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Optimizing Effluent Quality: A Multifaceted Approach to Reduce TDS in Food Industry ETPs

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Abstract: This study delves into strategies aimed at reducing Total Dissolved Solids (TDS) in water sources throughout Andhra Pradesh, India, with a specific focus on Vijayawada, Rajahmundry, Bapatla, Nellore, and Rangampeta. These locations represent a spectrum of water quality challenges, reflecting the diverse nature of TDS issues across the state. Our investigation spans various TDS reduction techniques, encompassing conventional methods such as Borax Powder and Multi-Effect Evaporators, natural alternatives like Vetiver Root, Gooseberry Bark, and Lemon Peel, as well as commercially available options including Peanut Husk, Sodium Citrate, Sodium Sulphate, and Sodium EDTA Solution. The overarching objective is to develop a practical framework for optimal TDS reduction strategies tailored to the unique factors of each location. Through rigorous evaluation of the efficacy and cost-effectiveness of each technique, we aim to empower stakeholders with the necessary insights for informed decision-making in clean water management across Andhra Pradesh. By conducting a comparative analysis of conventional, natural, and commercial methods, this study offers comprehensive insights into addressing TDS issues while considering both effectiveness and economic viability. The strategic selection of these specific locations within Andhra Pradesh facilitates a nuanced understanding of the diverse water quality challenges prevalent within the state. This ensures that the framework developed through this research can effectively address the varied needs and circumstances encountered across different regions. Ultimately, the findings of this study hold the promise of significantly enhancing water quality and accessibility in Andhra Pradesh, while also offering valuable lessons and insights applicable to similar regions grappling with TDS-related issues globally.

Keywords: Water Quality, TDS Reduction Techniques, Cost-Benefit Analysis, Location- Specific Strategies, Borax Powder

I. INTRODUCTION

A. Introduction

Effluent water from Effluent Treatment Plants (ETPs) often contains various impurities that can pose environmental and health risks. These impurities include residual organics, dye molecules, faecal pathogens, antibiotic residues, emerging contaminants, and industrial wastewater. Effluent water may also contain high levels of bisphenol A, fluoroquinolones, and sulfamethoxazole, which can lead to membrane fouling and failure (Srinivasan et al., 2011; Hendricks et al., 2012; Morin-Crini et al., 2022). Additionally, the effluent may exhibit an increase in physico-chemical characteristics when stored in effluent pits, potentially leading to water pollution in case of accidental release or spill (Adam et al., 2023). The variability of impurity concentration in effluents, depending on the type of industry and its processes, further complicates the treatment process (Gao et al., 2008).

Total dissolved solids (TDS) refer to the total concentration of inorganic and organic substances dissolved in water. TDS can include a variety of ions, metals, and other compounds, and it is an important parameter for assessing water quality (Ali et al., 2022). High levels of TDS can affect the taste of water and may also indicate the presence of contaminants (Mashhadi et al., 2016). Therefore, it is crucial to reduce TDS in water sources, especially in industrial, agricultural, and domestic settings.

The effects of TDS on iron oxidation and cell growth have been challenging to quantify, highlighting the need for a framework to interpret experimental data in this context (Blight et al., 2012). Moreover, textile effluents characterized by high TDS levels have implications for industrial and agricultural water use (Gunasekar et al., 2015). High TDS levels have been reported to limit the industrial and agricultural use of water, emphasizing the potential consequences of TDS on water usability (Ebele et al., 2016). Furthermore, TDS in emulsions has been shown to impact physical properties such as viscosity and adhesiveness, indicating its influence on product characteristics (Arganis et al., 2018).

In terms of human health, alkaline solutions with high TDS levels have been associated with high corrosion rates, highlighting the potential health risks associated with TDS in certain water sources (Bylapudi et al., 2020). Moreover, the potability of groundwater has been linked to

TDS levels, with high TDS causing gastrointestinal irritation and potential long-term health issues (Kawade et al., 2015). Additionally, TDS has been identified as a key parameter impacted by crude oil contamination, affecting water quality and potentially posing risks to human health (Ahmad et al., 2021).

Several methods have been proposed for reducing TDS in water. One study by Setiawan et al., (2021) demonstrated the utilization of carbon electrodes to reduce dissolved ions from coal stockpile wastewater, resulting in a significant decrease in TDS levels. Additionally, the use of membrane filtration and aerosolization methods has been suggested for quantifying a mixture of insoluble submicrometer particles and dissolved solids in water, which can contribute to reducing TDS (Park et al., 2011). Furthermore, the application of pulsed electric field processing has been shown to decrease the total dissolved solid value in orange milk, indicating its potential for TDS reduction in liquid products (Hariono et al., 2022).

It is important to note that the reduction of TDS is essential for ensuring the safety and quality of water for consumption and various industrial applications. The establishment of a conversion factor between electrical conductivity and TDS has been proposed as a means to accurately measure and control TDS levels in water purification processes (Hubert & Wolkersdorfer, 2015). Moreover, the correlation between electrical conductivity and TDS in natural waters has been studied to provide insights into the relationship between these parameters, which can be valuable for TDS management (Thirumalini & Joseph et al., 2009).

B. Statement of Proposal

1) Background

Total dissolved solids (TDS) are one of the important chemical parameters in water quality monitoring. It refers to the sum of total organic and inorganic substances in water, which consists of both cations (e.g., calcium, magnesium, potassium, and sodium) and anions (e.g., carbonates, nitrates, bicarbonates, chloride, and sulphates). Both natural and anthropogenic activities are the sources of TDS. Natural sources include seawater intrusion, mineral springs, salts, and carbonate deposits, and anthropogenic sources include sewage, urban runoff, industrial wastewater, and chemicals in the water and wastewater treatment process. According to the Indian standard, the permissible limit of TDS in drinking water is 500 and 2000 ppm if there are no other sources of water available. It causes harmful effects in an aquatic environment if the concentration is higher than 2000 ppm. (Shyamala et al., 2008)

Kind of industry	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	N (mg/L)	P (mg/L)	pH
Brewery	137-1909		820-8267			
	2900-3000	2000-6000	1200-3600	25-80	10-50	3.0 - 12.0
Dairy	44-1162		40-10077	44.0-133.2	4.9-84.0	6.1 - 8.0
	1100-1600	1400-2500	800-1000			
	250-2750	400-15200	650-6250	10.0-90		
	1600-3900	23000-40000		400-700	60-100	
	134-804	921-9004	483-6080	8-230	9-111.5	5.5-5.8
Fish processing	30-1305		60-6698	0.9-69.7	2.1-44.2	4.0-7.4
	14-12375	10-90000	12-78000	77-3000		3.8-10
Fruit and vegetable	177-4133		190-6113		3.1-8.6	6.0-7.7
Meat process.	48-6203		40-5749	30.5-62.9	3.7-127.2	5.9-7.3
Olive mill	75500	130100		460		
Potato chips	5000	6000	5000	250	100	
Soft drinks	23-667		608-4200			
Sugar and sweets	47-2153		177-26185		20.1-22.2	5.9-7.2
Sugar beet	6100	6600		10	2.07	
Winery	27-618		213-2400			
	150-200	18000-21000		310-410	40-60	

Table 1: Main Pollutants Concentration Ranges in Food and Beverage Industry Wastewater (Falletti et al., 2015)

Despite being a key driver of Andhra Pradesh's economy, the state's food industry has room for significant growth, particularly in food fortification and processing. India, including Andhra Pradesh, achieves only 7% value addition through fortification, far behind China (23%), the Philippines (45%), and the UK (188%). Similarly, India processes a mere 2% of fruits and vegetables, a stark contrast to Thailand (30%), Brazil (70%), the Philippines (78%), and Malaysia (80%). Recognizing this gap, the Indian government has set ambitious targets to reach 10% processing by 2010 (likely surpassed) and 25% by 2025, aiming to close the gap with leading nations. (Dev & Nuthalapati et al., 2004)

NIC '87 Code	Description of the item	Triennium Ending				
		1999-2000	2003-2004	2006-2007	2009-2010	2013-2014
201	Manufacture of the dairy Products	46	50	77	106	94
202	Canning and preservation of fruits	31	47	52	53	54
203	Processing, canning and preserving of fish, crustaceans and similar foods	18	18	27	30	31
204	Grain Milling	2245	2887	2460	3433	3566
205	Manufacture of bakery products	57	73	96	100	110
206	Manufacturing sugar and refining of	29	30	36	33	-
207	Production of indigenous sugar, Boora, Khandasari, gur etc from sugarcane, palm juice etc.	113	47	43	38	-
209	Manufacture of Hydrogenated vegetable oils and vanaspati ghee etc	10	16	24	22	24
210	Manufacture of hydrogenated vegetable oils and fats (other than hydrogenated)	7	8	43	14	-
211	Manufacture of vegetable oils and fats (other than hydrogenated)	393	570	750	763	-
215	Processing of edible nuts	11	210	364	400	448
216	Manufacture of ice	26	17	9	10	-
217	Manufacture of prepared animal and bird feed	19	23	49	64	70
218	Manufacture of starch	-	16	18	14	24
219	Manufacture of food products not elseware classified	300	218	144	127	-
	All food products	3433	4277	5282	5296	5350

Table 2: Number of Enterprises in Organized Manufacturing in Andhra Pradesh (Dev & Nuthalapati, 2004)

2) Problem Statement

Industries in several Andhra Pradesh cities – Vijayawada (housing Aparna Constructions & Industries Ltd. and Dr. Reddy's Laboratories Ltd.), Rajahmundry (known for ITC Limited and Godavari Fertilizers & Chemicals Ltd.), Bapatla (where Nagarjuna Fertilizers and Chemicals Limited is located), Nellore (with companies like Nellore Mica & Minerals Pvt. Ltd. and Thiruvuru Cables Ltd.), and Rangampeta (with industries like Andhra Sugars Ltd. and Nagarjuna Cement) – face a critical challenge: excessively high levels of Total Dissolved Solids (TDS) in their water supply. This high TDS content significantly restricts water usability for various industrial processes, potentially hampering production efficiency and growth.

Finding effective methods to reduce TDS levels is paramount. By implementing appropriate treatment solutions, the treated water can be used for industrial production and gardening, benefiting both companies and surrounding communities. Addressing this challenge is crucial for the sustainable development and economic prosperity of these regions.

3) Scope of the Study

The scope of this study is to investigate and address high Total Dissolved Solids (TDS) in the industrial water effluents of Industries present in Vijayawada, Rajahmundry, Bapatla, Nellore, and Rangampeta. The research will assess the mination, identify sources, and evaluate existing and emerging TDS reduction technologies. Pilot-scale trials will be conducted to test the most promising solution(s) in one or more cities. Finally, the study will analyze the economic and environmental feasibility of large-scale implementation, and develop recommendations for industries and policymakers to ensure sustainable and high-quality industrial water supply in Andhra Pradesh.

4) Objectives

- Determine the most suitable method for reducing Total Dissolved Solids (TDS) levels.
- Design and Planning of a Treatment method for reducing TDS Levels within a Plant.
- System Implementation and Validation at the Plant.

5) Expected Outcome

This project aims to achieve a three-step solution for high TDS: identifying the most effective method for the region, designing a customized treatment system for seamless integration within an industrial plant, and finally implementing and validating the system to ensure it meets the desired level of TDS reduction for optimal industrial water quality.

II. LITERATURE REVIEW

A. Total Dissolved Solids

Total dissolved solids (TDS) are a critical parameter in water quality assessment, as they can impact various aspects of water usage and environmental health. TDS represent the total concentration of inorganic and organic substances dissolved in water, including salts, minerals, and other chemical compounds (Weber-Scannell & Duffy et al., 2007). The TDS levels in water can have significant effects on various physiological parameters, as evidenced by a study on the effect of different water qualities on broiler chickens, which found differences in physiological parameters based on TDS levels (Hussain & Al-Salhie et al., 2022). Furthermore, TDS levels are also crucial in the context of water purification and treatment, as they can impact the effectiveness of water purification processes (Mashhadi et al., 2016).

The measurement and control of TDS are essential for various sectors such as industry, agriculture, livestock, and health (Mashhadi et al., 2016). TDS levels can be determined using various methods, including the use of ion electrode techniques, electrical conductivity measurements, and the implementation of statistical models for prediction (Helsel et al., 2020; Ali et al., 2022; Dahaan et al., 2016). Additionally, the correlation between TDS and electrical conductivity has been studied extensively, providing insights into the relationship between these two parameters in natural waters (Thirumalini & Joseph et al., 2009).

Moreover, TDS levels have been assessed in various environmental contexts, including groundwater quality assessment, leachate characterization near landfill sites, and the impact of solid waste disposal on groundwater quality (Mor et al., 2006; Kamboj & Choudhary et al., 2013; Yi & Stewart et al., 2017). High TDS levels have been associated with adverse effects on aquatic organisms, emphasizing the importance of monitoring and managing TDS concentrations in water bodies. Furthermore, TDS levels have been evaluated in the context of tourist attractions, where water quality assessments have been conducted to mitigate ecological destruction (Abas et al., 2022).

B. Sodium Citrate, Sodium Sulphate & Sodium EDTA Solution

In investigating the impact of Sodium Citrate, Sodium Sulphate, and Sodium EDTA solution on total dissolved solids in Effluent Treatment Plant (ETP), several studies provide relevant insights. demonstrated a reduction in total dissolved solids (TDS) by 70.2% using a syndicate for tannery effluent treatment (Okoduwa et al., 2017). The efficiency of TDS removal increased when the size of fiber particles decreased (100 µm) and when the concentration of EDTA salt increased to reach 78 mg/g of modified bagasse fibers (Rima et al., 2010). Additionally, highlighted the effective separation of suspended and dissolved solids, including sulphates, by cellulose acetate membranes in the treatment of leather effluent (Velu et al., 2015).

Furthermore, evaluated the phytoremediation potential of Eichhornia crassipes and Typha capensis for the removal of TDS from plastic recycling industrial effluent, indicating the potential of plant-based treatment methods (Mudavanhu et al., 2014).

Moreover, the study by emphasized the testing of effluent parameters, including TDS, in electroplating industrial effluents, signifying the significance of monitoring TDS levels in different industrial settings (Singh et al., 2016). Additionally, highlighted the high TDS content in untreated effluents from the batik industry, emphasizing the need for effective treatment methods to reduce TDS levels (Triwiswara et al., 2019). Furthermore, investigated the treatment of TDS from plastic industrial effluent using halophytic plants, indicating the potential of botanical approaches for TDS reduction (Saiyood et al., 2012).

C. Borax Powder Effect on TDS

The effects of borax powder on total dissolved solids (TDS) in effluent treatment plants have been a subject of interest in various studies. Borax has been investigated in different contexts, such as its impact on soil chemical properties and plant growth (Govinda et al., 2021), its use in metallic iron powder preparation (Long et al., 2016), and its application in foliar spray for enhancing the yield and quality of papaya (Kumar et al., 2022).

Additionally, borax has been studied in the reduction-magnetic separation of beach placer Hu et al. (2023) and in the direct laser writing of chitosan-borax composites (Vaughan et al., 2023). These studies provide insights into the diverse applications of borax and its potential effects on various environmental and industrial processes.

Furthermore, the literature includes research on the treatment of different types of effluents using various substances, such as Azadirachta Indica powder (Devi et al., 2021), yeast species isolates (Okoduwa et al., 2017), and synthetic resin effluent (Dahunsi & Oranusi et al., 2012). These studies have reported changes in physico-chemical properties, including TDS, as a result of effluent treatment. For instance, Abioye et al. observed a decline in TDS during the treatment of textile effluents using different microorganisms (Izah et al., 2017). Moreover, the impact of effluent treatment on TDS has been highlighted in studies assessing the removal of organic pollutants from textile mill effluents Izah et al. (2017) and the behavior, fate, and mass loading of short-chain chlorinated paraffins in wastewater treatment plants (Zeng et al., 2013).

In addition, the influence of effluent treatment on TDS has been investigated in the context of wastewater treatment plants. Studies have shown that the treatment process can lead to a decrease in TDS levels in effluent water compared with raw sewage amounts (Baharvand & Daneshvar et al., 2019). Moreover, the evaluation of a hybrid moving bed biofilm membrane bioreactor and a direct contact membrane distillation system for the purification of industrial wastewater emphasized the levels of TDS in effluents (Alharthi et al., 2022).

D. Importance of Multi – Effect Evaporator

The use of Multi-Effect Evaporator (MEE) systems in effluent treatment plants has been a subject of extensive research due to its potential impact on the reduction of total dissolved solids (TDS) in effluent. Multiple studies have highlighted the energy-intensive nature of MEE systems (Sharan & Bandyopadhyay, 2016), emphasizing the need for optimization to improve energy efficiency (Bo et al., 2019). Furthermore, the use of MEE with mechanical vapor recompression (MVR) has been identified as a promising alternative for wastewater treatment, with a lower environmental impact compared to single-effect evaporation (Ogletree et al., 2022). Additionally, the performance of thermal vapor compressors in low-temperature multi- effect evaporation (LT-MEE) desalination plants has been found to significantly influence energy efficiency and the gained output ratio (Ren et al., 2022).

Moreover, the potential of MEE systems to concentrate solutions has been recognized in various industries, including the pulp and paper industry (Kim et al., 2021).

The application of MEE in the treatment of pharmaceutical effluents has been explored, demonstrating its effectiveness in solids recovery and achieving zero-liquid discharge (Periyannan et al., 2022).

Furthermore, the economic feasibility of MEE for desalination has been investigated, highlighting its cost-effectiveness compared to other desalination processes (Alenezi et cl., 2021).

Effluent treatment processes involving MEE have also been associated with the reduction of total suspended solids (TSS) and TDS in industrial wastewater (Alharthi et al., 2022; Girish et al., 2014). Additionally, the treatment of raw sewage using advanced municipal sewage treatment plants has been shown to impact the mass loading of TDS in effluent water (Zeng et al., 2013). Furthermore, the use of aerobic microbial reactors has been found to effectively reduce particulate-bound solids and solubilize nutrients in recirculating aquaculture system (RAS) effluent, potentially influencing TDS levels in effluent (Tetreault et al., 2021; Tetreault et al., 2021).

E. Importance & uses of Vetiver Root

Vetiver roots have been studied for their potential in reducing total dissolved solids (TDS) in effluent treatment plants. The literature provides insights into the use of vetiver roots for phytoremediation purposes. Mahmoudpour et al. (2021) evaluated the phytoremediation potential of vetiver grass for wastewater treatment and found that lead concentration in vetiver roots is considered toxic if it exceeds 30 ppm. Additionally, Hasan et al. (2017) demonstrated the greater removal of heavy metals such as Cu, Fe, Mn, Pb, and Zn with greater root length and higher density of vetiver grass, which increased the surface area for metal absorption by plant roots from contaminated water. Furthermore, Qiu et al. (2021) studied the dose-effect relationship of water salinity levels on vetiver and found that the S K / Na ratio was higher in all treatments, indicating NaCl tolerance in vetiver, which may contribute to reducing TDS in effluent treatment plants.

In addition to the phytoremediation potential, the literature also provides information on the physical properties of vetiver roots. For instance, Dahaan et al. (2016) studied the influence of groundwater hypothetical salts on electrical conductivity and TDS, indicating that the estimations of TDS content are based on electrical conductivity measurements. Moreover, Teerawattanasuk et al. (2014) found that vetiver roots contributed higher components of shear strength compared to other grasses, indicating the potential for vetiver roots to withstand environmental pressures, which is relevant for their application in effluent treatment plants.

F. Importance & uses of Gooseberry Bark

To investigate the impact of gooseberry bark on total dissolved solids (TDS) in an Effluent Treatment Plant (ETP), it is essential to consider the potential health-promoting effects of dietary proanthocyanidins (PACs) found in gooseberry bark (Cires et al., 2017). PACs have been shown to have varying levels in different sources, with black gooseberry PACs having an average DP of 48, while wine and beer PACs have significantly lower levels (Cires et al., 2017). Additionally, the addition of carrageenan has been found to elevate total dissolved solids, indicating the potential for additives to impact TDS levels (Arganis et al., 2018).

Effluent treatment involves the reduction of various parameters, including TDS, in the effluent. Studies on the biotreatment of sugar industry effluent have shown a gradual reduction in TDS after treatment with specific tank cleaners, indicating the potential for certain treatments to impact TDS levels (Karthiga et al., 2019). Furthermore, the use of low effluent nutrient technologies has been explored to achieve lower TDS levels in wastewater treatment plants (Pagilla et al., 2006).

In the context of effluent treatment, the relationship between TDS and electrical conductivity (EC) is crucial. The estimation of TDS content is often based on EC measurements, highlighting the importance of monitoring EC to assess TDS levels (Dahaan et al., 2016). Additionally, the impact of water quality on health, specifically in relation to chronic kidney disease, has been linked to TDS levels, further emphasizing the significance of managing TDS in effluent (Gobalarajah et al., 2020).

Effluent treatment processes can also be influenced by the presence of emulsified organic phases, which can impact the toxicity and malodorousness of the effluent, underscoring the need to consider various factors that may affect effluent quality, including TDS levels (Boczkaj et al., 2014). Moreover, the evaluation of effluent treatment by different species of aquatic macrophytes has shown improvements in effluent quality, indicating the potential for natural processes to impact TDS levels in effluent (Cani et al., 2013).

G. Importance & uses of Lemon Peel

To investigate the impact of lemon peel on total dissolved solids (TDS) in an Effluent Treatment Plant (ETP), it is essential to consider the potential of lemon peel as a treatment agent for effluent. Lemon peel has been studied for its bioactive compounds, including pectic oligosaccharides (Gómez et al., 2013), essential oils (Rienoviar, 2023), and antioxidant activity (Terzioğlu & Sıcak et al., 2021). These compounds have been found to possess properties such as antibacterial and antioxidant activities, which could potentially contribute to the treatment of effluent. Additionally, lemon peel is known to contain bioactive compounds such as essential oils, flavonoids, phenolic compounds, and vitamins, which are potent natural antioxidants (Terzioğlu & Sıcak et al., 2021). Furthermore, the addition of lemon peel and pulp extract has been shown to affect the qualities and shelf life of meat, indicating its potential impact on organic matter in effluent (Hamma et al., 2020).

Effluent treatment involves the reduction of various physico-chemical parameters, including TDS, total suspended solids, and total alkalinity (Karthiga et al., 2019). The reduction of these parameters is crucial for improving effluent quality. Moreover, the presence of total dissolved solids in water has been linked to its impact on water quality and human health, as it can influence serum creatinine levels (Gobalarajah et al., 2020). Therefore, the potential of lemon peel in reducing TDS in effluent could have significant implications for water quality and environmental health.

It is also important to consider the methods for measuring TDS in water. The estimation of TDS content is commonly based on electrical conductivity (EC) measurements (Dahaan et al., 2016).

Additionally, the quantification of TDS in water can be carried out using standard solutions and expressed in units of ppm (Arganis et al., 2018). These methods are crucial for accurately assessing the impact of lemon peel on TDS in effluent.

H. Importance & uses Peanut Husk

To investigate the potential of peanut husk in reducing total dissolved solids (TDS) in effluent treatment plants, it is essential to consider the effectiveness of various agricultural waste materials in effluent treatment. The study by Abioye et al. demonstrated a decline in TDS during the treatment of textile effluents using different yeast species (Izah et al., 2017). Additionally, the study by highlighted the reduction of TDS by yeast species isolates from watermelon in tannery effluent treatment (Okoduwa et al., 2017). Furthermore, the research by emphasized the high levels of TDS in treated effluent, indicating the need for effective treatment methods (Rajkumar et al., 2016). These studies collectively underscore the significance of exploring alternative materials for effluent treatment, such as peanut husk.

Moreover, the study by showcased the potential of peanut husks in removing heavy metals through adsorption, indicating its capacity for treating effluents (Ricordel et al., 2001). Additionally, investigated the ability of peanut husks to remove nickel ions from aqueous solutions, further highlighting its adsorption capabilities (Burevska et al., 2017). These findings suggest that peanut husk has the potential to effectively reduce TDS in effluent treatment by adsorbing heavy metals and other dissolved solids.

Furthermore, the study by provided insights into the large quantities of peanut husks produced annually, indicating its availability as a potential resource for effluent treatment (Li et al., 2021). Additionally, the research by demonstrated the preparation of activated carbon from peanut husk, which could be utilized for TDS removal due to its adsorption properties (Abadir et al., 2018).

III. METHODOLOGY

A. Research Area/Method

This research investigates the effectiveness of various softening techniques in treating high Total Dissolved Solids (TDS) wastewater in Andhra Pradesh, India. The study will be conducted across five locations (Vijayawada, Rajahmundry, Bapatla, Nellore, and Rangampeta) within the state.

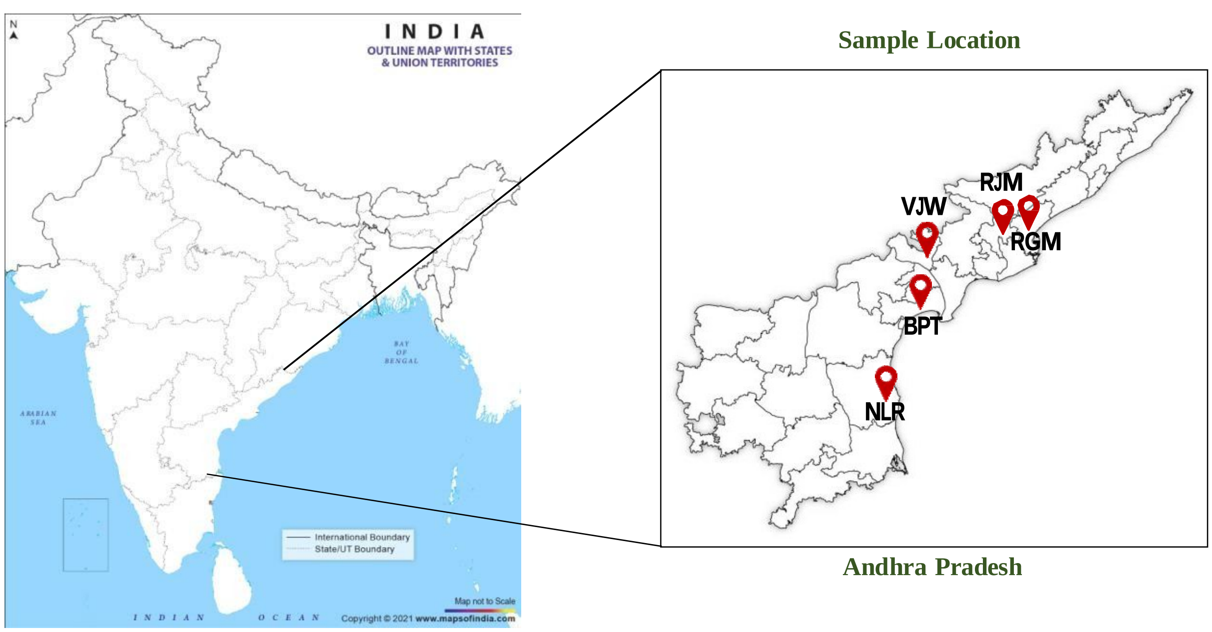

Figure 1: Water sample collection sites in Andhra Pradesh, India

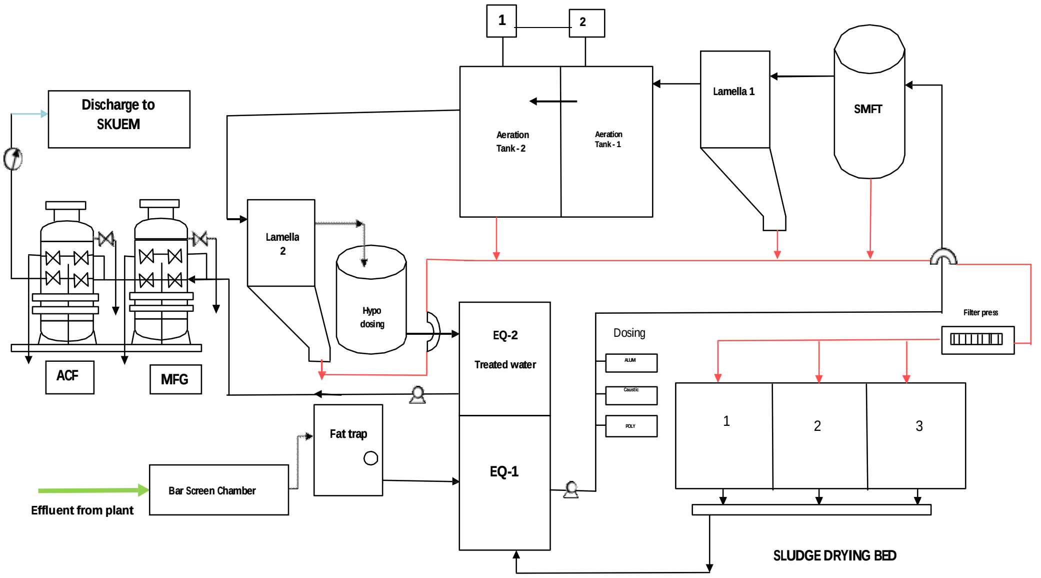

Figure 2: Vijayawada Location ETP PFD Drawing

Methods:
The research will employ a pre-experiment data collection phase followed by two main experiments.

B. Process of Sampling

Two water samples were collected for analysis:

- Boiler Blowdown: A sample was obtained directly from the boiler blowdown pipe. It's important to note that this sample was allowed to cool to room temperature before any testing commenced.
- RO Reject: The RO reject sample was taken from a location near the equalization tank.

Both samples were collected in clean, 5-liter cans. These cans were made of polyethylene. After collection, the samples were properly labelled with the source (boiler blowdown or RO reject), date, and time of collection. At the end the samples were stored at room temperature.

Figure 3: (a) RO Reject Sample Collection, (b) Boiler Blowdown Sample Collection

C. Pre-experiment Data Collection

Standard methods as specified by IS: 3025 will be used to measure the following parameters in the wastewater samples:

- Hardness: EDTA Titrimetric Method (IS: 3025 (Part 21)
- Chloride: Argentometric Method (IS: 3025 (Part 32))
- pH: Electrometric Method (IS: 3025 (Part 11))
- Turbidity: Nephelometric Method ((IS: 3025 (Part 10))
- Magnesium: Atomic Absorption Spectrophotometric Method
- TDS: Gravimetric Method

Hardness:

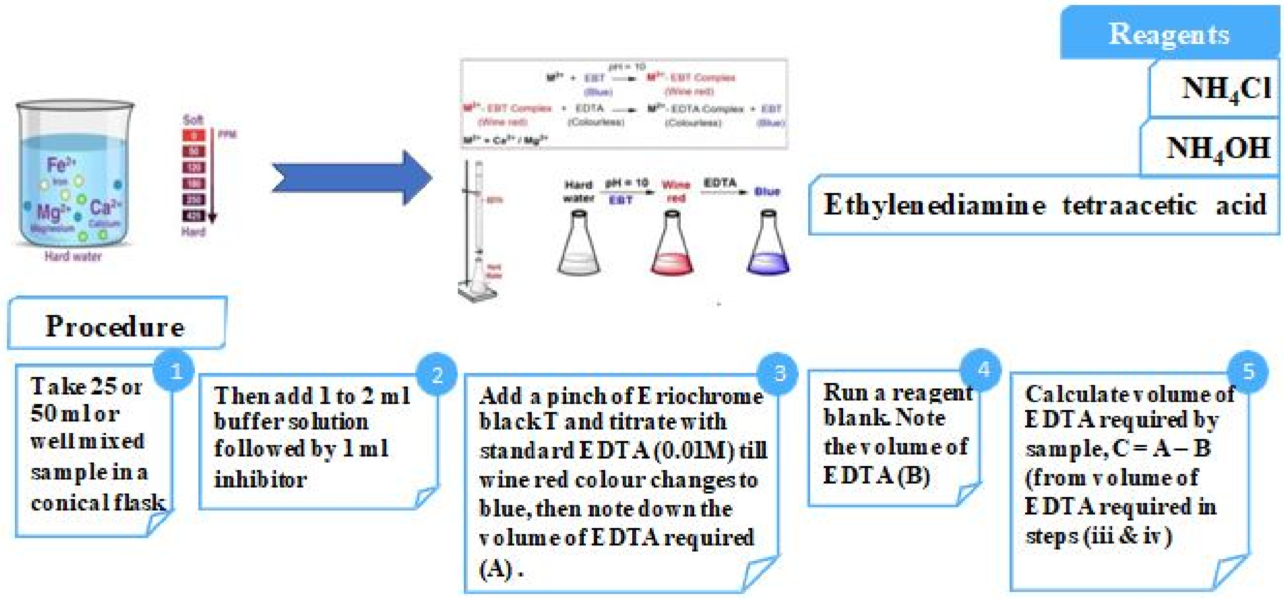

Figure 4: Method to identify Hardness (EDTA Method)

EDTA Method is used to measure the amount of hardness present in the water.

Chloride:

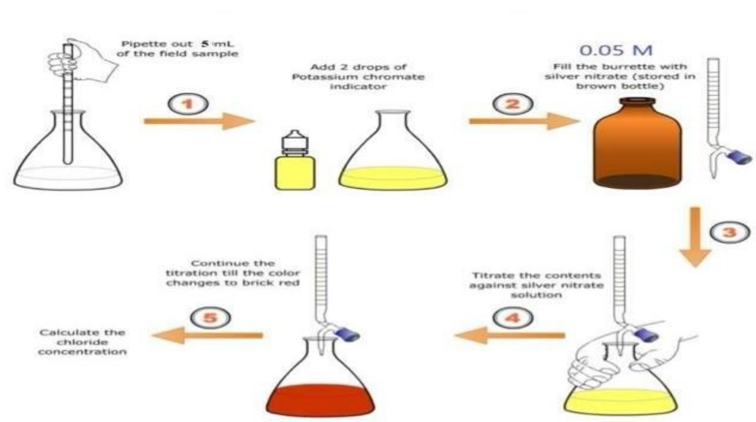

Figure 5: Method to identify Chloride (Argentometric Method)

Argentometric Method is used to measure the amount of Chloride present in water

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pH:

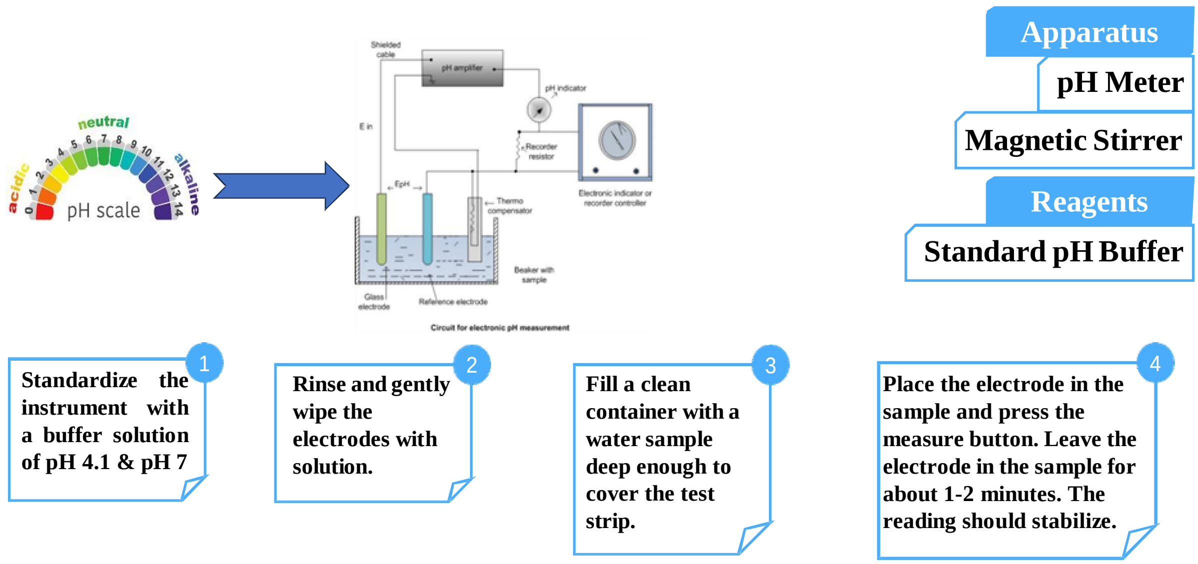

Figure 6: Method to identify pH (Electrometric Method)

Electrometric Method is to quantify pH in water

Turbidity:

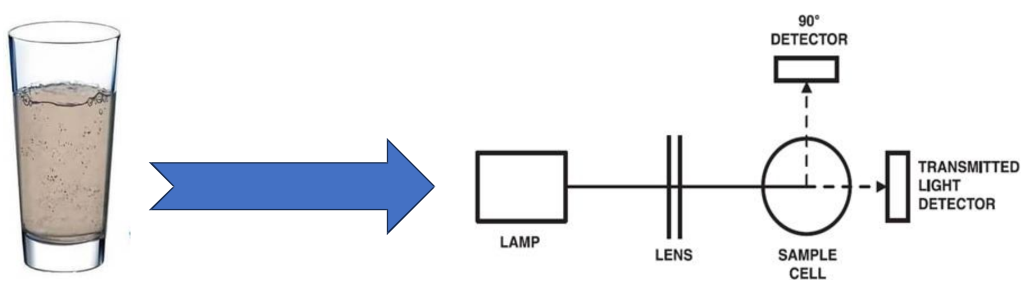

Figure 7: Method to identify Turbidity (Nephelometric Method)

Nephelometric Method is used to quantify Turbidity.

D. Analysis using Sodium Citrate, Sodium Sulphate & Sodium EDTA Solution:

Filteration using 0.45 µm Filter Paper to remove Suspended solids

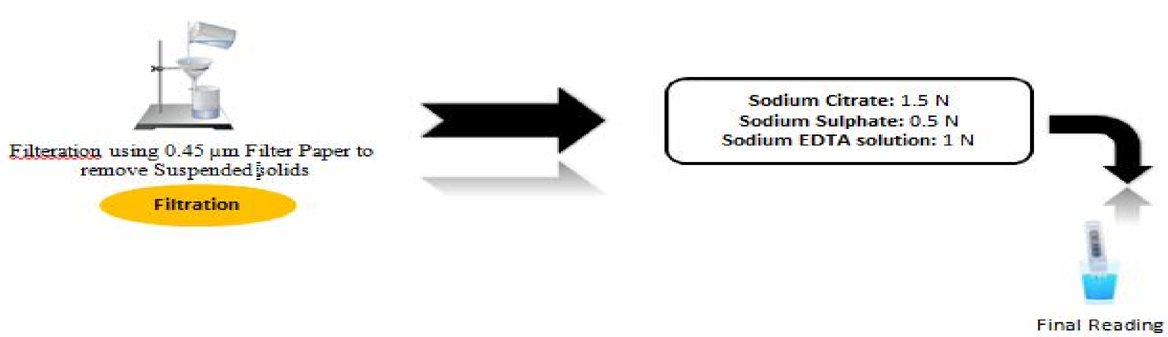

Figure 8: Procedure for conducting Sodium Citrate, Sodium Sulphate, Sodium EDTA Solution to reduce Total Dissolved Solids

Materials:
- RO Reject Water (250 mL)
- Boiler Blowdown Water (750 mL)
- TDS meter
- Beaker or graduated cylinder (1 L)
- Smaller beakers or flasks (for mixing the chemical solution)
- Sodium Citrate (1.5N solution)
- Sodium Sulphate (0.5N solution)
- Sodium EDTA Solution (1N solution)

Procedure:
1. Prepare the 1L solution:
   - Combine 250 mL of RO Reject Water and 750 mL of Boiler Blowdown Water in the 1 L beaker or graduated cylinder.
   - Stir the solution well to ensure it's evenly mixed.
2. Measure the initial TDS:
   - Use the TDS meter to measure the TDS of the 1 L solution.
   - Record the reading.
3. Prepare the chemical solution (5 mL):
   - Wear gloves and safety glasses while handling chemicals.
   - Using the smaller beakers or flasks, carefully measure:
     - 0.75 mL of Sodium Citrate (1.5N solution)
     - 1.25 mL of Sodium Sulphate (0.5N solution)
     - 1.25 mL of Sodium EDTA Solution (1N solution)
     - Combine these measured volumes in a separate beaker or flask.
     - You can add some distilled water to the solution to reach exactly 5 mL, but the contribution of TDS from this small amount of water is negligible.
4. Measure the final TDS:
   - Add the prepared 5 mL chemical solution to the 1 L solution from step 1.
   - Stir the combined solution well.
   - Use the TDS meter again to measure the TDS of the solution after adding the chemicals.
   - Record the reading.
5. Compare the results:
   - Subtract the initial TDS reading (from step 2) from the final TDS reading (from step 4).
   - This value represents the change in TDS after adding the chemicals.

E. Analysis using Borax Powder

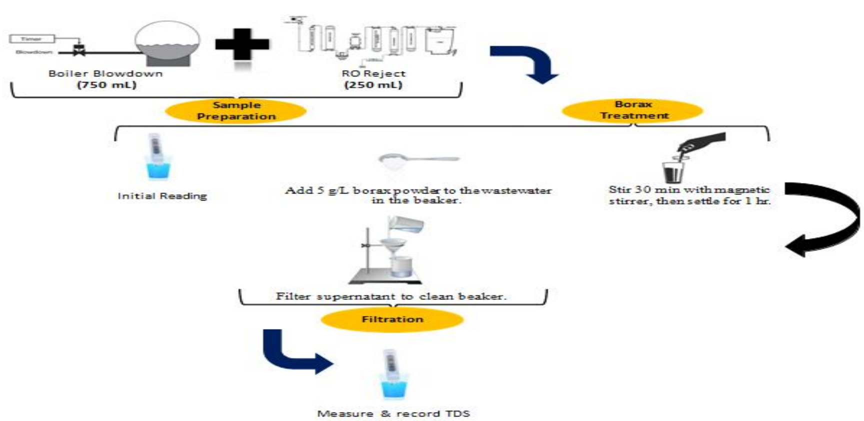

Figure 9: Procedure to reduce Total Dissolved Solids using Borax Powder

Materials:

- •RO Reject Water (250 mL)
- •Boiler Blowdown Water (750 mL)
- •TDS meter
- •Beaker or graduated cylinder (1 L)
- •Spoon or stirrer
- •Borax powder (5g)

Procedure:

1. Prepare the 1L solution:
   - Combine 250 mL of RO Reject Water and 750 mL of Boiler Blowdown Water in the 1 L beaker or graduated cylinder.
   - Stir the solution well to ensure it's evenly mixed.
2. Measure the initial TDS:
   - Use the TDS meter to measure the TDS of the 1 L solution.
   - Record the reading.
3. Add Borax powder:
   - Wear gloves and safety glasses (optional, but recommended for handling chemicals).
   - Using the spoon, carefully add 5g of Borax powder to the 1 L solution.
4. Stir and dissolve Borax:
   - Stir the solution continuously for a few minutes to allow the Borax powder to dissolve completely.
   - Make sure there are no undissolved particles remaining.
5. Measure the final TDS:
   - Use the TDS meter again to measure the TDS of the solution after adding the Borax powder.
   - Record the reading.
6. Compare the results:
   - Subtract the initial TDS reading (from step 2) from the final TDS reading (from step 5).
   - This value represents the change in TDS after adding Borax powder.

F. Analysis using Multi – Effect Evaporator:

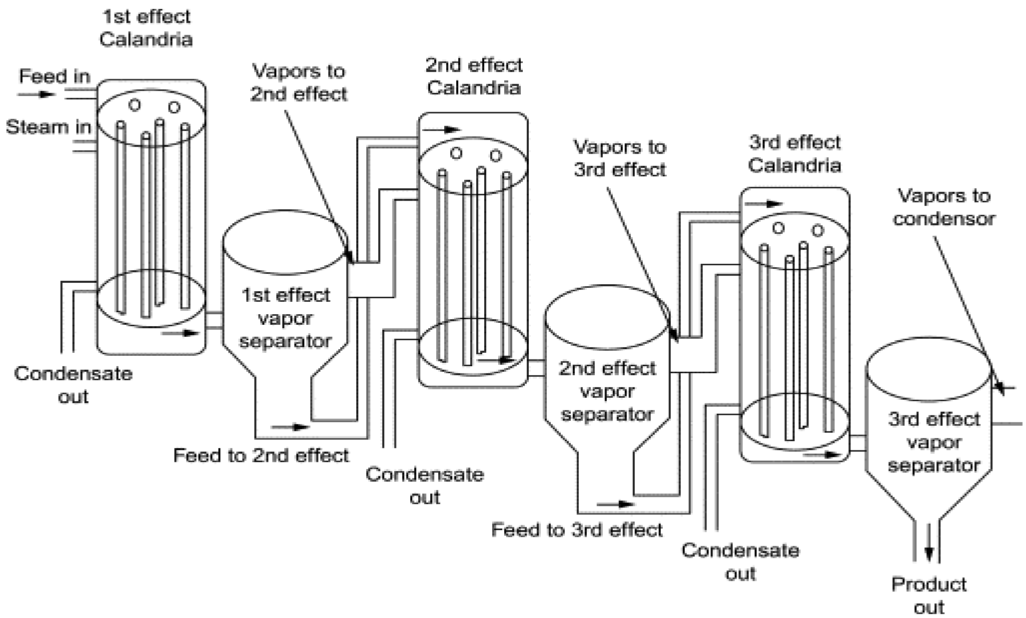

Figure 10: Drawing of Multi Effect Evaporator

Materials:
- Multi-Effect Evaporator (MEE) unit
- 1 Liter container
- TDS meter

Procedure:
1. Pre-treatment: Depending on the initial water quality and the specific MEE design, pre-treatment steps might be necessary. This could involve processes like filtration, coagulation, or softening to remove suspended solids or undesired ions that could hinder the MEE's performance (Hanamapure et al., 2016).
2. Feed Solution Preparation:
    - Fill the 1-liter container with the water requiring TDS reduction.
    - Measure the initial TDS of the water using the TDS meter. Record this value.
3. MEE Operation:
    - Following the manufacturer's instructions, carefully operate the MEE unit.
    - Feed the 1 liter of water into the MEE's first effect (the chamber with the highest pressure).
    - The heat source (e.g., steam) in the MEE will cause the water to evaporate, leaving behind a concentrated brine solution with higher TDS. The vapor, containing relatively pure water, will be transferred to subsequent effects at lower pressures.
    - In each effect, the vapor from the previous effect acts as the heating source for the current effect, utilizing latent heat for further evaporation, making the MEE an energy-efficient process (Karnena & Bhargava, et. al., 2013).
4. Sample Collection and TDS Measurement:
    - Once the evaporation process is complete, collect a sample of the distillate (the purified water vapor condensed) from the final effect of the MEE.
    - Measure the TDS of the distillate using the TDS meter. Record this final TDS value.

Data Analysis:
% Reduction in TDS = [(Initial TDS - Final TDS) / Initial TDS] x 100

G. Analysis using Vetiver Root

Figure 11: Visual representation of vetiver roots

Materials
- Vertical glass column
- Vetiver grass roots (dried and cleaned)
- Reservoir for hard water (capacity > 1 L)
- Tubing (appropriate size for flow rate)
- Flowmeter (optional)
- Collection container (capacity > 1 L)

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Preparation:

1. Vetiver Root Packing:
   - Dry and clean the vetiver grass roots thoroughly.
   - Pack the glass column with the vetiver roots to a desired density. The density may affect treatment efficiency and needs to be optimized based on initial experiments.
2. System Setup:
   - Connect the reservoir containing the hard water to the top of the glass column using the tubing.
   - Ensure a secure connection to prevent leaks.
   - Place the flowmeter (optional) in the line between the reservoir and the column if you want to precisely monitor the flow rate.
   - Connect the bottom of the glass column with tubing leading to the collection container.

Treatment Process:

1. Water Flow Initiation:
   - Open the valve on the reservoir to start the flow of hard water through the column.
   - Adjust the flow rate to maintain a steady stream of approximately 10 mL per minute. You can use the flowmeter to achieve this precisely. (Ebrahim et al., 2011)
2. Treatment Duration:
   - Allow 1 liter of hard water to pass through the vetiver root column. The optimal treatment duration may need to be determined based on initial tests to ensure effective removal of hardness minerals.
3. Sample Collection:
   - Once 1 liter of water has passed through the column, collect the treated water from the collection container.

H. Analysis using Gooseberry Bark

Figure 12: Visual representation of gooseberry bark

Materials:

•Gooseberry bark (dried and crushed)
•Glass columns (capable of holding 1 liter)
•Filter material (e.g., gravel, sand) for column base (optional)
•Reservoir for hard water (capacity > 1 liter)
•Tubing and connectors for water flow
•Flow meter or graduated cylinder for monitoring flow rate
•Sample collection containers
•Water hardness test kit (or appropriate analytical method)

Preparation:

1. Gooseberry Bark Preparation:
   - Obtain dried gooseberry bark and crush it into a coarse powder. Avoid excessively fine particles that might impede water flow.
2. Column Set-up:
   - Place a layer of filter material (e.g., gravel, sand) at the bottom of the glass column to prevent clogging and ensure even water distribution.
   - Pack the crushed gooseberry bark into the column, ensuring minimal air gaps while allowing water flow.
   - Secure the top of the column with a material like cheesecloth to prevent bark material from washing out.
3. Water Reservoir Preparation:
   - Fill the reservoir with the hard water to be treated.
4. Flow System Set-up:
   - Connect the reservoir to the top of the column using tubing and connectors.
   - Include a flow meter or a graduated cylinder at the column outlet to monitor the flow rate of water passing through the gooseberry bark. (Vatchalan, L. et. al 2022)

Treatment Process:

1. Treatment Initiation:
   - Adjust the flow rate to 10 ml per minute using the flow meter or by collecting and measuring the volume of water exiting the column in a specific time interval.
2. Sample Collection:
   - Collect water samples from the column outlet at predetermined time intervals (e.g., every 30 minutes, 1 hour) throughout the desired treatment duration.
3. Treatment Termination:
   - Once the treatment period is complete, stop the water flow and carefully remove the gooseberry bark from the column for further analysis (optional).

Analysis:

1. Water Hardness Measurement:
   - Use the water hardness test kit or appropriate analytical method to measure the hardness of the collected water samples.
2. Data Analysis:
   - Compare the initial hardness of the influent water (hard water) with the hardness values obtained from the collected samples to assess the effectiveness of gooseberry bark in reducing water hardness.

I. Analysis using Lemon Peel

Figure 13: Visual representation of lemon peel

Materials:

- Lemon peels (dried and crushed)
- Glass columns (capable of holding 1 liter)
- Filter material (e.g., gravel, sand) for column base (optional)
- Reservoir for hard water (capacity > 1 liter)
- Tubing and connectors for water flow
- Flow meter or graduated cylinder for monitoring flow rate
- Sample collection containers
- Water hardness test kit (or appropriate analytical method)

Preparation:

- Lemon Peel Preparation:
  - Wash lemons thoroughly and remove the peels. Dry the peels completely in a well-ventilated area or oven at a low temperature to prevent mold growth.
  - Once dry, crush the peels into a coarse powder. Avoid excessively fine particles that might impede water flow.
- Column Set-up:
  - Place a layer of filter material (e.g., gravel, sand) at the bottom of the glass column to prevent clogging and ensure even water distribution.
  - Pack the crushed lemon peel into the column, ensuring minimal air gaps while allowing water flow.
  - Secure the top of the column with a material like cheesecloth to prevent bark material from washing out.
- Water Reservoir Preparation:
  - Fill the reservoir with the hard water to be treated.
- Flow System Set-up:
  - Connect the reservoir to the top of the column using tubing and connectors.
  - Include a flow meter or a graduated cylinder at the column outlet to monitor the flow rate of water passing through the lemon peel.

Treatment Process:

- Treatment Initiation:
  - Adjust the flow rate to 10 ml per minute using the flow meter or by collecting and measuring the volume of water exiting the column in a specific time interval.
- Sample Collection:
  - Collect water samples from the column outlet at predetermined time intervals throughout the desired treatment duration.
- Treatment Termination:
  - Once the treatment period is complete, stop the water flow and carefully remove the lemon peel from the column for further analysis.

Analysis:

- Water Hardness Measurement:
  - Use the water hardness test kit or appropriate analytical method to measure the hardness of the collected water samples.
- Data Analysis:
  - Compare the initial hardness of the influent water (hard water) with the hardness values obtained from the collected samples to assess the effectiveness of lemon peel in reducing water hardness.

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J. Analysis using Peanut Husk

Figure 14: Visual representation of peanut husk

Materials:

- •Peanut husks (dried and crushed)
- •Glass columns (capable of holding 1 liter)
- •Sand Filter material for column base
- •Reservoir for hard water (capacity > 1 liter)
- •Tubing and connectors for water flow
- •Flow meter or graduated cylinder for monitoring flow rate
- •Sample collection containers
- •Water hardness test kit

Preparation:

- Peanut Husk Preparation:
  - Obtain dry peanut husks and crush them into a coarse powder. Avoid excessively fine particles that might impede water flow.
- Column Set-up:
  - Place a layer of filter material (e.g., gravel, sand) at the bottom of the glass column to prevent clogging and ensure even water distribution.
  - Pack the crushed peanut husk into the column, ensuring minimal air gaps while allowing water flow.
  - Secure the top of the column with a material like cheesecloth to prevent husk material from washing out.
- Water Reservoir Preparation:
  - Fill the reservoir with the hard water to be treated.
- Flow System Set-up:
  - Connect the reservoir to the top of the column using tubing and connectors.
  - Include a flow meter or a graduated cylinder at the column outlet to monitor the flow rate of water passing through the peanut husk.
  - Treatment Process:
- Treatment Initiation:
  - Adjust the flow rate to 10 ml per minute using the flow meter or by collecting and measuring the volume of water exiting the column in a specific time interval.
- Sample Collection:
  - Collect water samples from the column outlet at predetermined time intervals throughout the desired treatment duration.

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- Treatment Termination:
  - Once the treatment period is complete, stop the water flow and carefully remove the peanut husk from the column for further analysis (optional).
  - Analysis:
- Water Hardness Measurement:
  - Use the water hardness test kit or appropriate analytical method to measure the hardness of the collected water samples. (Singh, S et al., 2011).

IV. RESULTS & DISCUSSION

A. Results from Pre Experiment Data

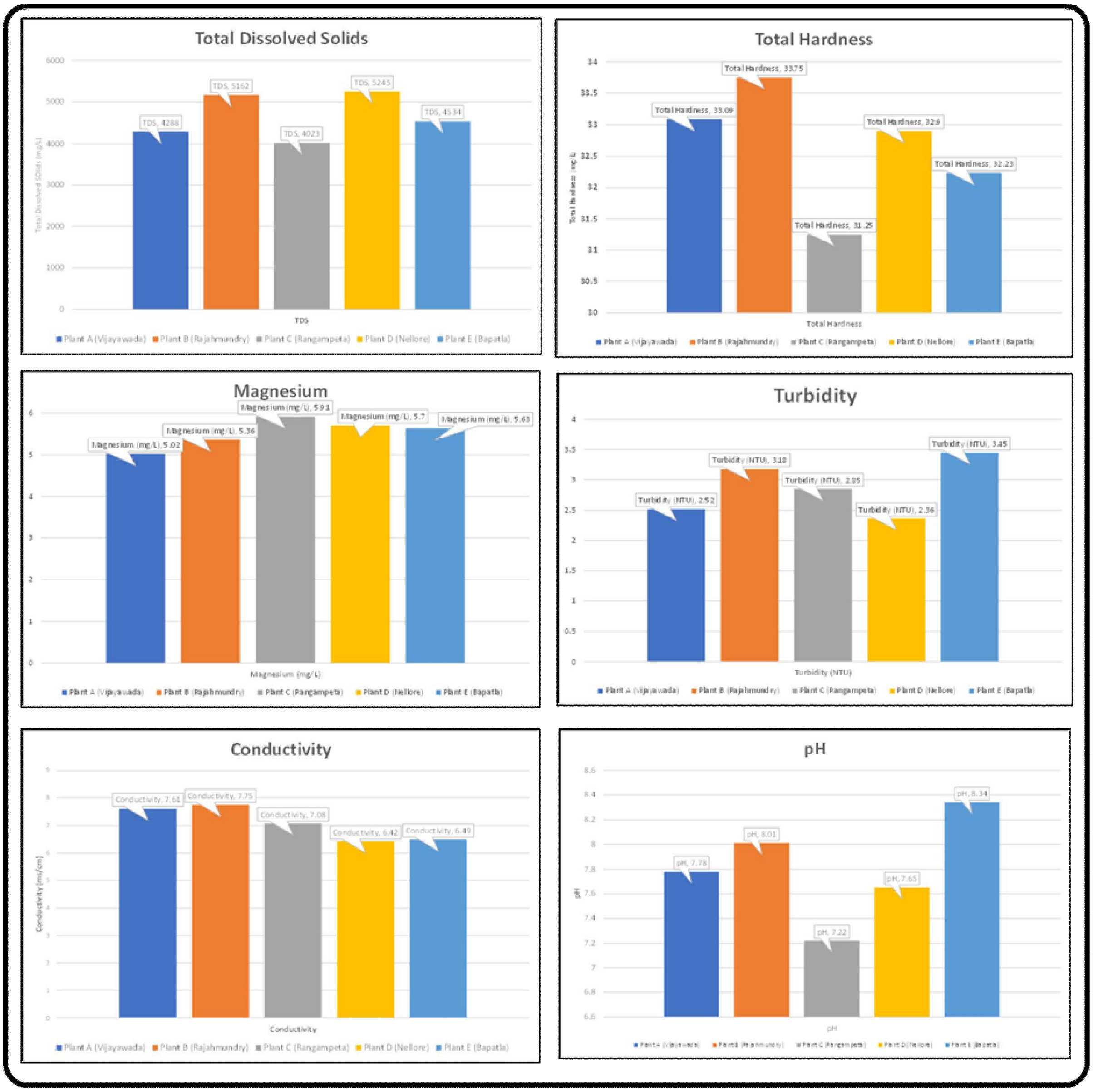

Figure 15: Graphical Representation of Pre - Experiment Result

B. Blank Solution Results

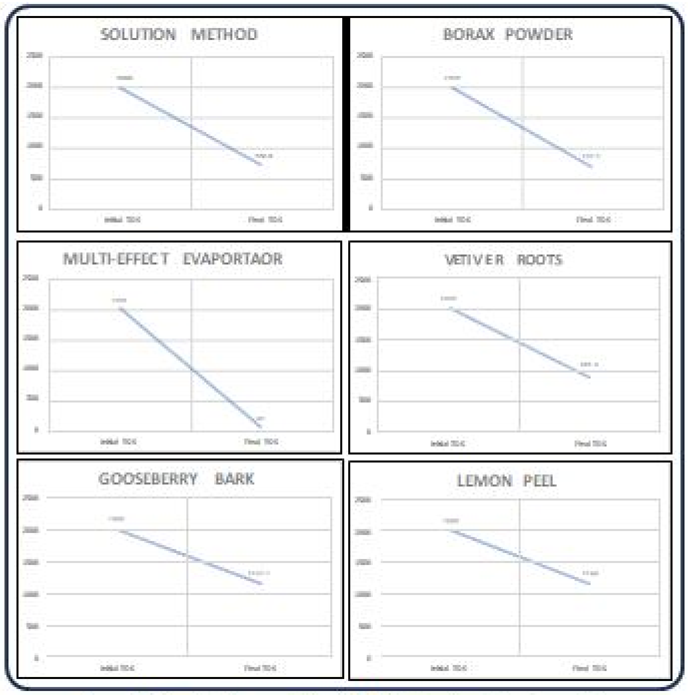

Figure 16: Graphical Representation of Blank Solution for all the given method

C. Results from Borax Powder Experiment

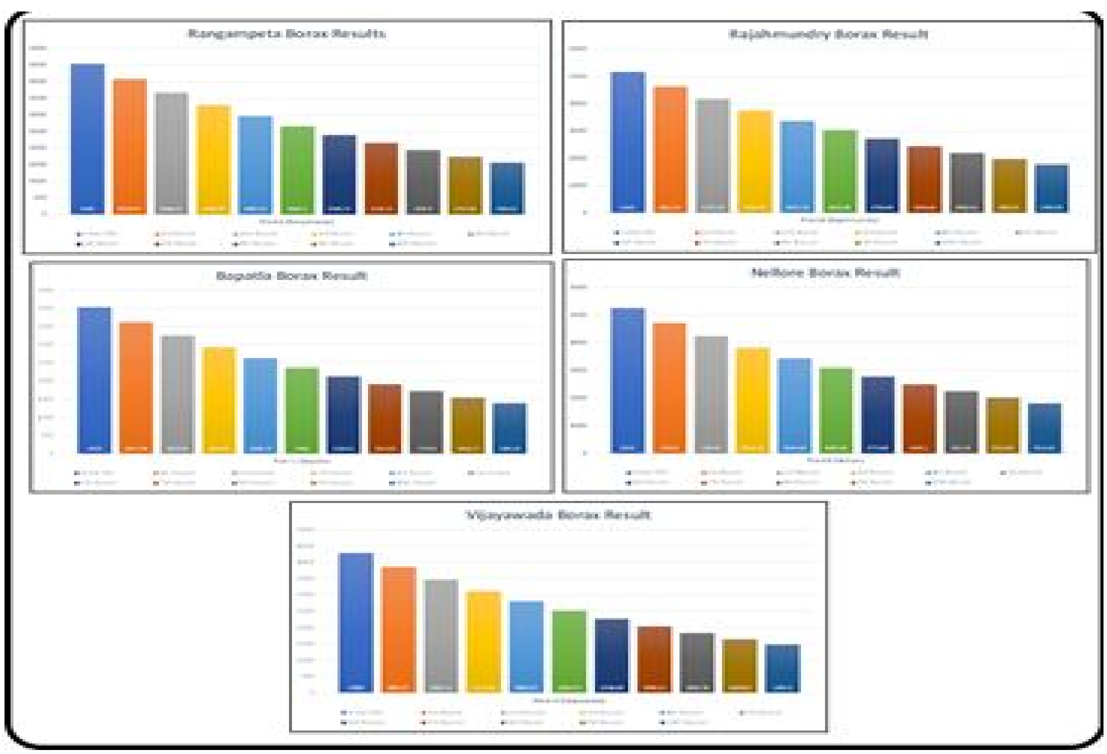

Figure 17: Graphical Representation of Borax Result for Day 1

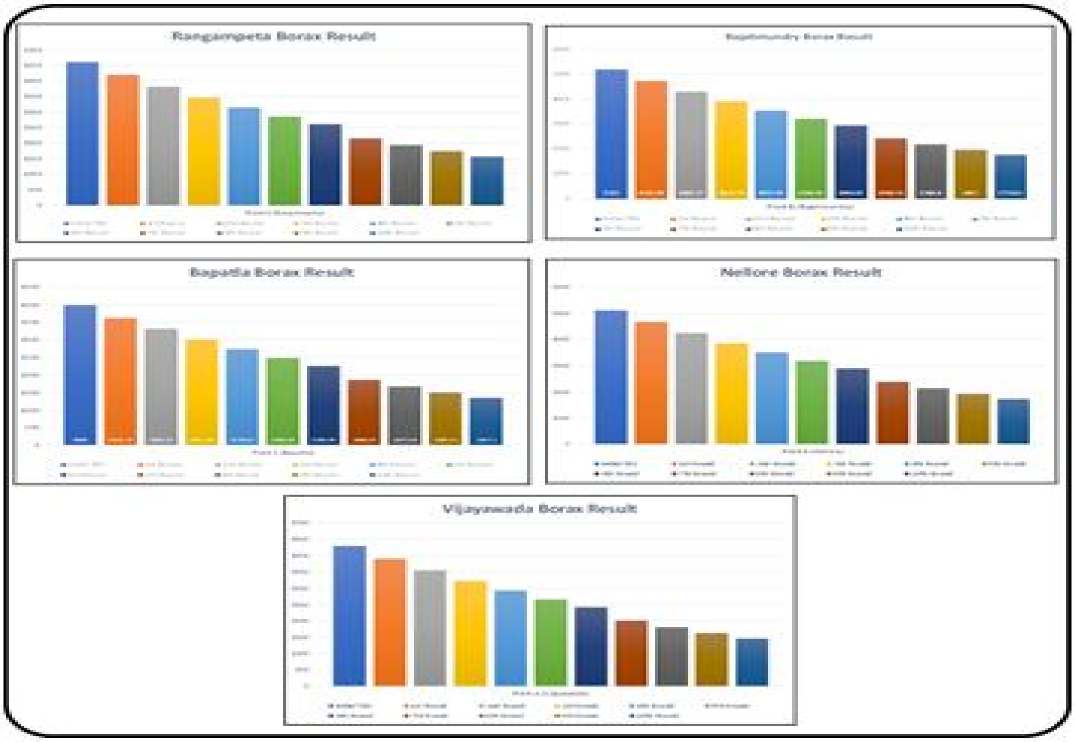

Figure 18: Graphical Representation of Borax Result for Day 2

The addition of 5g of borax powder resulted in a total dissolved solids (TDS) reduction rate of 65.37%. These results suggest that borax powder can be an effective agent in reducing total dissolved solids (TDS) in water. A reduction of 65.37% is significant and could have important implications for a variety of applications, such as wastewater treatment and desalination. Further research is needed to determine the optimal dosage of borax powder for different water qualities and to investigate the potential mechanisms by which borax reduces TDS.

D. Results from Sodium Citrate, Sodium Sulphate & Sodium EDTA Solution Experiment

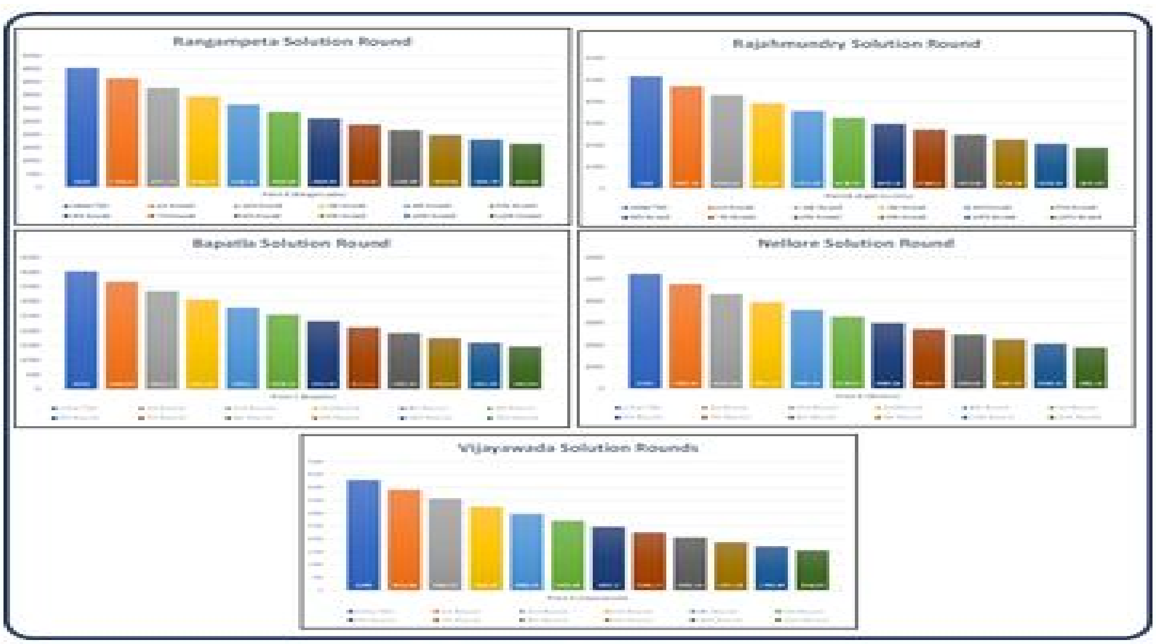

Figure 19: Graphical Representation of Sodium Citrate, Sodium Sulphate & Sodium EDTA solution Result for Day 1

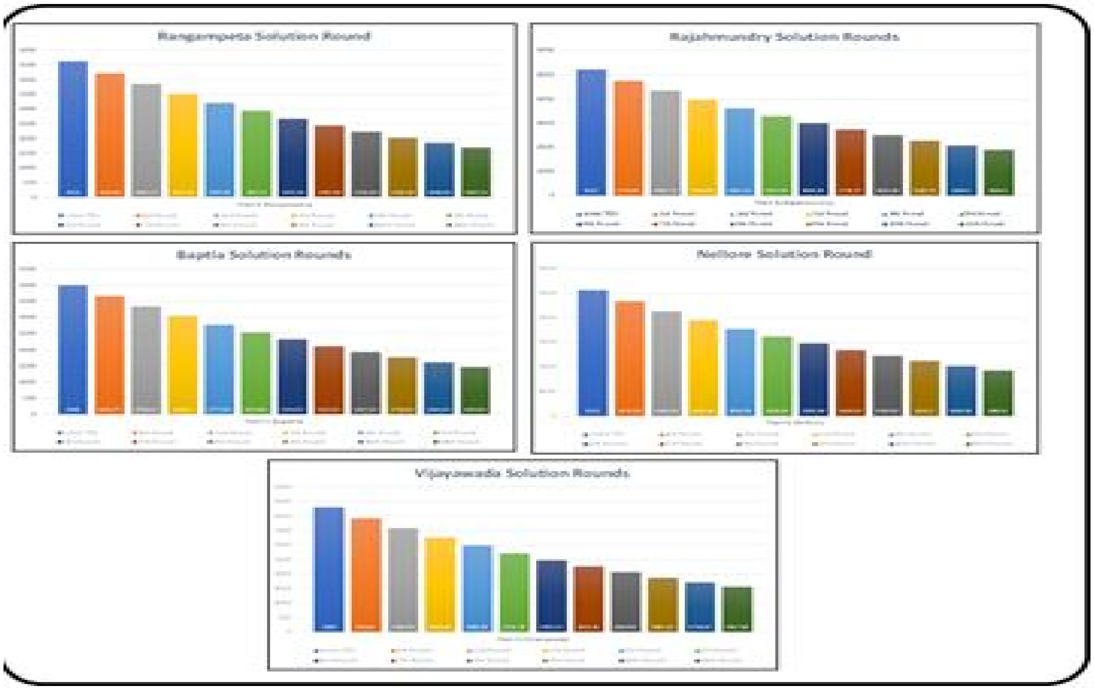

Figure 20: Graphical Representation of Sodium Citrate, Sodium Sulphate & Sodium EDTA solution Result for Day 2

The experiment observed that 5ml of a solution containing Sodium Citrate, Sodium Sulphate, and Sodium EDTA resulted in a total dissolved solids (TDS) reduction rate of 63.66%. This finding suggests that the combination of these three chemicals can be effective in reducing the total dissolved solids (TDS) in a solution. Further studies are needed to determine the optimal dosage and application conditions for this treatment method. It is also important to investigate the potential mechanisms by which these chemicals reduce TDS.

E. Results from Multi – Effect Evaporator Experiment

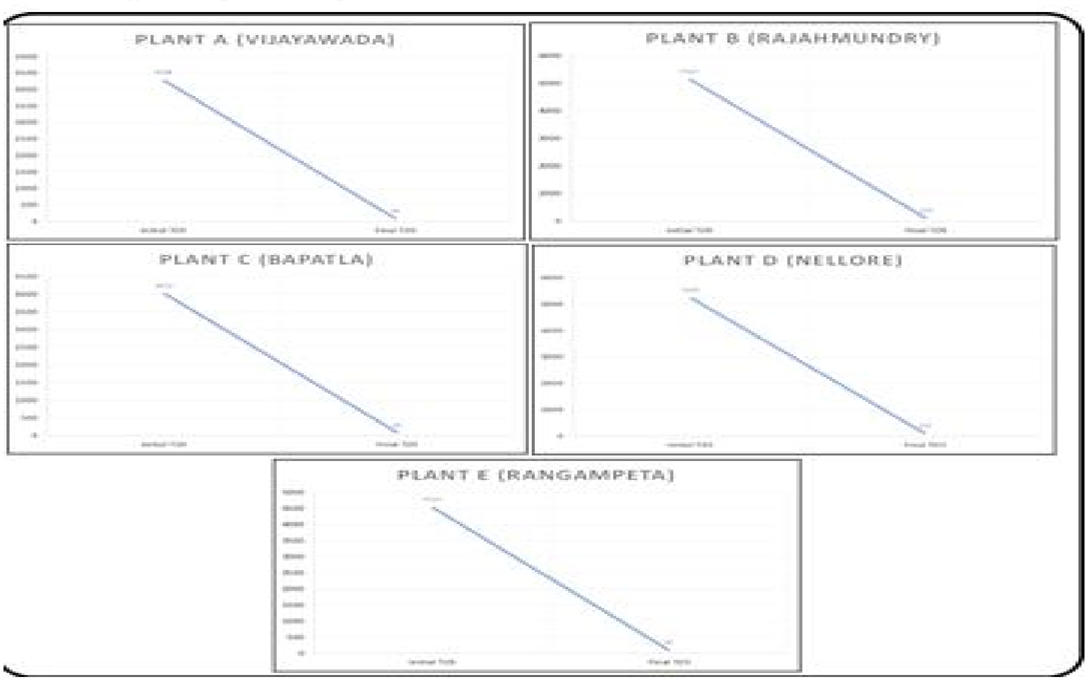

Figure 21: Graphical Representation of MEE Result for Day 1

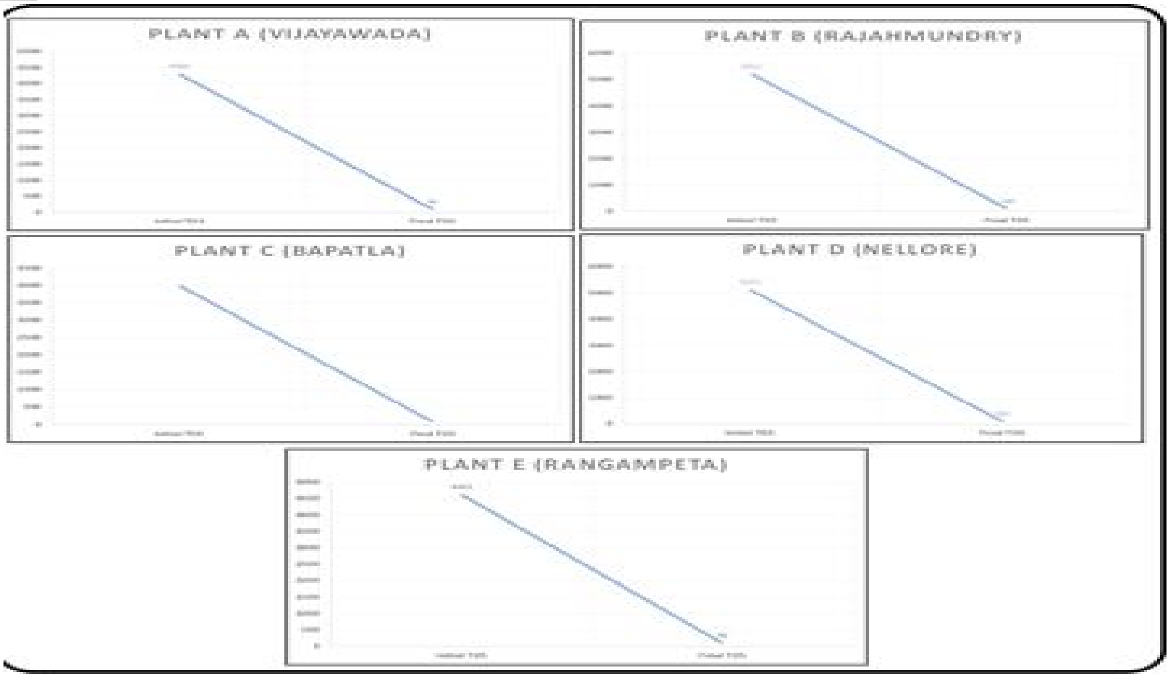

Figure 22: Graphical Representation of MEE Result for Day 2

The experiment observed that a Multi Effect Evaporator achieved a total dissolved solids (TDS) reduction rate of 98%. This finding indicates that Multi Effect Evaporation is a highly effective method for removing dissolved solids from a solution. However, it is important to consider the following limitations:

- Cost: Multi Effect Evaporators are likely expensive to install and operate.
- Energy Consumption: The evaporation process requires significant energy input, which can have environmental implications.
- Maintenance: These systems require regular maintenance to ensure optimal performance.

Therefore, while Multi Effect Evaporation offers exceptional efficiency, its suitability depends on factors like budget, energy availability, and long-term maintenance consideration

F. Results from Vetiver Roots Experiment

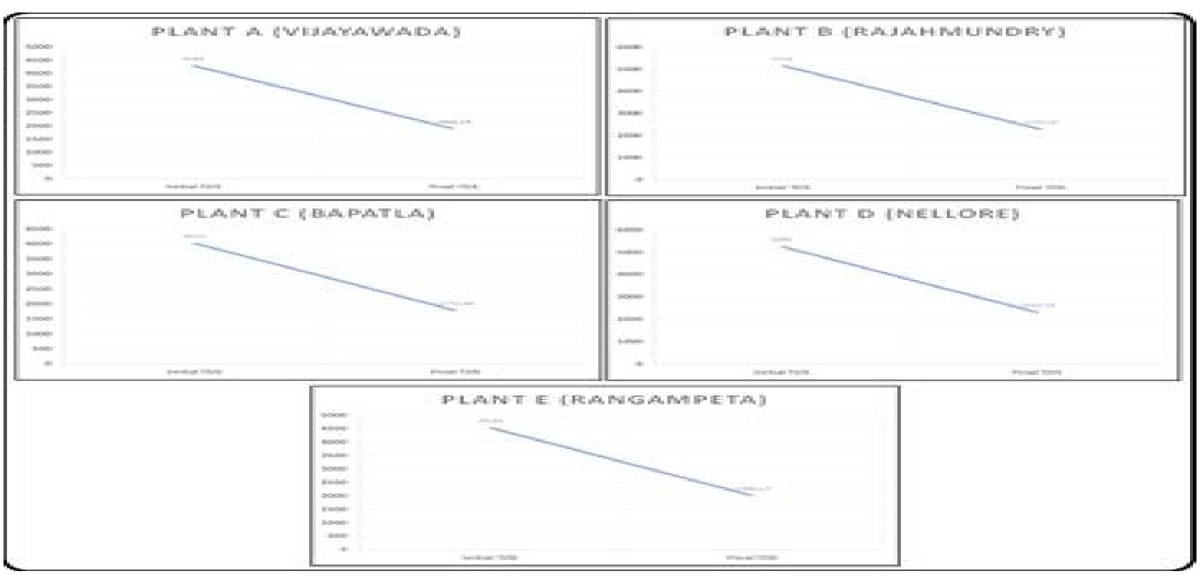

Figure 23: Graphical Representation of Vetiver Roots for Day 1

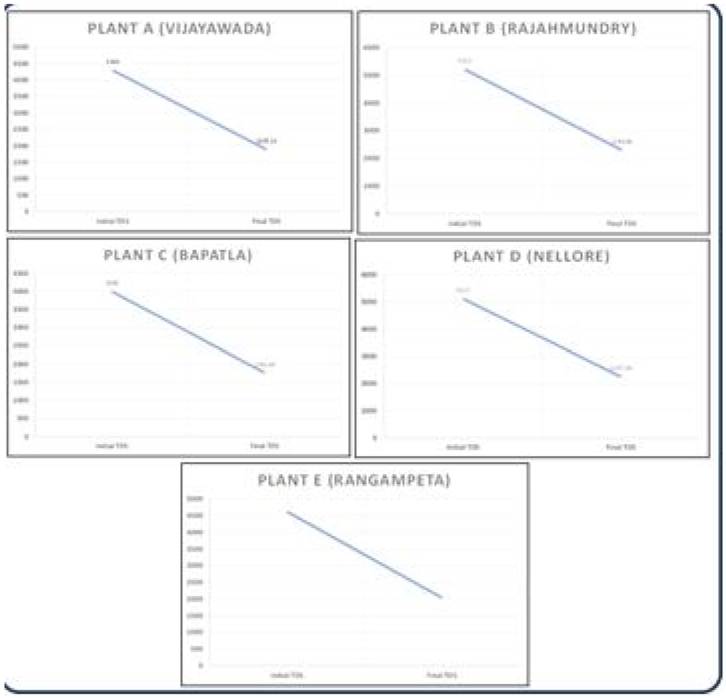

Figure 24: Graphical Representation of Vetiver Roots for Day 2

The experiment observed that 5g of Vetiver Roots achieved a total dissolved solids (TDS) reduction rate of 55.93%. This finding suggests that Vetiver Roots have potential as a natural and potentially sustainable method for TDS reduction. A reduction rate of 55.93% is promising, particularly for applications seeking an eco-friendly approach.

G. Results from Gooseberry Bark Experiment

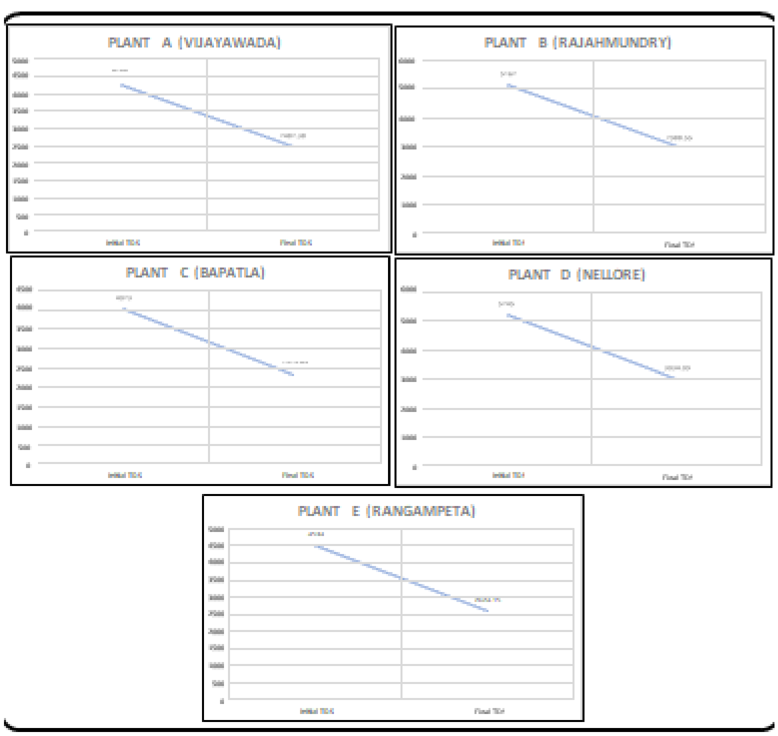

Figure 25: Graphical Representation of Gooseberry Bark for Day1

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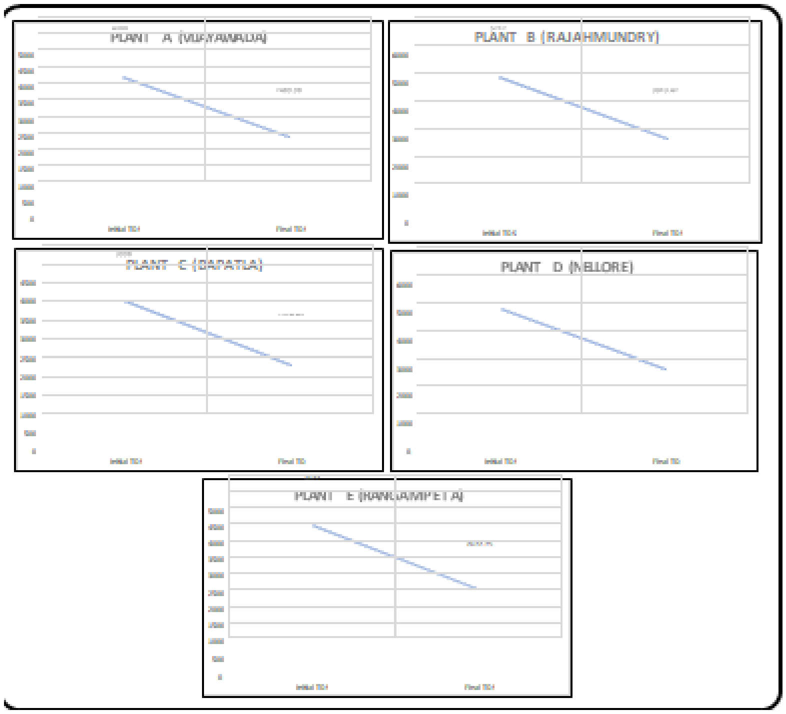

Figure 26: Graphical Representation of Gooseberry Bark for Day 2

The experiment found that 5g of Gooseberry Bark achieved a total dissolved solids (TDS) reduction rate of 42.14%. This result indicates that Gooseberry Bark has some potential for reducing TDS. While a 42.14% reduction rate is moderate compared to other methods, it suggests Gooseberry Bark warrants further investigation, particularly if it offers advantages in terms of cost, sustainability, or ease of use.

H. Result from Lemon Peel Experiment

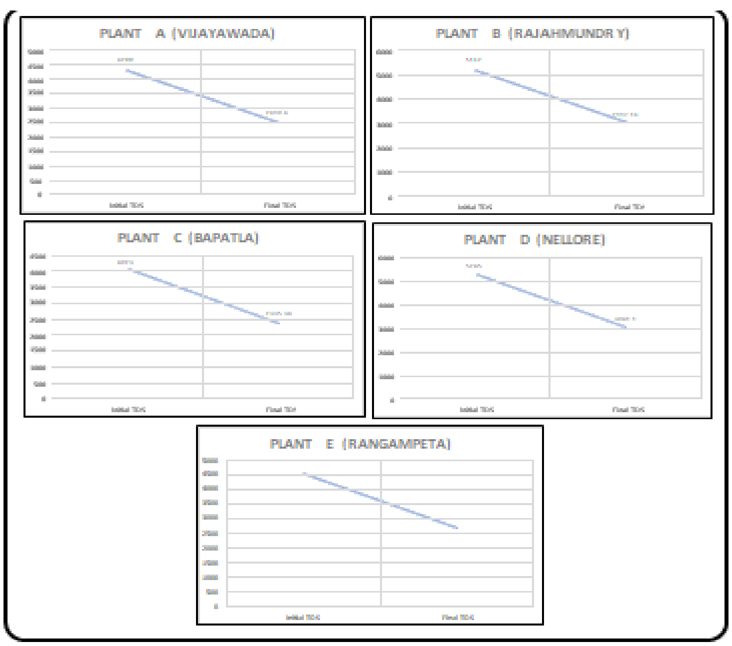

Figure 27: Graphical Representation of Lemon Peel for Day 1

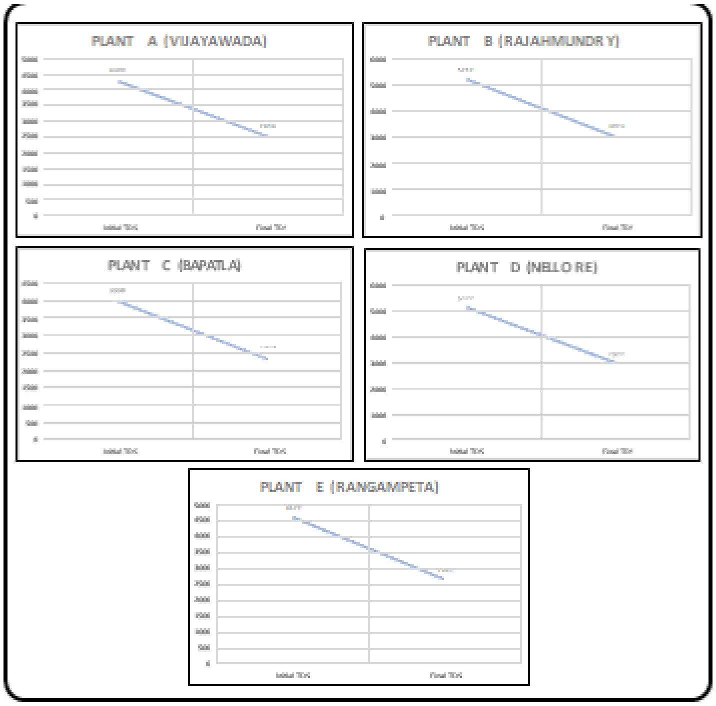

Figure 28: Graphical Representation of Lemon Peel for Day 2

The experiment found that 5g of lemon peel achieved a total dissolved solids (TDS) reduction rate of 42%. This result indicates that lemon peel has some potential as a natural and potentially low-cost method for reducing TDS. A 42% reduction rate is moderate compared to other methods, but it suggests promise for further investigation, particularly if it offers advantages in terms of sustainability and ease of use.

I. Result from Peanut Husk Experiment

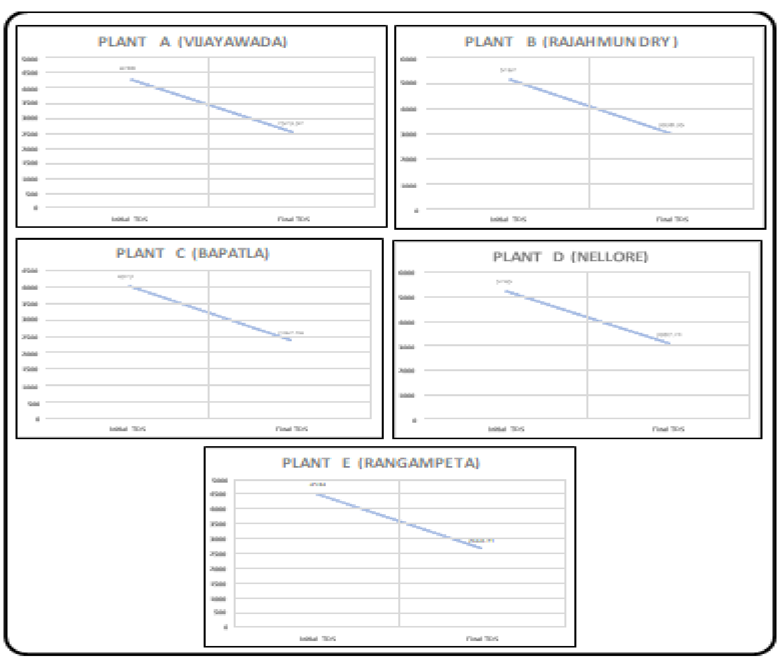

Figure 29: Graphical Representatives for Peanut Husk for Day 1

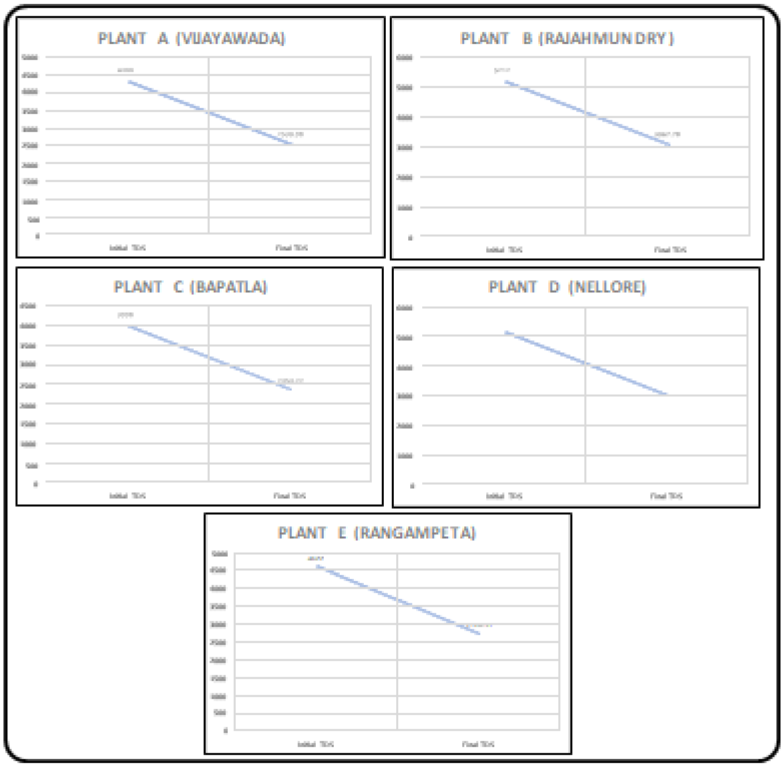

Figure 31: Graphical Representation of Peanut Husk for Day 2

Write a result & discussion using the following data: After the Experiment it was observed that 5g lemon peel total dissolved Solids reduction rate of 42%. This finding suggests that peanut husk has potential as a low-cost and eco-friendly method for reducing TDS in water. While a 41.14% reduction rate is moderate compared to some other methods, its potential sustainability and affordability warrant further investigation.

V. CONCLUSION, LIMITATIONS & SCOPE OF FUTURE WORK

This experiment successfully compared various methods for reducing total dissolved solids (TDS) in water. While the Multi Effect Evaporator achieved the highest reduction rate, its high cost, energy consumption, and maintenance requirements limit its practicality. Borax powder emerged as the most promising solution. It achieved a significant reduction rate (65.37%) while offering potential advantages in terms of cost-effectiveness, energy efficiency, and sustainability. This combination makes borax powder a compelling choice for large-scale implementation in facilities seeking to reduce TDS. Therefore, implementing borax powder tanks represents a well-balanced approach. This method offers a combination of efficacy, cost- consciousness, and environmental friendliness, making it a practical solution for targeted TDS reduction.

The following are the limitations of the project:

1) Lower Efficiency: While Borax powder offers a good balance, its reduction rate (65.37%) is significantly lower compared to the Multi Effect Evaporator (98%). This might be an issue for facilities requiring stricter effluent standards.
2) Scalability: The effectiveness of some methods, particularly those using natural materials like Vetiver Roots or Gooseberry Bark, may not translate directly to large- scale applications.
3) Limited Scope: The study only investigated a select few methods. Other potential options may exist and warrant exploration.

The following are the scope of future work:

While Borax powder appears to be a promising solution for reducing TDS in the current context, further research can optimize and expand upon this initial success:

- Optimize Borax Powder Application: Investigate the optimal dosage and application methods of Borax powder for different types of water and desired reduction rates. This could involve testing different concentrations and durations of Borax powder exposure.

- Combination Treatment: Explore the potential benefits of combining Borax powder treatment with other methods like Vetiver roots or natural filtration media. This might offer a cost-effective approach while achieving even higher reduction rates.
- Environmental impact assessment: Conduct a thorough evaluation of the environmental impact associated with large-scale Borax powder usage. Assess potential effects on local ecosystems and develop strategies to minimize any negative impacts.
- Regeneration and Disposal: Investigate methods for regenerating spent Borax powder or safely disposing of it after use. This would ensure the long-term sustainability of the treatment process.
- Long-term effects and monitoring: Implement long-term monitoring programs to assess the effectiveness of Borax powder treatment over extended periods. This will help identify any potential long-term effects on water quality or infrastructure..

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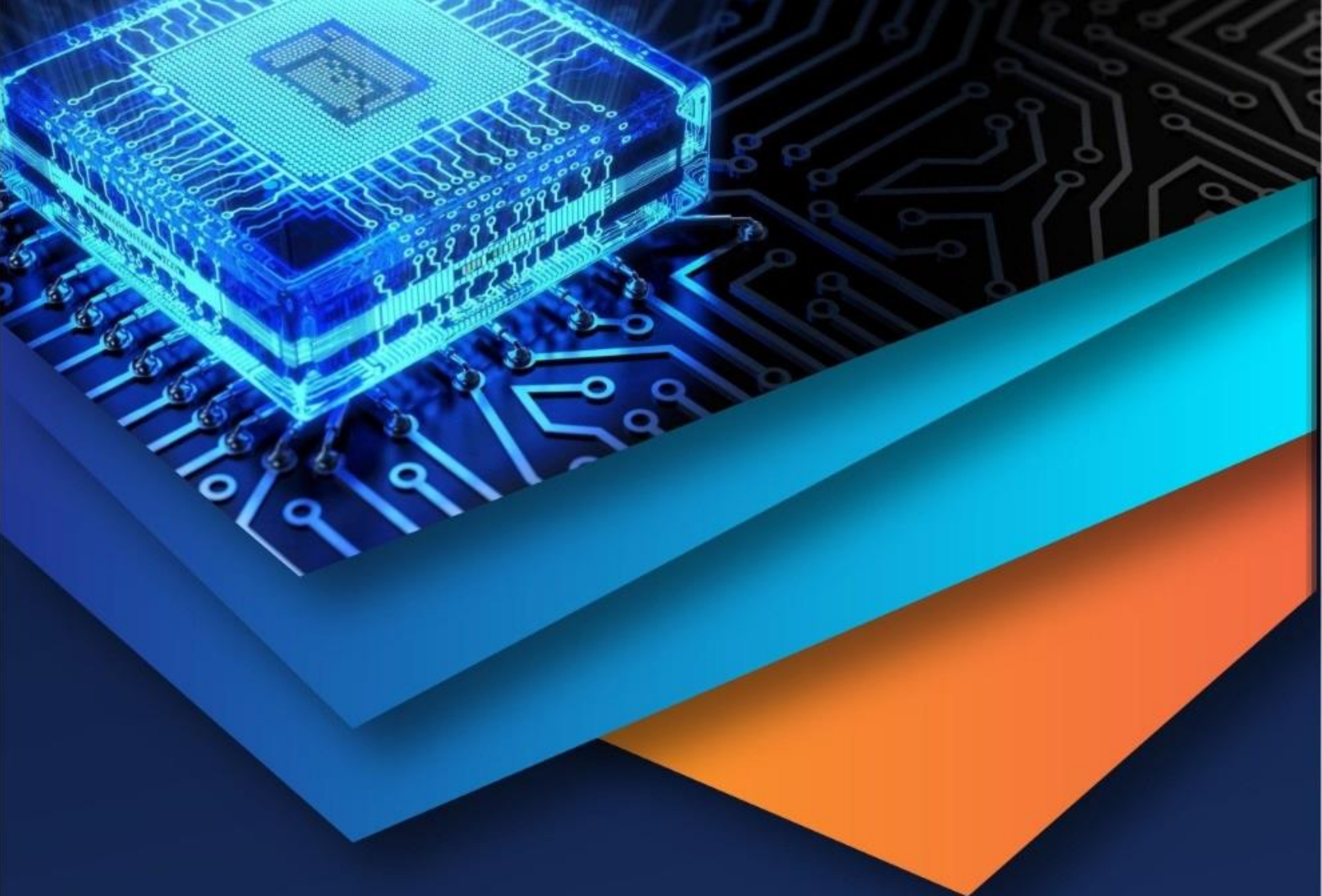

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