Removing Microplastics from Water Using Ferrofluids

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Introduction:

Plastic pollution in water is a large issue around the world. In fact, around the globe, the production or creation of plastic has nearly doubled from 2005-2025 alone. Mass production of plastic is not sustainable for the environment, and recycling plastic alone will not address the issue of plastic pollution. Plastic pollution has been shown to have negative effects on the environment, impacting ecosystems and the organisms in them, including us.

For example, a 2024 study in The New England Journal of Medicine found that people with microplastics in their artery plaque had a 4.5 times greater risk of heart attack, stroke, or death within three years compared to those without

Microplastics accumulate in oceans, rivers, and sediments, disrupting ecosystems and contaminating drinking water sources. They can persist for hundreds of years because plastics degrade very slowly. Fish, shellfish, and plankton ingest microplastics, mistaking them for food. This leads to blockages, internal injuries, and starvation since the plastic provides no nutrients. It can also alter behaviour and reproduction in marine animals. A 2025-study of commercial fishes in the South China Sea and Straits of Malacca found microplastics in edible tissue of several species commonly eaten. This raises concern for human exposure via seafood.

Inhaled or ingested microplastics can cause inflammation, oxidative stress, and cellular damage in tissues. Microplastic particles have been found in lungs, blood, and placentas, raising concerns about systemic effects. Many plastics contain additives (like BPA, phthalates, flame retardants) that can leach out and disrupt hormones or damage organs.

Chronic exposure may contribute to endocrine disorders, reproductive problems, or cancers. A review article published in 2025 found that micro- and Nano plastics (MNPs) can enter the human body via ingestion, inhalation, and possibly skin contact; they can be transported through the circulatory system, and accumulate in various organs and tissues.

Microplastics enter effluent water through a combination of domestic, industrial, and urban sources. When people wash synthetic fabrics such as polyester, nylon, or acrylic, large numbers of microfibers are released into wastewater. Similarly, cosmetics and cleaning products Industrial sources. Even though modern wastewater treatment plants can remove a large portion of these particles, a small fraction, especially micro- and Nano plastics, pass through the filters and remain in the treated effluent water that is discharged into rivers, lakes, and oceans.

Over time, these microplastics accumulate in aquatic ecosystems, where they are ingested by fish, shellfish, and other organisms, entering the human food chain. Humans are exposed to microplastics mainly through drinking contaminated water, eating seafood, and inhaling airborne particles that originate from effluent discharge or sewage sludge. Thus, microplastics in effluent water form part of a continuous pollution cycle in which plastics from human activities re-enter the environment and ultimately return to the human body.

Microplastics have now been detected in tap water around the world, raising serious concerns about their potential impact on human health. These tiny plastic particles smaller than 5 millimetres enter water supplies through multiple pathways. A major source is effluent water from wastewater treatment plants, which often still contains microplastics that pass-through filtration systems. When this treated water is discharged into rivers or reservoirs, it contaminates the sources from which drinking water is drawn.

Focusing on the leather and garment industries around small towns in India, it has been observed that many people involved in these sectors are not well educated about proper methods for treating effluent water. As a result, untreated wastewater is often discharged into large water bodies or allowed to seep into the groundwater. This practice poses serious environmental risks, threatening ecosystems and human health. According to my research, the issue stems not only from a lack of awareness but also from the need for cost-effective solutions. Therefore, through this study, I aim to investigate whether ferrofluid can effectively reduce microplastics from wastewater in a budget-friendly and sustainable manner.

Across India, Effluent Treatment Plants (ETPs) play a vital role in managing industrial wastewater. They are commonly used in large industries such as textiles, leather, chemicals, and pharmaceuticals. However, in many small towns and industrial clusters, particularly in states like Tamil Nadu (Ranipet, Vellore), Uttar Pradesh (Kanpur), Punjab (Ludhiana), and West Bengal (Kolkata’s leather complex), the installation and maintenance of ETPs remain a major challenge.

Many small and medium enterprises (SMEs) either lack proper ETPs or operate them inefficiently due to high operational costs, limited technical knowledge, and low awareness about environmental impacts. As a result, untreated or partially treated wastewater is often discharged into rivers or allowed to percolate into the ground, contaminating soil and groundwater.

Typical Cost Ranges

- For very small-scale plants (e.g., packaged units of 500 litres to 2 KLD) the cost can be around ₹1.35 lakh (≈ ₹135,000) for the unit itself.
- For small–medium industrial ETPs (say 10–100 KLD) the capital cost is often in the range ₹2.5 lakh to ₹10 lakh (≈ ₹0.25 to 1 million) depending on complexity.
- For larger ETPs / common effluent treatment plants (CETPs) or those requiring advanced treatment (high TDS, ZLD etc), costs can go up to ₹3-4 crore per MLD (≈ ₹30-40 million per 1 million litres/day) in some cases

So now we are going to find out is ferrofluid good enough to remove microplastic from water or not?

Research question?

Will ferrofluid be able to remove microplastic from water?

Hypothesis:

It is hypothesized that increasing the ferrofluid concentration in contaminated water will significantly increase the removal efficiency of microplastics, up to a certain saturation level beyond which the effect may plateau.

Ferrofluids are composed of magnetic nanoparticles that can interact with microplastic particles through physical and chemical attractions such as hydrophobic interactions and surface adhesion. When exposed to an external magnetic field, these ferrofluid-coated microplastics can be pulled out of the water using magnets, thereby reducing pollution levels.

At low ferrofluid concentrations, only a portion of the microplastics may come in contact with magnetic nanoparticles, leading to limited removal efficiency. As the concentration of ferrofluid increases, more nanoparticles are available to bind with the microplastics, resulting in higher removal rates. However, after reaching a saturation point, adding additional ferrofluid is not expected to further improve efficiency because most microplastic surfaces will already be coated or magnetically responsive. Beyond this point, excess ferrofluid may even hinder visibility and increase contamination of the treated water.

Therefore, the relationship between ferrofluid concentration and microplastic removal is expected to show an initial increase followed by a plateau, demonstrating an optimal ferrofluid concentration for effective and economical cleanup.

Method:

This project is divided into two parts

Part 1: Making of ferrofluid

Part 2: using ferrofluid to remove microplastic from different varieties of water

Part 1: Making of ferrofluid

Procedure:

- Prepare 100 mL of 1M $FeCl_2$ and 100 mL of 2M $FeCl_3$ solutions.
- Mix $FeCl_2$ and $FeCl_3$ solutions in a 1:2 ratio.
- Add NH_4OH slowly while stirring until pH 10.
- Stir for 30 minutes.
- Add oleic acid (surfactant) to stabilize nanoparticles.
- Centrifuge and wash nanoparticles with distilled water.
- Disperse nanoparticles in a carrier liquid (e.g., water or oil) to create ferrofluid

Part 2: Using ferrofluid to remove microplastic from different varieties of water

- Effluent water
- Ocean water

Effluent water

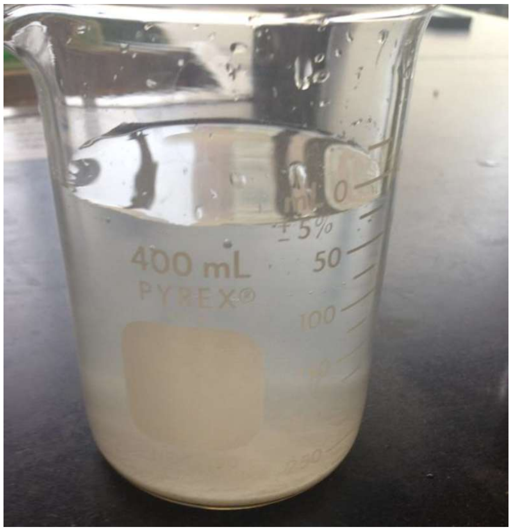
Mixing with effluent water:

- Introduce the ferrofluid into microplastic-contaminated water.
- Stir or circulate to ensure nanoparticles attach to microplastic particles (both Fibers and fragments).

Magnetic separation:

- Use a **magnet or magnetic separator** to attract the ferrofluid-microplastic clusters.
- The cleaned water can then be collected.

Ocean water



- Release the ferrofluid in a **controlled area** of contaminated seawater.
- Use **stirring mechanisms or slow circulation** to maximize contact between ferrofluid and microplastics.

Aggregation

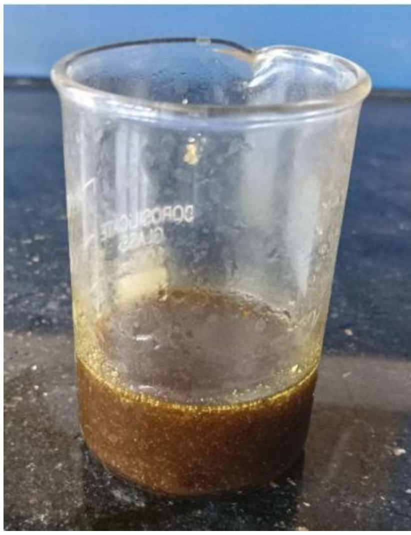
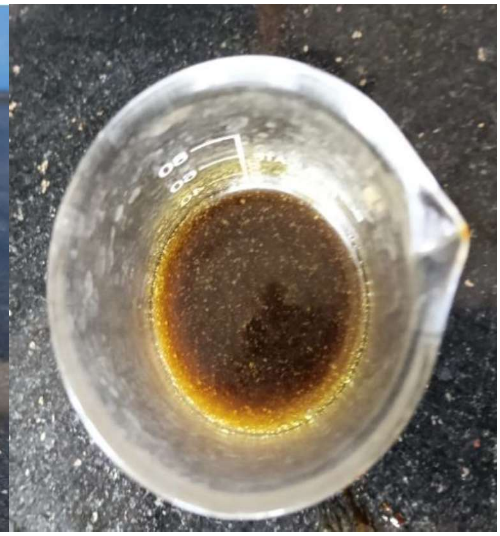
- Microplastics attach to ferrofluid nanoparticles due to **hydrophobic interactions**, forming magnetic clusters.

Magnetic Extraction

- Apply **strong magnets** or magnetic collectors to pull out the ferrofluid-microplastic aggregates.

Result:

Part 1- Ferrofluid

This is ferrofluid with this we are going to remove microplastic from effluent water and ocean water

Part 2-

This is result for pH level before using ferrofluid and expected final colour

Type of Water	Initial Colour	Final Colour	Initial pH
Effluent Water	Brownish	Black	7.2
Ocean Water	Light Blue	Dark Grey	8.1

This is for amount of microplastic found

Type of water	Magnet Strength (Gauss)	Duration of Magnet Application (min)	Microplastics Collected (mg)	PH LEVEL
Effluent Water	1500	3		
Effluent Water	2000	5		
Ocean Water	1500	3		
Ocean Water	2000	5		

The remaining result is in process

Discussion:

Based on my results and theoretical understanding, the method of using ferrofluid to extract microplastics from two types of water bodies proved to be successful. The ferrofluid was effective in attracting and removing small plastic particles from the simulated water systems. However, some limitations were also observed.

After extraction, the treated water was not suitable for drinking because traces of ferrofluid remained suspended, turning the water black in colour. Although this treated water can be repurposed for non-potable uses such as washing vehicles or cleaning surfaces, it is not safe for human consumption. Additionally, using this technique on a large scale, such as in ocean cleanup, would require a significant quantity of ferrofluid, making it costly and less practical in its current form.

In future research, I aim to improve the process by developing more eco-friendly magnetic fluids or alternative low-cost materials that can remove microplastics effectively without contaminating the water or altering its appearance.

Conclusion:

This confirms the potential of ferrofluids as a promising tool for addressing microplastic pollution in small-scale water systems, particularly in industrial wastewater such as that produced by the leather and garment sectors in India.

However, the study also revealed key limitations. The treated water turned dark due to the presence of ferrofluid residues and was therefore unsuitable for drinking or direct release into natural water bodies. In addition, large-scale applications—such as cleaning ocean water—would require significant quantities of ferrofluid, making the process expensive and difficult to implement sustainably.

Future research should focus on refining this technique to make it more environmentally friendly and cost-effective. This could include developing biodegradable or water-compatible magnetic fluids, improving recovery methods for ferrofluid particles, and testing the process on real industrial effluents. With continued innovation, ferrofluid-based treatment could become a practical and affordable solution for reducing microplastic pollution in developing regions.

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