



# Eco-Friendly Utilization Of Mango Leaves As Biosorbent To Eliminate Iron Content From Water

<sup>1</sup>Dr. Anjali P. Sasidharan, <sup>2</sup>Amrita Sathyan, <sup>3</sup>Adhithya K., <sup>4</sup>Akshai Krishna P. A., <sup>5</sup>Krishna E. B.

<sup>1</sup>Associate Professor, <sup>2</sup>Student, <sup>3</sup>Student, <sup>4</sup>Student, <sup>5</sup>Student

<sup>1</sup>Civil Engineering,

<sup>1</sup>Vidya Academy Of Science And Technology, Thalakkottukara, Thrissur, India

**Abstract:** The presence of elevated iron concentrations in groundwater poses significant environmental and public health challenges, especially in regions dependent on this resource for drinking and agricultural use. Conventional methods for iron removal often involve expensive, energy-intensive processes and chemical treatments that can have adverse ecological impacts. This study explores the potential of biosorbents—natural, biodegradable materials derived from biological sources—as an eco-friendly and cost-effective alternative for the removal of iron from groundwater. Biosorbents such as agricultural by-products, algae, and microbial biomass have been shown to exhibit high metal-binding capacities due to their functional groups, which facilitate the adsorption of iron ions. The research focuses on evaluating the efficiency of mango as a biosorbent in iron removal and the effect on its efficiency when the biosorbents are taken in different proportions. By harnessing biosorption mechanisms, this approach offers a sustainable solution that reduces environmental footprints, lowers operational costs, and promotes the use of renewable resources in water treatment technologies.

**Keywords-** Mango leaves, Synthetic Iron solution, FTIR, Adsorption isotherm, Adsorption kinetics

## I. INTRODUCTION

Iron is the fourth most abundant element in the Earth's crust and one of the most common metals found in groundwater. Its presence is mainly due to the natural breakdown and weathering of iron-rich minerals such as hematite, magnetite, limonite, pyrite, and siderite. Under low-oxygen (anaerobic) conditions, iron dissolves into groundwater, interacting with organic matter and other chemical compounds. Industrial activities, agricultural runoff, and the use of iron-containing materials in water infrastructure can further contribute to iron contamination in water sources.

Traditional chemical methods for iron removal are often costly and can introduce secondary pollutants. Consequently, biosorption, a process utilizing natural, biodegradable materials known as biosorbents, has emerged as a sustainable alternative. Biosorbents derived from agricultural waste, algae, and microbial biomass have shown potential in effectively adsorbing iron from water. This approach not only harnesses low-cost, renewable resources but also minimizes chemical usage, aligning with sustainable and eco-friendly practices. The focus on biosorbents for iron removal exemplifies an intersection of environmental science and engineering, offering a practical solution that reduces reliance on chemical treatments while promoting resource recovery and environmental stewardship. This study explores various biosorbents and their effectiveness in eliminating iron, aiming to contribute to cleaner water resources and sustainable water treatment technologies.

## 1.1 OBJECTIVES OF THE STUDY

- i. **Development of Eco-Friendly Sorbents:** The study focuses on creating natural, biodegradable, and cost-effective sorbent for iron removal from drinking water, providing a sustainable alternative to conventional chemical treatments—especially beneficial for rural and economically challenged regions.
- ii. **FTIR Characterization:** Fourier Transform Infrared Spectroscopy (FTIR) is used to analyze the chemical composition and functional groups of the biosorbent, helping to understand their interaction with iron ions and ensuring their effectiveness before and after adsorption.
- iii. **Optimization of Adsorption Conditions:** The study evaluates how various factors—such as pH, contact time, sorbent dosage, and iron concentration—affect adsorption efficiency to identify the optimal conditions for maximum iron removal.

## II. MATERIALS REQUIRED

### 2.1 Raw Material Used

Mango leaves

### 2.2 Reagents Used

Hydrochloric Acid concentrated (1N) containing less than 0.00005 percent iron.

Diluted sulfuric acid (H<sub>2</sub>SO<sub>4</sub>)

### 2.3 Apparatus Used

UV Visible Spectrophotometer - For use at 510 nm, providing a light path of 1 cm or longer.

pH meter

Boiler

## III. METHODOLOGY

### 3.1 Preparation of Biosorbents

Mango leaves were used as biosorbent in this study. The collected mango leaves were first washed thoroughly with distilled water and treated with diluted sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) to modify their surface characteristics. Later they were then allowed to dry under sunlight. Once completely dried, the leaves were ground into a fine powder to enhance their adsorption properties. Further they were sieved using a 75-micron sieve to obtain uniform particle size for better adsorption efficiency. These were then used for further experimental analysis to evaluate their effectiveness in removing iron content from water.

## IV. RESULTS

### 4.1 Batch Adsorption Studies

A batch adsorption study was conducted to evaluate the efficiency of plant-based biosorbents, such as dried mango leaves, in removing iron from water. A synthetic iron solution with initial concentration of 10mg/L was prepared to simulate iron contamination. The dried adsorbents were introduced into the solution, and the mixture was stirred to ensure proper contact between the adsorbent and iron ions. Various physicochemical parameters, including pH, contact time, and adsorbent dosage, were monitored to assess their influence on the adsorption process. After the adsorption period, the biosorbent was separated through filtration, leaving behind the treated solution. The remaining iron concentration was then analyzed using a spectrophotometer, which measured the absorbance at a specific wavelength. The removal efficiency was calculated using the formula, where  $C_0$  is the initial iron concentration and  $C_t$  is the final concentration after treatment. The results provided insights into the potential of plant biosorbents as a sustainable and cost-effective method for iron removal from water.

#### 4.1.1 Effect of pH on Iron Removal

Effect of pH were studied for the pH ranging from 4 to 9 and the results were obtained. This was varied by using 1N NaOH. The results obtained were shown that the pH has an important influence in the removal of iron from the solution. pH is a significant parameter for adsorption of metal particles from aqueous solution since it influences the solubility of the metal particles concentration of the counter particles on the functional groups of the adsorbent and the degree of ionization of the adsorbate during reaction. The tables 1 showing the experimental values obtained for mango leaves during the batch adsorption study.

Table 4.1: Effect of pH of mango leaves

pH	Efficiency (%)
4	93.2
5	93.4
6	91.16
7	81.54
8	87.47
9	89.71

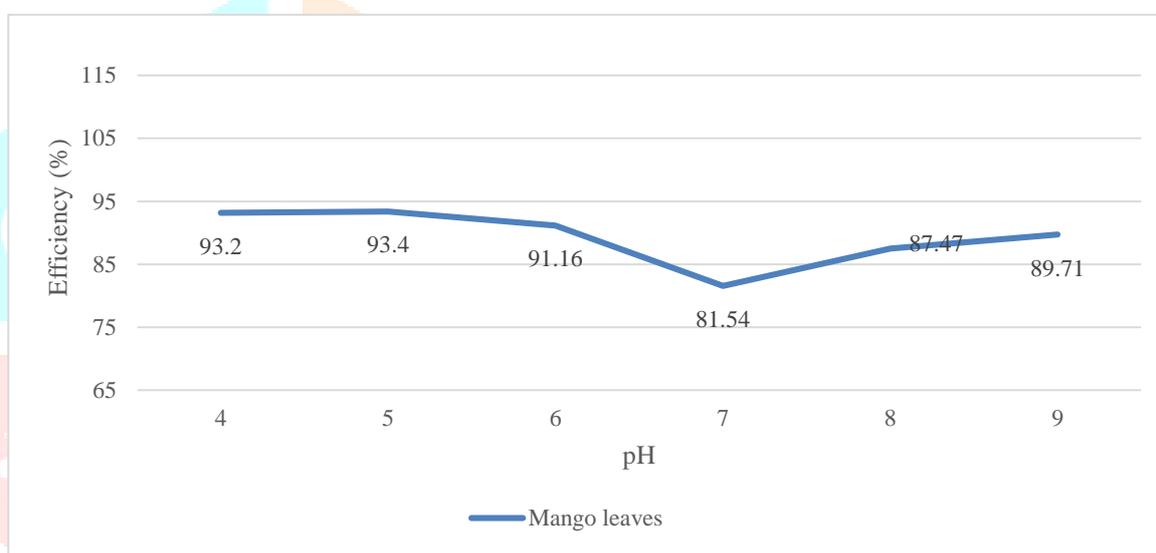


Fig.1: Effect of pH

#### 4.1.2 Effect of Contact Time on Iron Removal

The effect of contact time was studied for different contact times varies from 15 minutes to 120 minutes with adsorbent dose 1g/L, pH 5, initial iron concentration 10mg/L and the agitation 150 rpm. The maximum adsorption was obtained within the 30 minutes of shaking. After that the percentage removal of iron from synthetic solution did not give greater increment because as the contact time increased the active sites on the adsorbent were filled. Initially rate of adsorption is greater than rate of desorption. At equilibrium, rate of adsorption is equal to desorption. After equilibrium, rate of desorption is more than adsorption. Hence as the time increases from equilibrium efficiency decreases. The tables 2 showing the experimental values obtained for Mango leaves during the batch adsorption study.

Table 4.2: Effect of contact time

Time (min.)	Efficiency (%)
15	83.78
30	93.4
60	93.24
90	92.92
120	87.95

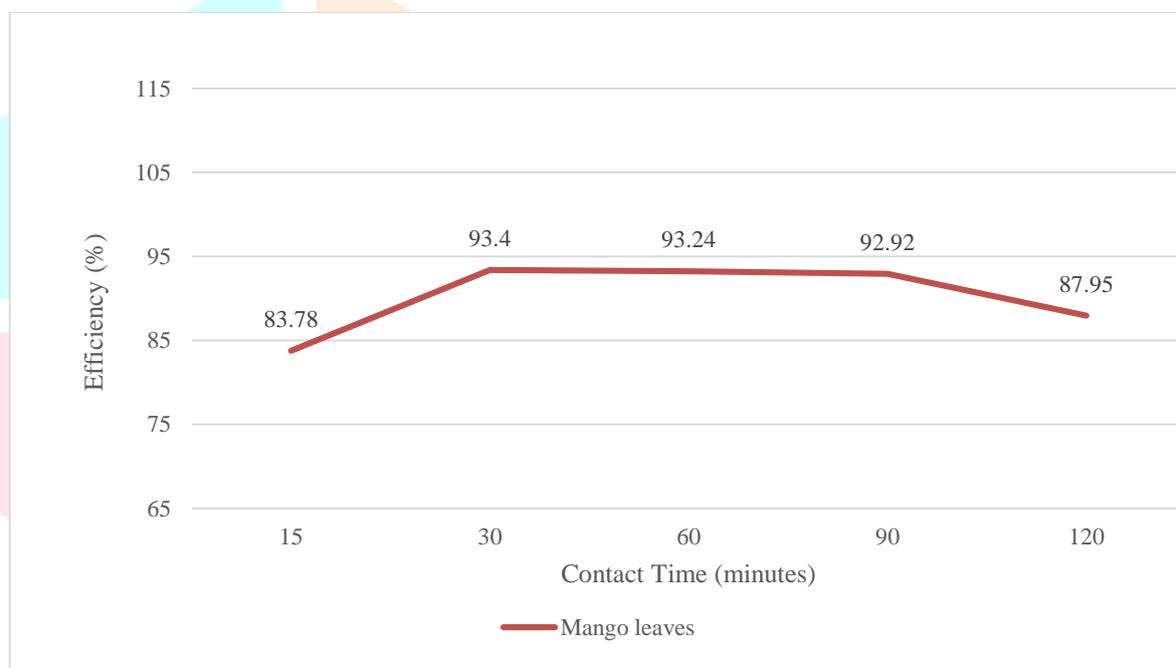


Fig.2: Effect of Contact Time

#### 4.1.3 Effect of Adsorbent Dosage

The effect of adsorbent dosage on the removal of iron by Mango leaves were studied. The weight of Mango leaves was varied from 2g/L to 5g/L keeping all the other experimental variables, pH 5 for mango, Initial iron concentration 10mg/L., and contact time 30 minutes. From the results, it was seen that the percentage removal of the metal particles increments with increasing the adsorbents doses from 2g/L g to 4 g/L and further increment of the adsorbent dosages did not give greater augmentation in the percentage of the metal particle expelled. The increase in the percentage removal of ion with increase in adsorbent dose is mainly due to the greater accessibility of exchangeable sites or surface area at higher dosage of adsorbents. The table 3 showing the experimental values obtained for Mango leaves during the batch adsorption study.

Table 4.3: Effect of adsorbent dosage

Amount (g)	pH	Contact time (min)	Efficiency (%)
2	5	30	83.25
3	5	30	86.38
4	5	30	55.59
5	5	30	47.58

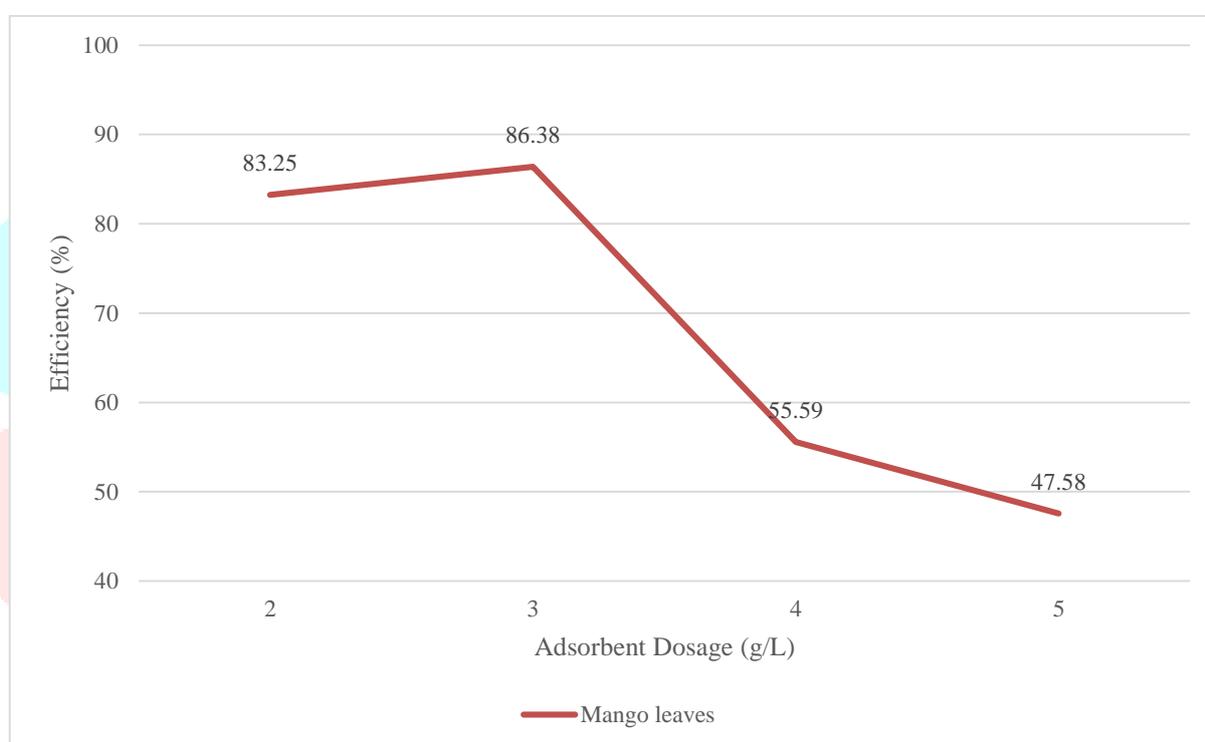


Fig.3: Effect of Adsorbent dosage

#### 4.1.4 Effect of Initial Ion Concentration on Iron Removal

The effect of initial iron concentrations of the removal of total iron on mango leaves adsorbent was studied as shown in figure 8. The pH of the synthetic metal ion the solution was adjusted to 5 for mango leaves and the fixed dosage of adsorbent is 1 g/L is added and shaking for 30 minutes. It can be seen from table 4 that the highest efficiency was found to be in 5mg/L.

Table 4.4: Effect of initial concentration

Iron concentration(mg/L)	Efficiency (%)
1	20.72
5	99.98
10	99.48

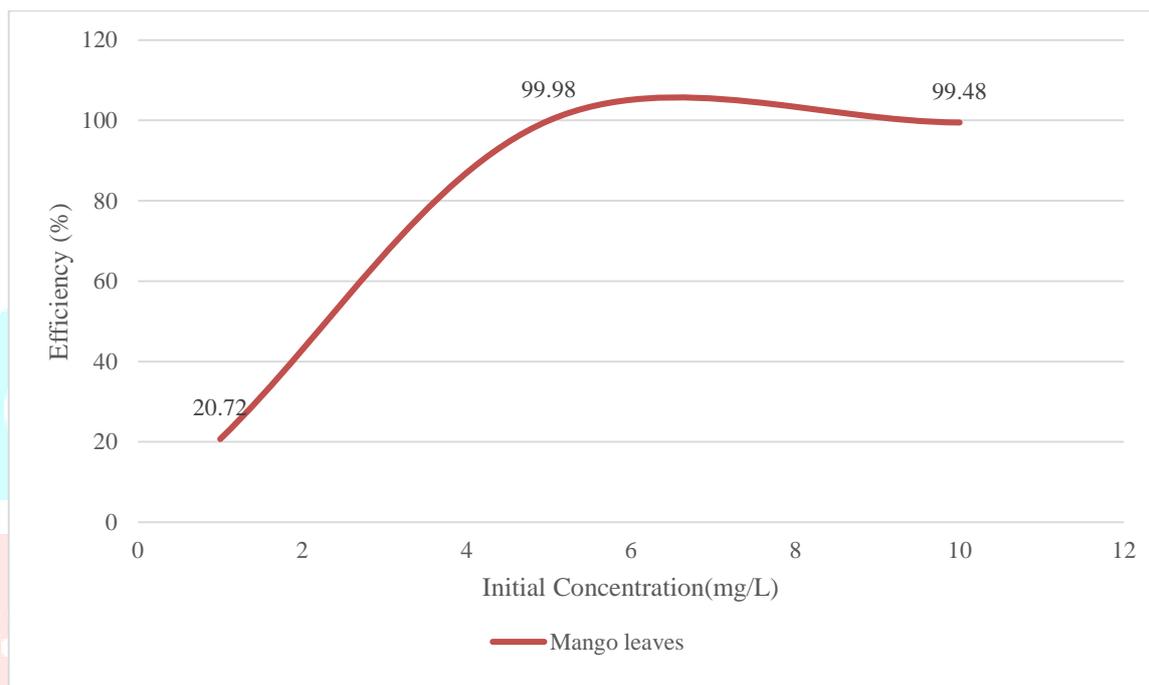


Fig.4: Effect of varying initial concentration

## 4.2 FTIR STUDY

Fourier Transform Infrared (FTIR) Spectroscopy is a powerful analytical technique used to identify chemical functional groups in a sample by measuring how it absorbs infrared (IR) light. It provides a molecular fingerprint of a substance, making it useful for material characterization, quality control, and chemical analysis.

FTIR works based on the principle that molecules absorb specific frequencies of IR light, causing their bonds to vibrate. These vibrations correspond to different functional groups, such as hydroxyl (-OH), carbonyl (C=O), carboxyl (-COOH), and amine (-NH<sub>2</sub>). The absorption pattern is recorded as a spectrum, showing peaks at characteristic wavelengths (measured in cm<sup>-1</sup>). Here, the FTIR of mango leaves both before and after treatment are studied.

### 4.2.1 FTIR Study of Mango Leaves Before Treatment

The FTIR spectrum of mango biosorbent before treatment provides insight into the functional groups present in the material. The broad peak observed around 3200-3600 cm<sup>-1</sup> corresponds to O-H stretching, indicating the presence of hydroxyl groups from cellulose, hemicellulose, or lignin. The peak around 2800-3000 cm<sup>-1</sup> is associated with C-H stretching, characteristic of aliphatic compounds. A noticeable peak near 1600-1700 cm<sup>-1</sup> corresponds to C=C stretching, which suggests the presence of aromatic compounds. Additionally, peaks in the 1000-1300 cm<sup>-1</sup> range indicate C-O stretching, confirming the presence of alcohols, ethers, or carboxyl groups, which play a crucial role in adsorption.

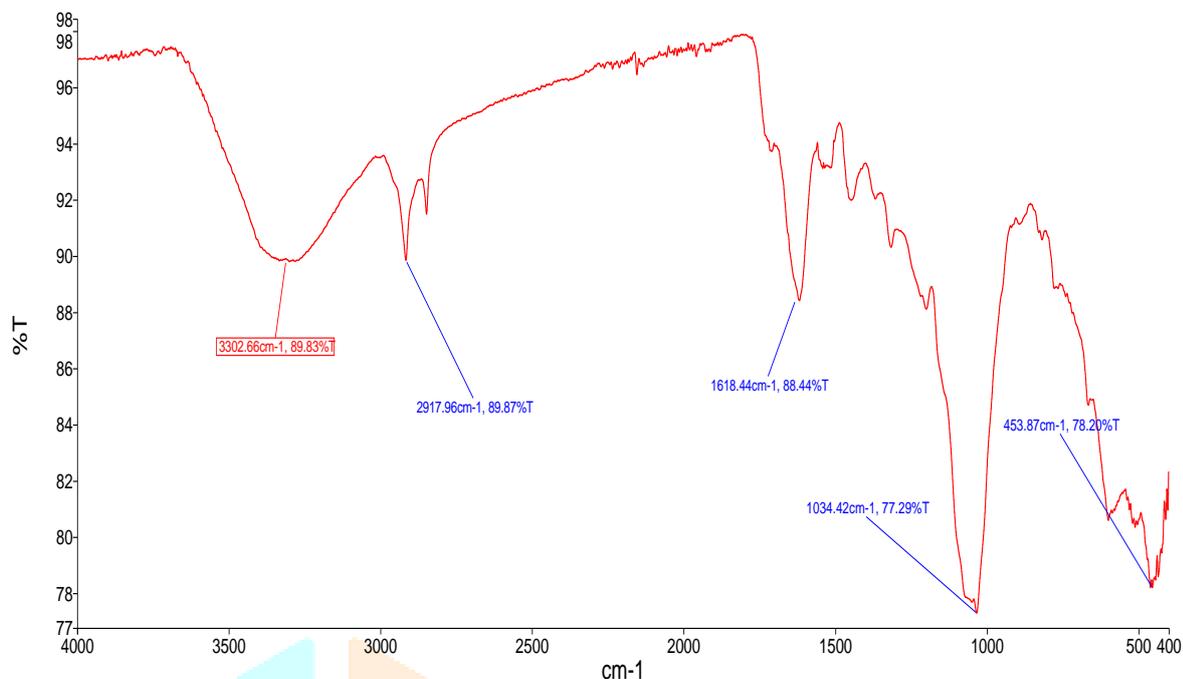


Fig.5: FTIR representation of Mango leaves before treatment

#### 4.2.2 FTIR Study of Mango Leaves After Treatment

The FTIR spectrum of mango biosorbent after treatment shows significant changes compared to the before-treatment spectrum, indicating interactions between functional groups and the adsorbed contaminants. The broad O-H stretching peak around 3200-3600 cm<sup>-1</sup> remains present, suggesting hydroxyl group involvement in metal binding. The C-H stretching bands in the range of 2800-3000 cm<sup>-1</sup> indicate that the aliphatic structure is largely intact. The presence of C=C stretching near 1600-1700 cm<sup>-1</sup> suggests that aromatic groups remained, though shifts in this region indicate possible interactions. Additionally, the C-O stretching peak observed between 1000-1300 cm<sup>-1</sup> confirms the role of alcohols, esters, or carboxyl groups in adsorption. The observed changes in peak intensities and positions suggest that hydroxyl, carbonyl, and aromatic functional groups played a role in binding iron ions, confirming the effectiveness of the biosorption process.

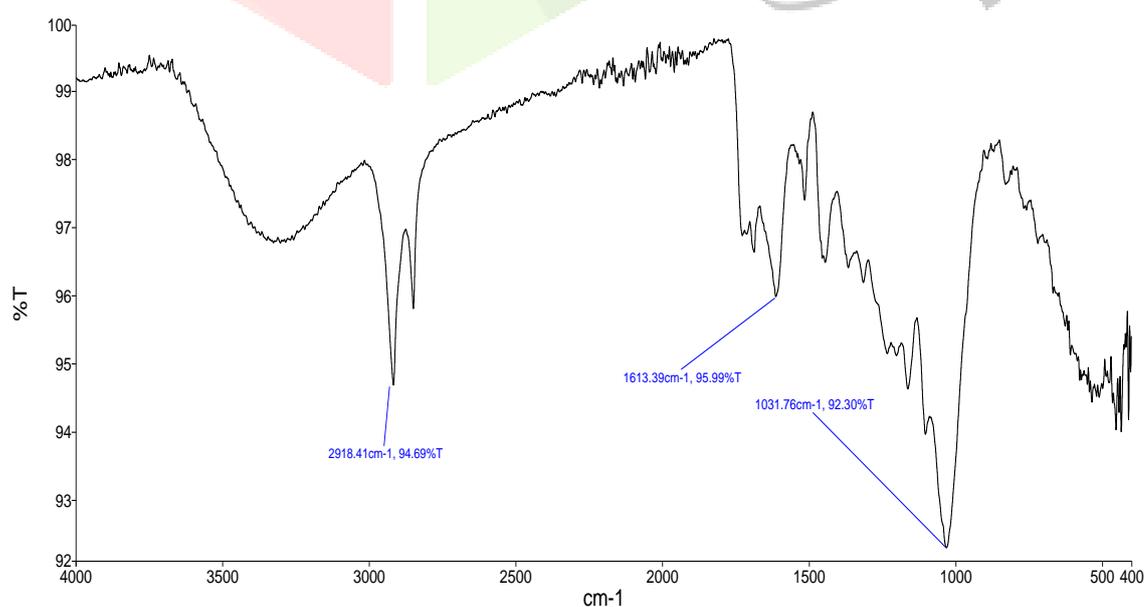


Fig.6: FTIR representation of Mango leaves after treatment

### 4.3 KINETICS AND ISOTHERM

#### 4.3.1 Adsorption Kinetics

The first-order kinetics model is used to describe adsorption processes where the rate of adsorption is proportional to the number of vacant sites on the adsorbent surface. The linear form of the first-order kinetic equation used in this study is:

$$\log(q_e - q_t) = \log q_e + \frac{K_d}{2.303} \times t$$

where:

$q_e$  is the amount of adsorbate adsorbed at equilibrium (mg/g)

$q_t$  is the amount of adsorbate adsorbed at time  $t$  (hours)

$k_d$  is the first-order rate constant (1/hour)

$t$  is the contact time (hours)

A plot of  $\log(q_e - q_t)$  versus  $t$  should yield a straight line with a slope of  $-K_d/2.303$  and an intercept of  $\log q_e$  if the adsorption follows first-order kinetics.

The second-order kinetics model assumes that the rate-limiting step of adsorption involves chemical adsorption. The linear form of the second-order kinetic equation is:

$$\frac{1}{q_t} = \left( \frac{1}{kq_e^2} \right) \frac{1}{t} + \frac{1}{q_e}$$

where:

$t$  is the contact time (hours)

$q_t$  is the amount of adsorbate adsorbed at time  $t$  (mg/g)

$q_e$  is the amount of adsorbate adsorbed at equilibrium (mg/g)

$k$  is the second-order rate constant (g/mg hour)

A plot of  $t/q_t$  versus  $t$  should give a straight line with a slope of  $1/q_e$  and an intercept of  $1/(kq_e^2)$  if the adsorption follows second-order kinetics. From the graph, the values of  $q_e$  and  $k_2$  can be calculated.

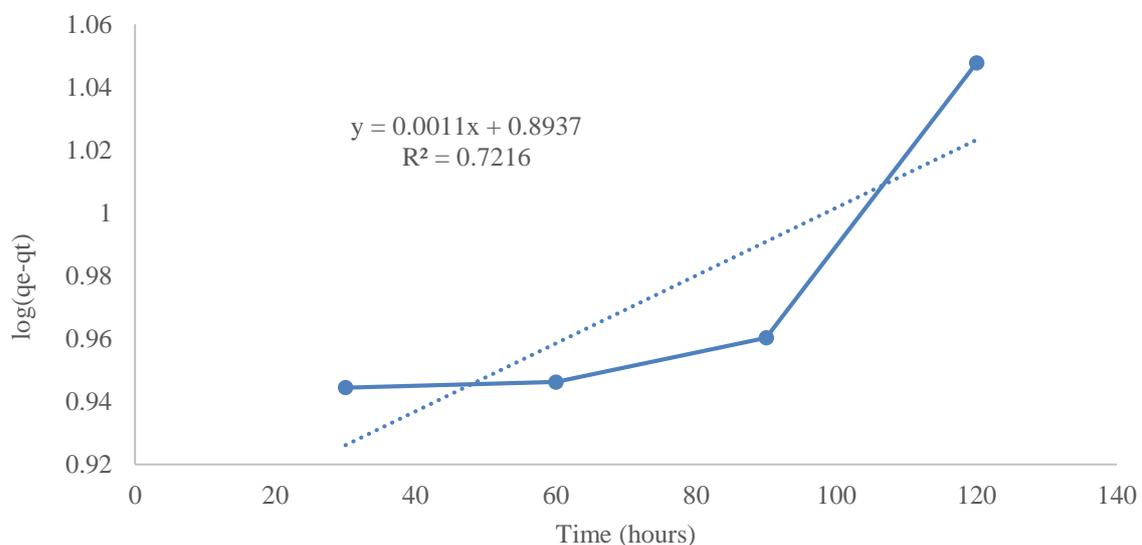


Fig.7: First-order kinetics for mango leaves

The kinetics for the sorption of iron on mango leaves were evaluated using pseudo-first-order and pseudo-second-order models and the best model was assessed by the value of linear coefficient of determination ( $R^2$ ). The study was conducted for an iron concentration of 113.49 mg/L at pH 5 for mango leaves. The pseudo-first-order kinetics model of mango leaves is shown in Figure 7 and pseudo second-order kinetics model is shown in figure 8.

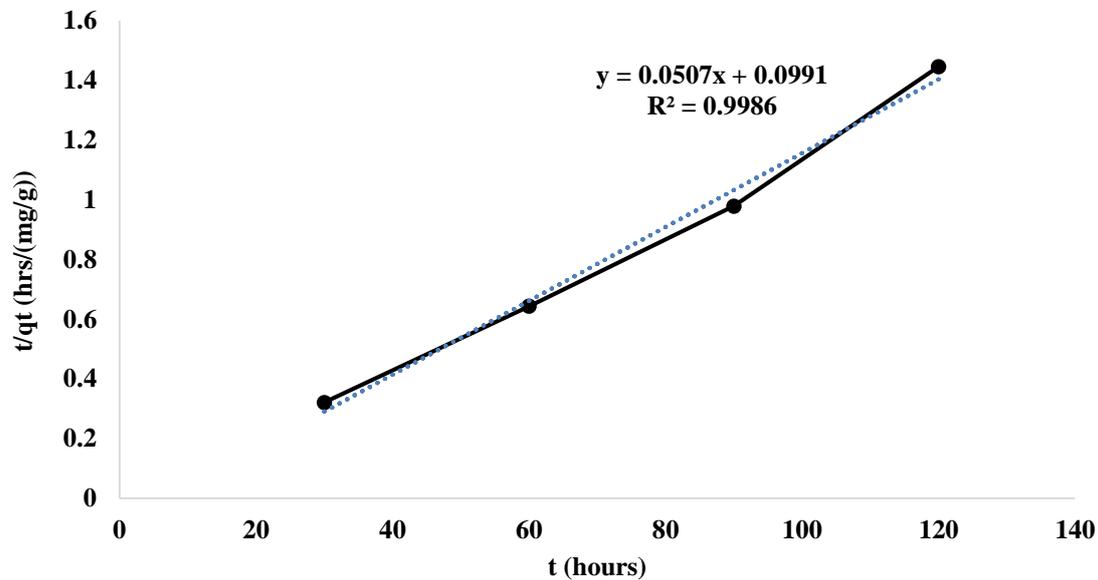


Fig.8: Second-order kinetics for mango leaves

The pseudo-second-order kinetics model showed higher  $R^2$  value than pseudo-first-order kinetic model for the sorbent. The maximum adsorption capacity figured from the pseudo-second-order kinetics model displayed close proximity to the experimental results for all the sorbents. Hence the iron sorption by Mango leaves followed pseudo-second-order kinetics, which indicates the adsorption rate is dependent on adsorption capacity and not on the concentration of iron. The results showed increased  $k_2=0.029$  for mango leaves biosorbents in removing iron compared to  $k_1$ .

#### 4.3.2 Adsorption Isotherms

The adsorption behaviour of the sorbents was modelled by fitting the results of iron removal obtained from experiments conducted for various influent iron concentrations at pH 5 for mango leaves and contact time 30 minutes into Langmuir and Freundlich isotherms. The best fit isotherm model is determined based on high  $R^2$  values. For Mango leaves, Langmuir isotherm model, the  $R^2 = 0.4342$  and for that of Freundlich isotherm  $R^2 = 0.8801$ . Based on the data, the iron adsorption behaviour of Mango leaves was better defined by Freundlich isotherm. The linear plots of the best-fitted isotherm Mango leaves (Freundlich isotherm) are given in Figure 9. The Freundlich isotherm analysis of this study gave the value of Freundlich adsorption coefficient ( $n$ ) lying between 1 and 10, which indicates, adsorption is favourable. The higher affinity between adsorbate and adsorbent is indicated by the value of ' $n$ '. The  $n$  value for mango is 2.4224.

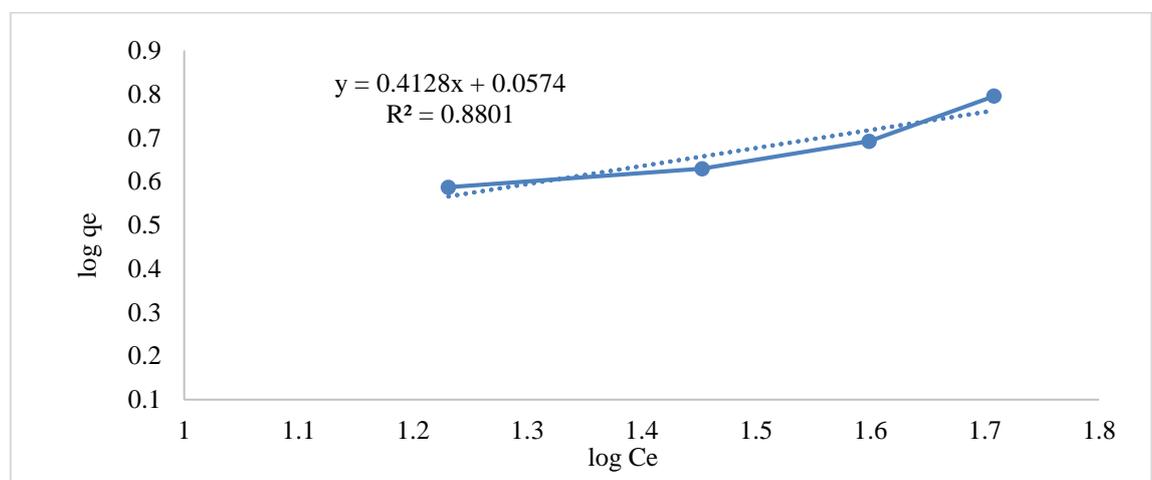


Fig. 9: Freundlich isotherm for Mango leaves

## CONCLUSION

This study primarily focuses on utilizing eco-friendly biosorbents, specifically mango leaves, to eliminate iron content from water. Mango leaves were evaluated for their effectiveness in removing iron from synthetic water solutions, highlighting their potential as a sustainable alternative to traditional treatment methods. The research demonstrated that mango leaves effectively adsorb iron, with the highest removal efficiency observed at pH 5 and a contact time of 30 minutes. Key factors influencing the adsorption process included pH, contact time, and adsorbent dosage. FTIR analysis showed a disappearance of specific functional group peaks in mango leaves after adsorption, indicating active involvement in the adsorption mechanism. The adsorption kinetics followed a second-order model, with a higher rate constant ( $k_2 = 0.029$ ) compared to the first-order model. Additionally, the Freundlich isotherm provided the best fit for the adsorption data, with an  $R^2$  value of 0.8801, supporting multilayer adsorption on heterogeneous surfaces. Further research is recommended to optimize the practical application of mango leaf biosorbents in real-world conditions, focusing on factors such as water quality variations, biosorbent regeneration, and long-term performance. Exploring other natural biosorbents could further enhance the development of efficient and cost-effective water treatment solutions.

## REFERENCE

1. Baharudin F. and Tadza M. M., (2017): 'Removal of iron and manganese in groundwater using natural biosorbent', IOP conference series: earth and environmental science, vol. 401, 4th-5th December 2017
2. Ben-Ali S. (2021): 'Application of raw and modified pomegranate peel for wastewater treatment: A literature overview and analysis', International Journal of Chemical Engineering, Volume 2021, Issue 1, 21 January 2021
3. Dey S., Kotaru N. S., Veerendra G. T. (2022): 'The removal of iron from synthetic water by the application of plant leaf biosorbents', Cleaner engineering and technology, vol. 9, August 2022
4. Dey S., Sreenivaslu A., Veerendra G. T., (2022): 'Synthesis and characterization of mango leaves biosorbents for removal of iron and phosphorous from contaminated water', Applied Surface Science Advances, vol. 11, October 2022
5. Kanamarlapudi S. L., Chitalpudi V.K. and Muddada S. (2018): 'Application of biosorption for removal of heavy metals from wastewater', Biosorption 18, vol. 69, 2018
6. Leong KO (2018): 'Adsorption of heavy metals using banana peels in wastewater treatment', The Eurasia Proceedings of Science and Technology Engineering and Mathematics, pp. 312-317, 2018
7. Osman and Ahmed I. (2023): 'Methods to prepare biosorbents and magnetic sorbents for water treatment: a review', Environmental Chemistry Letters, vol. 21, pp. 2337-2398, 04 May 2023
8. Parvatham S. D. Asha Rani N. R. (2021): 'Evaluation of wastewater treatment using banana fruit peel powder as natural coagulant', IRJIET International Research Journal of Innovations in Engineering and Technology, vol. 5, No. 6, pp. 58-65, June 2021
9. Ramazanoglu D., Mohammed Z. A. and Maher K. A. (2022): 'Extraction of some heavy metal ion from aquatic solution by banana peel-based biosorbents', Environmental Research and Technology, vol. 5, Issue 1, pp. 50-55, 31 March 2022
10. Saxena A., Bhardwaj M. and Allen T. (2017): 'Dorption of heavy metals from wastewater using agricultural-industrial waste and biosorbents', Water science, vol. 49, pp. 189-197, 03 May 2019
11. Shaibur M.R., Khatun Y., Howlader M., (2024): 'Determination of water quality and efficient removal of arsenic and iron from groundwater using mahogany fruit husk and banana peduncle charcoals'
12. Lemma M., Kalsido A.W., Wamolo Wotee M. (2024): 'Removal of river water turbidity and total dissolved solids using natural coagulants derived from banana peel and Moringa stenopetala seed', AQUA — Water Infrastructure, Ecosystems and Society Vol 73 No 7 june 2024
13. Ramavandi B (2014): 'Treatment of water turbidity and bacteria by using a coagulant extracted from Plantago ovata', Water Resources and Industry Volume 6, August 2014, Pages 36-50, July 2014
14. Gupta VK, Nayak A, Agarwal S. (2015): 'De Gisi S, Lofrano G, Grassi Bioadsorbents for remediation of heavy metals: Current status and their future prospects', march 2015
15. De Gisi S, Lofrano G, Grassi M (2016): 'Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: A review', Sustainable Materials and Technologies Volume 9, September 2016, Pages 10-40
16. Jiang W, Lin L, Xu X (2021): 'A Critical Review of Analytical Methods for Comprehensive Characterization of Produced Water'
17. Ullusna a. (2020): 'Removal of lead from aqueous solution by green synthesis of adsorbents using sapodilla leaves extract'

18. Baharudin F., Tadza M.M., Imran S.M., (2018): 'Removal of iron and manganese in groundwater using natural bio sorbent'
19. Krishna D., Sree R.P. (2013): 'Removal of Chromium from Aqueous Solution by CustardApple (Annona Squamosa) Peel Powder as Adsorbent'
20. Anjali P. Sasidharan (2021): 'Novel polyurethane foams loaded with nanoparticles -synthesis, characterization, and evaluation of phosphate and coliforms removal efficacies'.
21. IS 3025 (Part 53): 2003 'Methods of Sampling and Test (Physical and Chemical) for Water and Waste water.

