test results ranging from 1.04 to 1.37. However surprisingly the least electrical conductivity has been shown by the water samples that underwent electro-coagulation treatment alone. The least electrical conductivity was exhibited by the 1st sample of electro-coagulation treatment with the resulting value of 0.83.

The electrical conductivity values for water to be acceptable for drinking are between 0.3 and 1.5, from the figures 5.21 and 5.22, it is evident that apart from the water sample that underwent nano-bubble and RO treatment all the other samples portray electrical conductivity values within the acceptable range.

Hence in the case of electrical conductivity it can be concluded that nano-bubble and RO process in unison for the treatment of water isn't effective at all producing a value of 61.97.

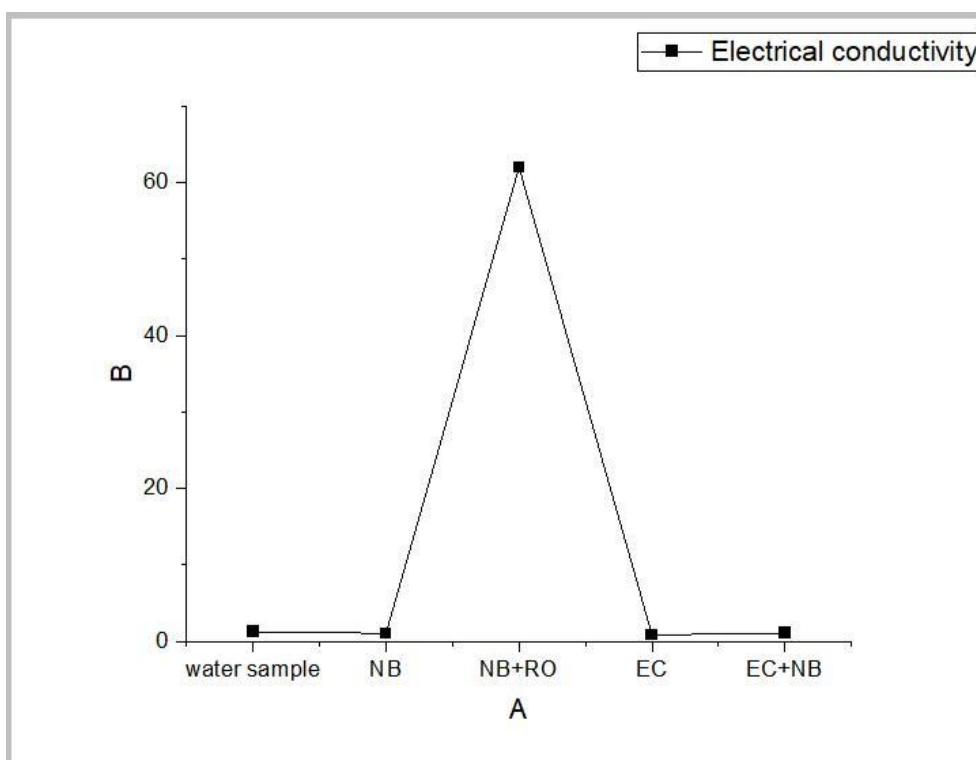


FIG 5.21: ELECTRICAL CONDUCTIVITY GRAPH

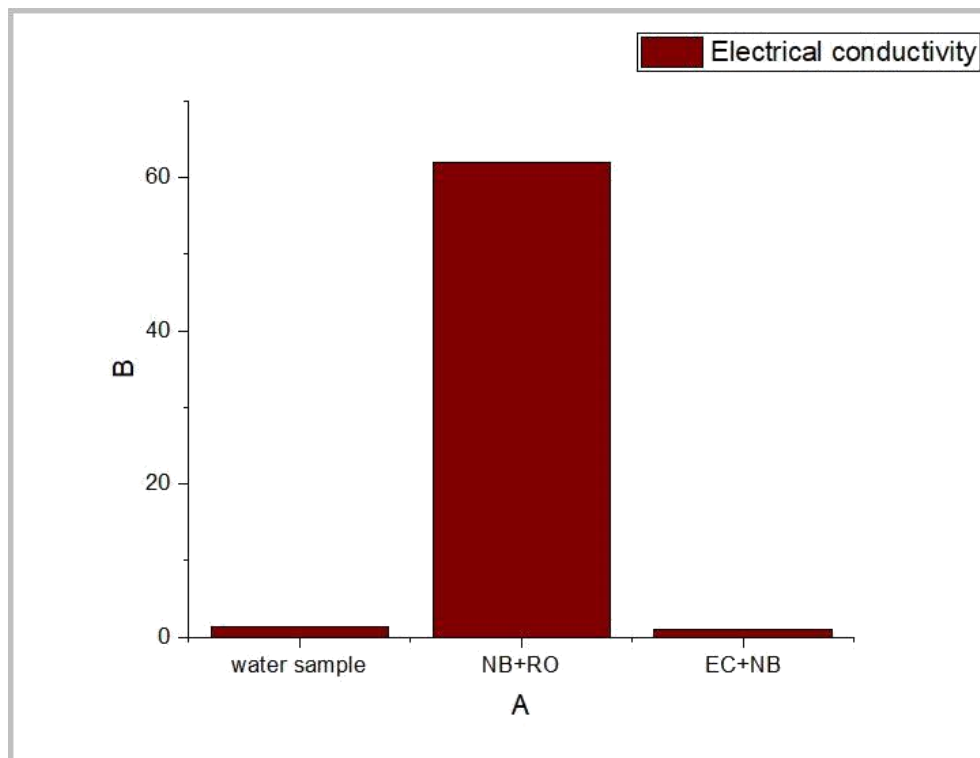


FIG 5.22: ELECTRICAL CONDUCTIVITY COMPARISON CHART

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 SUMMARY:

- When comparing the overall procedure and the test results, EC+NB outperforms NB+RO.
- As this work is focused on reduction of TDS and water wastage, EC+NB has the greater benefit and produced the best results when compared to NB+RO.
- Due to this the alternative proposal stands positive for further study and investigation.

6.2 CONCLUSION:

The goal of this project was to demonstrate that EC+NB is superior to NB+RO for reducing TDS of a water sample and to minimize the wastage of water that occurs while using an RO equipment. As a conclusion from all the various water quality test results it was found that, EC+NB has a modest edge as compared to NB+RO for many test factors. Although NB+RO passes majority of the tests. It fails at others, like as in electrical conductivity and pH. In many circumstances, EC+NB has significant advantages over the NB+RO procedure. Hence when comparing the overall procedure and the test results, EC+NB outperforms NB+RO. As this project is focused on reduction of TDS and water wastage, EC+NB has the greater benefit and produced the best results when compared to NB+RO. Due to this the alternative proposal stands positive for further study and investigation.

CHAPTER 7

REFERENCES

1. Ahmadi R, Khodadadi Darban A. Modeling and optimization of nano-bubble generation process using response surface methodology. *International journal of nanoscience and nanotechnology*. 2013;9(3):151-162.
2. Azevedo A, Oliveira H, Rubio J. Bulk nanobubbles in the mineral and environmental areas: Updating research and applications. *Adv Colloid Interface Sci*. 2019;271:101992.
3. Bouaifi M, Hebrard G, Bastoul D, Roustan M. A comparative study of gas hold-up, bubble size, interfacial area and mass transfer coefficients in stirred gas– liquid reactors and bubble columns. *Chemical engineering and processing: Process intensification*. 2001;40(2):97-111.
4. Bousher A, Shen X, Edyvean RGJ. Removal of coloured organic matter by adsorption onto low-cost waste materials. *Water Res*. 1997;31(8):2084-2092.
5. Butler E, Hung YT, Yeh RYL, Suleiman Al Ahmad M. Electrocoagulation in wastewater treatment. *Water (Basel)*. 2011;3(2):495-525.
6. Chaturvedi SI. Electrocoagulation: a novel waste water treatment method. *International journal of modern engineering research*. 2013;3(1):93-100.
7. Chen G. Electrochemical technologies in wastewater treatment. *Sep Purif Technol*. 2004;38(1):11-41.
8. Chen G, Chen X, Yue PL. Electrocoagulation and electroflotation of restaurant wastewater. *Journal of environmental engineering*. 2000;126(9):858-863.
9. Deng C, Yang L, Chen HJ, Yang MC, Zhu YZ. Progresses in research and application of micro-nano bubble generating device. *Shiyou Huagong/Petrochemical Technology*. 2014;43(10):1206-1213.
10. Drondina R V, Drako I V. Electrochemical technology of fluorine removal from underground and waste waters. *J Hazard Mater*. 1994;37(1):91-100.
11. Garcia-Segura S, Eiband MMSG, de Melo JV, Martínez-Huitle CA. Electrocoagulation and advanced electrocoagulation processes: A general review about the fundamentals, emerging applications and its association with other technologies. *Journal of Electroanalytical Chemistry*. 2017;801:267-299.
12. Hakizimana JN, Gourich B, Chafi M, et al. Electrocoagulation process in water treatment: A review of electrocoagulation modeling approaches. *Desalination*. 2017;404:1-21.

13. Holmberg M, Kühle A, Garnæs J, Mørch KA, Boisen A. Nanobubble trouble on gold surfaces. *Langmuir*. 2003;19(25):10510-10513.
14. Hu CY, Lo SL, Kuan WH. Effects of co-existing anions on fluoride removal in electrocoagulation (EC) process using aluminum electrodes. *Water Res*. 2003;37(18):4513-4523.
15. Jia W, Ren S, Hu B. Effect of water chemistry on zeta potential of air bubbles. *Int J Electrochem Sci*. 2013;8(4):5828-5837.
16. Katal R, Pahlavanzadeh H. Influence of different combinations of aluminum and iron electrode on electrocoagulation efficiency: Application to the treatment of paper mill wastewater. *Desalination*. 2011;265(1-3):199-205.
17. Khan P, Zhu W, Huang F, Gao W, Khan NA. Micro–nanobubble technology and water-related application. *Water Supply*. 2020;20(6):2021-2035.
18. Kulkarni AA, Joshi JB. Bubble formation and bubble rise velocity in gas–liquid systems: a review. *Ind Eng Chem Res*. 2005;44(16):5873-5931.
19. Kyzas GZ, Matis KA. Electroflotation process: A review. *J Mol Liq*. 2016;220:657-664.
20. Ljunggren S, Eriksson JC. The lifetime of a colloid-sized gas bubble in water and the cause of the hydrophobic attraction. *Colloids Surf A Physicochem Eng Asp*. 1997;129:151-155.
21. Lou ST, Ouyang ZQ, Zhang Y, et al. Nanobubbles on solid surface imaged by atomic force microscopy. *Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures Processing, Measurement, and Phenomena*. 2000;18(5):2573-2575.
22. Merzouk B, Madani K, Sekki A. Using electrocoagulation–electroflotation technology to treat synthetic solution and textile wastewater, two case studies. *Desalination*. 2010;250(2):573-577.
23. Miettinen T, Ralston J, Fornasiero D. The limits of fine particle flotation. *Miner Eng*. 2010;23(5):420-437.
24. Mohammad AW, Teow YH, Ang WL, Chung YT, Oatley-Radcliffe DL, Hilal N. Nanofiltration membranes review: Recent advances and future prospects. *Desalination*. 2015;356:226-254.
25. Mollah MYA, Morkovsky P, Gomes JAG, Kesmez M, Parga J, Cocke DL. Fundamentals, present and future perspectives of electrocoagulation. *J Hazard Mater*. 2004;114(1-3):199-210.
26. Mollah MYA, Morkovsky P, Gomes JAG, Kesmez M, Parga J, Cocke DL. Fundamentals, present and future perspectives of electrocoagulation. *J Hazard Mater*. 2004;114(1-3):199-210.

27. Naje AS, Chelliapan S, Zakaria Z, Abbas SA. Treatment performance of textile wastewater using electrocoagulation (EC) process under combined electrical connection of electrodes. *Int J Electrochem Sci*. 2015;10(7):5924-5941.
28. Nandi BK, Patel S. Effects of operational parameters on the removal of brilliant green dye from aqueous solutions by electrocoagulation. *Arabian Journal of Chemistry*. 2017;10:S2961-S2968.
29. O'connor CT, Randall EW, Goodall CM. Measurement of the effects of physical and chemical variables on bubble size. *Int J Miner Process*. 1990;28(1-2):139-149.
30. De Rijk SE, den Blanken JG. Bubble size in flotation thickening. *Water Res*. 1994;28(2):465-473.
31. Shen F, Chen X, Gao P, Chen G. Electrochemical removal of fluoride ions from industrial wastewater. *Chem Eng Sci*. 2003;58(3-6):987-993.
32. Siringi DO, Home P, Chacha JS, Koehn E. Is electrocoagulation (EC) a solution to the treatment of wastewater and providing clean water for daily use. Published online 2012.
33. Takahashi M, Chiba K, Li P. Free-radical generation from collapsing microbubbles in the absence of a dynamic stimulus. *J Phys Chem B*. 2007;111(6):1343-1347.
34. Thakur LS, Mondal P. Techno-economic evaluation of simultaneous arsenic and fluoride removal from synthetic groundwater by electrocoagulation process: optimization through response surface methodology. *Desalination Water Treat*. 2016;57(59):28847-28863.
35. Tsai JC, Kumar M, Chen SY, Lin JG. Nano-bubble flotation technology with coagulation process for the cost-effective treatment of chemical mechanical polishing wastewater. *Sep Purif Technol*. 2007;58(1):61-67.
36. Vepsäläinen M, Sillanpää M. Electrocoagulation in the treatment of industrial waters and wastewaters. In: *Advanced Water Treatment*. Elsevier; 2020:1-78.
37. Wang S, Liu M, Dong Y. Understanding the stability of surface nanobubbles. *Journal of Physics: Condensed Matter*. 2013;25(18):184007.
38. Wu C, Nasset K, Masliyah J, Xu Z. Generation and characterization of submicron size bubbles. *Adv Colloid Interface Sci*. 2012;179:123-132.
39. Zodi S, Potier O, Lapique F, Leclerc JP. Treatment of the industrial wastewaters by electrocoagulation: Optimization of coupled electrochemical and sedimentation processes. *Desalination*. 2010;261(1-2):186-190.

CHAPTER 8

APPENDIX

Kiran

by P KA

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