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ANALYSIS OF MICROPLASTICS IN WASTEWATER TREATMENT PLANT AND ITS DISPOSAL

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Abstract: Microplastics, defined as plastic particles less than 5 mm in diameter, have become pervasive environmental contaminants, presenting significant challenges to wastewater treatment plants (WWTPs) and waste disposal systems. This study provides a comprehensive analysis of the presence and management of microplastics in WWTPs, focusing on their behavior during treatment processes and subsequent disposal strategies. Microplastics enter wastewater through various sources, including household products, industrial activities, and environmental runoff. Upon entering WWTPs, these particles are subjected to multiple treatment stages: primary (screening and sedimentation), secondary (biological treatment), and tertiary (advanced treatment technologies). However, conventional treatment methods are generally insufficient to fully remove microplastics, resulting in their accumulation in the treatment sludge. This study explores a novel method for managing microplastics by incorporating it into bitumen, presenting a sustainable approach to disposal. The research investigates the reuse of microplastics by blending it with bitumen, examining the potential benefits. Through laboratory experiments and analysis, this study evaluates the feasibility and effectiveness of this disposal method while considering its impact on the physical and mechanical properties of the asphalt mix. In this project, we investigate the presence and impact of microplastics within wastewater treatment plants (WWTPs) and explore sustainable disposal solutions to mitigate their environmental consequences.

Keywords - Microplastics, Wastewater Treatment Plant, Electrocoagulation, Density Separation, Fenton Oxidation

1.INTRODUCTION

Microplastic pollution in wastewater poses significant environmental and potential human health risks due to the pervasive use and persistence of plastic materials. Defined as plastic particles smaller than 5 millimeters, microplastics infiltrate wastewater systems from both primary and secondary sources, posing significant ecological and potential human health risks. Originating from primary sources, such as microbeads in personal care products, and secondary sources, like the degradation of larger plastic debris, microplastics contaminate aquatic and terrestrial ecosystems. Their ingestion by marine organisms disrupts feeding, behavior, and reproduction, impacting ecosystem health and potentially entering the human food chain. To address this issue, wastewater treatment plants must adopt advanced separation technologies such as filtration, density separation, and electrostatic separation to efficiently remove microplastics from wastewater. Environmentally sustainable disposal methods are also essential to prevent further contamination. One innovative approach is incorporating separated microplastics into bitumen for asphalt pavement, enhancing its properties while reducing the use of virgin materials. However, effective management of microplastic pollution requires a comprehensive approach that includes source reduction strategies, such as sustainable product design, improved recycling infrastructure, and public awareness campaigns. By integrating these solutions, it is possible to mitigate the environmental footprint of microplastics and safeguard ecological and human health. However, effective management of microplastic pollution requires a comprehensive approach that includes source reduction strategies, such as sustainable product design, improved recycling infrastructure, and public awareness campaigns.

1.1 Microplastics Sources and Constituents

Microplastics (MPs) can originate from both land-based and sea-based sources, but it is terrestrial environments that are more susceptible to plastic contamination when compared to oceans. This is due to the fact that over 80% of the total input of MPs into the environment is attributed to land-based sources, including poorly managed waste disposal, landfills, wastewater treatment plant residues, agricultural activities, indoor dust emissions, and particles deposited from the atmosphere. In contrast, marine-based activities, such as fishing, aquaculture, illegal dumping at sea, shipping, and harbors, account for less than 20% of the overall input. MPs are disseminated globally through terrestrial, marine, and atmospheric pathways. Microplastics are classified into two main categories based on their origin: primary and secondary. Primary MPs are intentionally produced due to their commercial viability and are utilized in a wide array of applications. For example, they are used in the manufacturing of small microbeads employed in various industries, including plastics, detergents, inks, paints, concrete, polymer cement, paper production, wastewater treatment, sewage sludge dewatering, polishing agent, horticulture, agriculture, and personal care products. Primary MPs also encompass the production of synthetic fibers in small sizes for the clothing industry.

Secondary MPs, on the other hand, are particles that result from the degradation of larger plastic items such as bottles, clothing, pipes, and packaging materials. They also encompass synthetic fibers released during the laundering of synthetic textiles in washing machines, with approximately 35% of oceanic MPs originating from microfibers discharged during the washing of synthetic fabrics.

1.2 Need of Microplastics Removal in Wastewater Treatment Plant

Microplastics pose a significant environmental threat, particularly in water bodies, posing risks to aquatic ecosystems and human health. Wastewater treatment plants (WWTPs) play a crucial role in managing microplastic pollution, receiving wastewater from households, industries, and urban runoff. However, conventional treatment processes are not fully equipped to effectively eliminate microplastics, leading to their discharge into rivers, lakes, and oceans. Improving wastewater treatment methods to capture and eliminate microplastics before they reach open waters can significantly reduce their harmful impact on marine biodiversity. Microplastics in wastewater also pose risks to drinking water quality and human health, as they can bypass conventional filtration processes, leading to inflammation, cellular damage, and disruption of endocrine functions in humans. Removing microplastics at the wastewater treatment stage can limit their presence in drinking water supplies and reduce potential health hazards. Microplastic contamination in treated sludge used for agriculture is another growing concern. Many WWTPs produce sludge as a byproduct, which can accumulate in the soil, affecting its structure, water retention capacity, and microbial composition. Implementing advanced microplastic removal techniques in wastewater treatment can help prevent soil degradation and ensure sustainable agricultural practices. In conclusion, removing microplastics from wastewater is a crucial step in mitigating environmental and health risks, ensuring safer drinking water and healthier agricultural lands.

2.METHODOLOGY

Managing microplastic pollution in wastewater involves a step-by-step process that starts with collecting samples from wastewater streams. These samples are then thoroughly analyzed to detect and measure the amount of microplastics present. Once identified, specialized separation techniques are used to remove the microplastics from the water. During treatment, microplastics often accumulate in the sludge, so it's important to examine the sludge as well. Two main methods are used to remove microplastics from sludge: electrocoagulation and Fenton's oxidation. Electrocoagulation works by using electric currents to cause the microplastics to clump together, making them easier to separate. Fenton’s oxidation, on the other hand, uses a mix of hydrogen peroxide and iron catalysts to break down the microplastics chemically. After these contaminants are removed, the treated sludge is not just discarded instead, it’s put to good use. It is incorporated into bitumen and used for road construction. This innovative approach not only reduces environmental pollution but also promotes sustainability by giving waste materials a second life. It’s a great example of the circular economy in action, turning a pollution problem into a solution for infrastructure development.

3.ANALYSIS OF MICROPLASTICS IN WASTEWATER

Characterizing wastewater is a crucial step in understanding its quality and deciding how best to treat it. This process involves studying the physical, chemical, and biological properties of the water to identify what contaminants are present, in what amounts, and how they might affect both human health and the environment. As part of this study, samples were collected from the inlet and outlet of the KWA Water Treatment Plant in Irikkur to see how effective the treatment process was. To get a clear picture, the water was tested using several experimental methods. Turbidity was measured to check how cloudy the water was, which can indicate the presence of suspended particles. Dissolved oxygen levels were tested using the Winkler method, since low oxygen levels can suggest pollution and affect aquatic life. The total amount of solids both those dissolved in the water and those floating in it was determined by evaporating the water and weighing the leftover residue. Chloride levels were also checked using a titration method, as high levels can point to contamination from things like sewage or industrial waste. These tests helped us assess how polluted the water was before treatment and how clean it became after, providing valuable insights into the efficiency of the treatment plant. This kind of detailed analysis not only supports better water management but also helps ensure that the treated water is safe and environmentally compliant. This comprehensive approach helps ensure that the treated water meets environmental and public health standards, offering insights for further improvement and sustainable water management.

Fig 3.1 Wastewater sample

Table 3 Characteristics of wastewater

SL No	Experiments	Results		Permissible Limit
		Inlet	Outlet	
1	Turbidity	195 NTU	45ntu	1 NTU
2	Total Dissolved Solids	850mg/L	686mg/L	500mg/L
3	Chlorides	320mg/L	280mg/L	250mg/L
4	Dissolved Oxygen	0mg/L	5mg/L	4-7mg/L

3.1. Analysis of wastewater

Analyzing a sample of wastewater involves a series of steps to assess its physical, chemical, and biological properties. Below is an overview of the general process for analyzing wastewater samples, which can be tailored based on specific requirements or parameters of interest. Fig 3.1 wastewater sample To accurately identify and isolate microplastic particles from the collected inlet water samples, a digestion process was employed to remove organic contaminants that could interfere with the analysis. This process began with the use of hydrogen peroxide (H_2O_2) as an oxidizing agent, aimed at breaking down and eliminating organic matter. Each 300 ml sample was treated with 150 ml of 30% hydrogen peroxide solution and heated to 75°C to optimize the oxidation process. After heating, the samples were left undisturbed for 24 hours to ensure complete digestion. This approach effectively targeted and removed organic contaminants, reducing the likelihood of misidentifying organic matter as microplastics. As a result, the residue left after treatment primarily consisted of microplastic particles, allowing for accurate identification and characterization in the next stages of the study. After separating the microplastics from organic matter and other contaminants, density separation was conducted to isolate the microplastics. A salt solution was prepared by mixing equal amounts of sodium chloride (NaCl) at a density of 1.2 g/cm³ with water. This mixture was left undisturbed for 24 hours to allow the microplastics to float to the surface. The supernatant was then centrifuged at 3000 rpm for 15 minutes to further separate the microplastics, after which it was filtered into glass bottles using Whatman 5 filter paper with a pore size of 2.5 µm. The microplastics collected on the filter paper were oven-dried at 60°C for 2 hours to remove any remaining water content. Once dried, the samples were weighed using an analytical balance and transferred to glass slides for visual analysis using a compound microscope. The microplastics were photographed and categorized based on their shape, color, and size. The extracted microplastics were examined using a Leica DMC 2900 microscope at a magnification of 6X to observe and characterize the particles in detail. This microscopic analysis provided a closer look at the physical features of the microplastics, such as their shape, size, and surface texture. Images of the microplastic particles collected from the inlet of the treatment plant were captured during this process, offering visual evidence of their presence and characteristics.

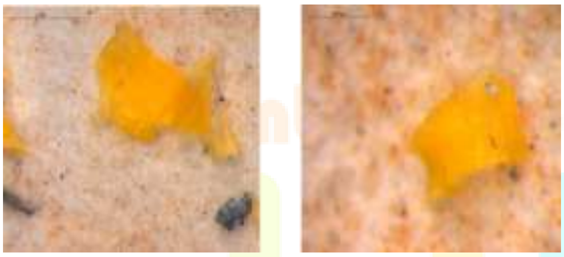

Fig 3.1.1 Microscopic images of inlet water sample

Fig 3.1.2 Microscopic image of outlet water sample

3.2. Quantitative Analysis and Calculation

To see how well the KWA Water Treatment Plant in Irikkur removes microplastics from wastewater, we carried out a simple test by comparing the amount of residue in water samples taken before and after treatment. We started by weighing just the filter paper, which came to 2165.5 mg. Then, we filtered a 300 mL sample of untreated water from the plant's inlet, and the total weight of the filter paper plus the residue was 2332.5 mg. This means the residue alone weighed 167 mg. We did the same with a treated sample from the outlet, which gave a total weight of 2192.5 mg, so the residue there was just 27 mg. Using these values, we calculated the plant's efficiency in removing microplastics using a standard formula and found it to be about 83.8%. This shows that the treatment process is doing a great job in significantly reducing microplastic content, helping to ensure the water released is much cleaner and safer for the environment.

4.SEPARATION OF MICROPLASTICS FROM SLUDGE

For removal of microplastics from sludge we adopted two methods: Fenton oxidation and electrocoagulation

4.1. Fenton Oxidation

This study investigates the application of Fenton oxidation for the removal of microplastics from sludge. The process begins with the collection of 200 mL of sludge containing microplastics, ensuring uniform distribution. The pH of the sludge is measured and adjusted to the optimal range of 2.5 to 4 using either dilute sulfuric acid (H_2SO_4) to lower the pH or sodium hydroxide (NaOH) to raise it. Fenton reagents are then prepared, including a 0.1 M ferrous sulfate ($FeSO_4 \cdot 7H_2O$) solution and a 10% hydrogen peroxide (H_2O_2) solution. The Fenton reaction is initiated by adding 10 mL of the $FeSO_4$ solution and 20 mL of the H_2O_2 solution to the sludge, followed by gentle stirring for 15–30 minutes. During this reaction, hydroxyl radicals (•OH) are generated, which break down organic matter and degrade the microplastics. The mixture's pH is continuously monitored and adjusted as needed to maintain optimal conditions. The reaction is conducted at approximately 25°C to prevent overheating, which could reduce efficiency. After 1–2 hours, the microplastics are separated from the sludge using filtration or centrifugation, then dried at 60°C for 24 hours. The experiment achieved an 80% reduction in microplastic mass, demonstrating the Fenton oxidation process is highly effective for degrading or separating microplastics from sludge. The careful calibration of Fe^{2+} and H_2O_2 ensured the proper generation of hydroxyl radicals, which are critical for breaking down organic contaminants and microplastics. Removing 80% of microplastics from sludge has significant positive environmental impacts, reducing the load of plastic pollutants entering water bodies and the ecosystem.

Fig 4.1.1 Sludge deposition and bubble formed after 2hrs incubation

4.2. Electrocoagulation

Electrocoagulation setup was used with an iron electrode as the anode and a copper electrode as the cathode, connected in a beaker with a spacing of 6 cm between them. A 200 mL sludge sample was added to the beaker, and different concentrations of anhydrous Na_2SO_4 (0.01 M, 0.05 M, and 1 M) were used as the electrolyte. The experiment was conducted under two voltage conditions, 9V and 18V, to investigate the effect of voltage density on microplastic removal, as illustrated. To simulate contamination, granular microplastics polyethylene (PE) and polyvinyl chloride (PVC) were added to the sludge and thoroughly mixed for 5 minutes. Once the electrodes were connected, the solution became increasingly turbid due to the formation of polymer flocs during electrocoagulation. After the experiment, the mixture was gently stirred with a glass rod and left to settle on a clean, covered platform for 16 hours. During this settling period, a sludge blanket formed at the bottom of the reactor, effectively trapping most of the microplastics. The liquid above the sludge became noticeably clearer compared to the initial sample. The sludge blanket containing the microplastics was then separated using centrifugation at 3000 rpm for 10 minutes at room temperature. Following each experiment, the removal efficiency of microplastics was evaluated. The supernatant was carefully transferred to a clean glass beaker after settling. Subsequently, all collected supernatants were filtered using Whatman 5 filter paper. The filter paper was then air-dried, and the mass of the microplastics was determined by calculating the difference in the weight of the filter paper before and after filtration. This approach provided a quantitative assessment of microplastic removal during the electrocoagulation process.

Fig 4.2.1 Microplastics for spiking the sample

Fig 4.2.2 Sludge blanket formed after electrocoagulation

Fig 4.2.3 Centrifugation process

Fig 4.2.4 Microscopic image

4.3 Results and discussions

In a series of electrocoagulation experiments using two different electrode combinations (Al-Cu) and (Fe-Cu) researchers observed notable differences in how effectively microplastics were removed from wastewater. With the Al-Cu setup, the removal efficiency improved as both the voltage and electrolyte concentration increased. The best result here was a 90% removal rate, achieved at 18V and a molarity of 0.1 M. This suggests that higher voltages and stronger electrolytes help generate more coagulant and improve the conductivity of the solution, leading to better floc formation and microplastic capture. On the other hand, the Fe-Cu combination showed a lower maximum efficiency of 62% under the same conditions. While Fe electrodes are still effective, the results indicate that Al may be more efficient in producing reactive coagulants or facilitating floc formation in this setup. Overall, these findings highlight how crucial the choice of electrode material and operational conditions like voltage and electrolyte concentration are in enhancing the electrocoagulation process for removing microplastics from wastewater.

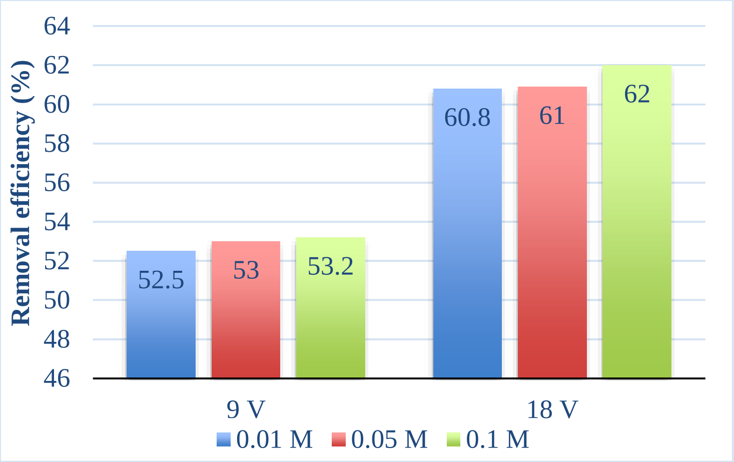

Fig 4.3.1 Removal Efficiency using Electrocoagulation (cathode Cu and anode Fe)

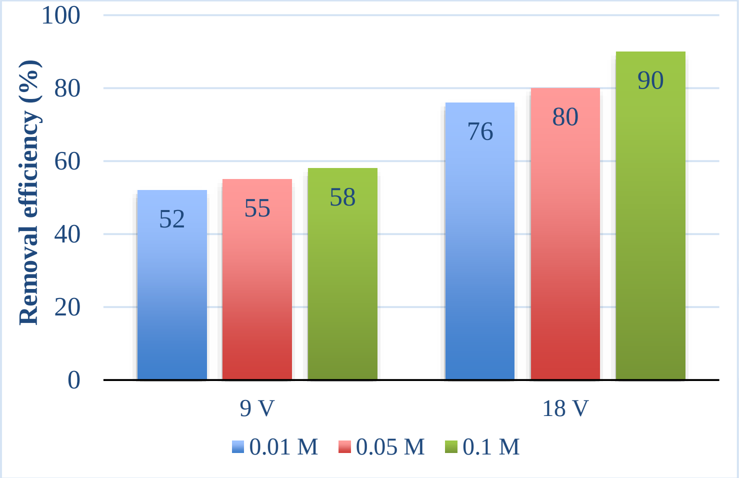

Fig 4.3.2 Removal Efficiency using Electrocoagulation (cathode Al and anode Fe)

5. DISPOSAL OF MICROPLASTICS BY FORMING PLASTIC MODIFIED BITUMEN

Repurposing microplastics from wastewater treatment plants into road construction is a smart and sustainable idea. Instead of letting these tiny plastic particles end up in our environment, they’re mixed into bitumen the material used to pave roads. This not only helps reduce plastic waste, but it also makes our roads stronger and last longer. When plastics are added, they improve how the bitumen behaves, making it thicker, more flexible, and better at withstanding heat and water. That means roads are less likely to crack or deform, which cuts down on repairs and maintenance costs good news for both governments and taxpayers. The process starts by picking out suitable microplastics, like polyethylene, polypropylene, or recycled plastic. These are then blended with hot bitumen (VG 30) to make sure the plastic spreads evenly. After mixing, the modified bitumen is tested to see how well it performs. The softening point test checks how it handles heat, the viscosity test looks at how it flows, and the ductility test sees how much it can stretch before it breaks. All in all, this is a clever way to turn waste into something useful helping our roads and our planet at the same time.

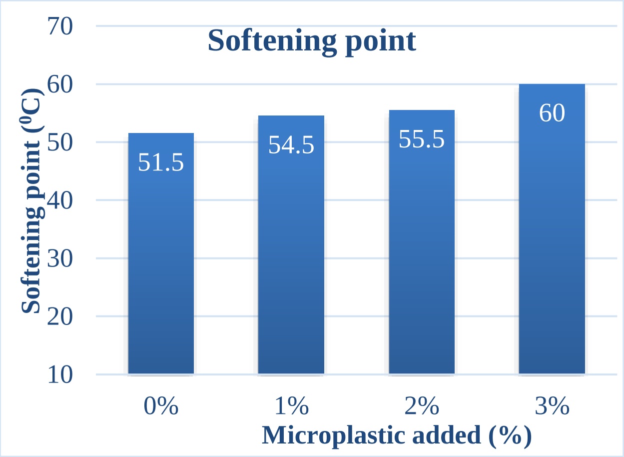

Fig 5.1.1 Softening point vs microplastics added

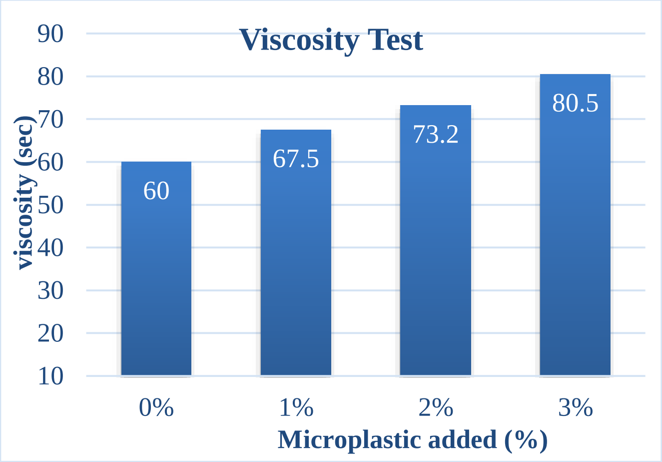

fig 5.1.2 Viscosity vs microplastics added

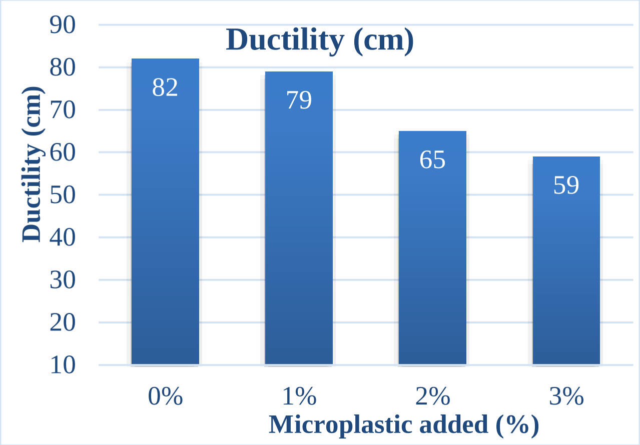

Fig 5.1.3 Ductility vs microplastics added

6.CONCLUSION

our project sheds light on the growing problem of microplastic pollution in wastewater and explores smart, sustainable ways to tackle it. When we analysed samples from the KWA treatment plant, we found a noticeable drop in microplastic levels from 167 grams at the inlet to 27 grams at the outlet. While this shows the plant is doing a good job, it also points to the need for better removal techniques. To dig deeper, we separated microplastics from the sludge and studied their makeup. To boost removal efficiency, we tested different treatment methods, like electrocoagulation and Fenton oxidation. Electrocoagulation stood out for being both cost-effective and environmentally friendly. Fenton oxidation, meanwhile, uses powerful hydroxyl radicals to break down microplastics, making it a strong chemical option for treating sludge. Together with process improvements, these methods show real potential in reducing microplastic pollution. But we didn't stop at removal. We also explored a creative and sustainable way to repurpose microplastics by mixing them into bitumen for road construction. This not only solves the problem of disposal but also improves the quality of bitumen, making it more resistant to heat and wear. The only drawback we found was reduced ductility, meaning the material becomes less stretchy. Finding the right balance between strength and flexibility will be key moving forward. Overall, our work highlights the need to keep advancing treatment technologies and to adopt sustainable practices. By improving how we treat wastewater and rethinking how we use waste, we can help create cleaner cities and more responsible ways to manage plastic pollution.

REFERENCES

[1] M Esskifati, Y El Hammoudani, K Haboubi, F Dimane, “Electrocoagulation as a Possible Treatment for Wastewater Contaminated with Microplastics - A Review”, BIO Web of Conferences, 2024, Volume 109

[2] Nioushasadat Haji Seyed Javadi, Ailar Hajimohammadi, Soheil Heydari, James Jeremy Kien Chung Ng, John Emmanuel Kypreos, Nasser Khalili, “Investigating the applicability of storage stability test for waste plastic modified bitumen: Morphological analyses”, Construction and Building Materials,2024, Volume 441

[3] Helena Ruff ell, Olga Pantos, Brett Robinson, Sally Gawa, “A method for the extraction of microplastics from solid biowastes including biosolids, compost, and soil for analysis by µ-FTIR”, MethodsX, Volume 12, June 2024

[4] Aakash Singh, Ankit Gupta, “Upcycling of plastic waste in bituminous mixes using dry process: Review of laboratory to field performance”, Construction and Building Materials, Volume 425, 2024

[5] JP Ribeiro, L Sarinho, MI Nunes, “Application of life cycle assessment to Fenton Sprocesses in wastewater treatment–A review”, Journal of Water Process Engineering, 2024, Volume 57

[6] M Ammar, E Yousef, MA Mahmoud, S Ashraf, J Baltrusaitis, “A Comprehensive Review of the Developments in Electrocoagulation for the Removal of Contaminants from Wastewater”, Separations, 2023, 10(6), 337

[7] AR Bracamontes-Ruelas, Y Reyes-Vidal, JR Irigoyen-Campuzano, L Reynoso- Cuevas, “Simultaneous oxidation of emerging pollutants in real wastewater by the advanced Fenton oxidation process”, Catalysts, 2023 ,13, 748

[8] Shams Forruque Ahmed, Nafisa Islam, Nuzaba Tasannum, Aanushka Mehjabin, Adiba Momtahin, Ashfaque Ahmed Chowdhury, Fares Almomanie, M. Mofijur, “Microplastic removal and management strategies for wastewater treatment plants”, Chemosphere, 2024, Volume 347

[9] M Shen, Y Zhang, E Almatrafi, T Hu, C Zhou, B Song, Z Zeng, G Zeng, “Efficient removal of microplastics from wastewater by an electrocoagulation process”, Chemical Engineering Journal, 2022, Volume 428

[10] Hamze Sharifi, Hossein Movahedian Attar, Bijan Bina, Occurrence and removal of microplastics in a municipal wastewater treatment plant with conventional activated sludge process: A case study in Isfahan, Iran, Environmental Health Engineering and Management, 2023, 10(1)