Abstract

Microplastics in both industrial effluent and ocean water pose a growing threat to ecosystems and human health. This project investigates an innovative removal method using ferrofluids — magnetic liquids that bind to microplastics and can be extracted with a magnet. By comparing results in effluent water and ocean water, we assess how well this technique performs under real-world conditions and its potential for scalable environmental cleanup.

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.

Introduction

Plastic pollution has become a major global crisis, with plastic production nearly doubling between 2005 and 2025. Because plastics degrade extremely slowly, they accumulate in water bodies and ecosystems, posing serious environmental and health risks. Microplastics—tiny plastic particles less than 5 mm—have been found in oceans, rivers, sediments, seafood, and even drinking water and human tissues.

Studies in recent years highlight their dangers:

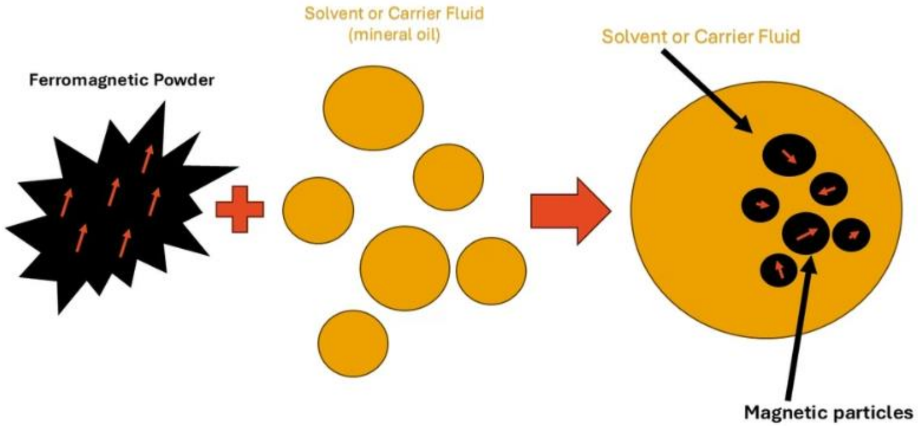
- A 2024 study in *The New England Journal of Medicine* showed that people with microplastics in their artery plaque had a **4.5 times higher risk** of heart attack, stroke, or death within three years.
- A 2025 study found microplastics in edible tissues of common fish species, raising concerns about human exposure through seafood.
- Research indicates that micro- and nano plastics can enter the body through ingestion, inhalation, and possibly skin, accumulating in organs and causing inflammation, oxidative stress, hormonal disruption, and potential chronic diseases.

Microplastics enter effluent water from domestic laundry (synthetic textiles), cosmetics, cleaning products, and industrial discharges. Although wastewater treatment plants remove many particles, micro- and nano plastics often pass through, re-entering the environment and eventually the human food chain.

In India, the problem is intensified in small towns with leather and garment industries, where lack of awareness and high costs lead to untreated wastewater being discharged into rivers or groundwater. While Effluent Treatment Plants (ETPs) exist, many small and medium enterprises struggle with installation and maintenance due to high costs and limited technical knowledge.

Typical ETP costs range from:

- ₹1.35 lakh for very small systems,
- ₹2.5–10 lakh for small/medium plants,
- ₹3–4 crore per MLD for large advanced systems.



Research question?

Will ferrofluid be able to remove microplastic from water?

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

Materials

- Magnetite powder (Fe_3O_4) – also sold as black iron oxide
- Vegetable oil, mineral oil, or light machine oil
- Strong neodymium magnet

Steps

- Add magnetite powder to a small container (around 1–2 teaspoons).
- Pour a small amount of oil (½ to 1 teaspoon) into the magnetite.
- Mix thoroughly until it becomes a smooth black liquid.
- Add a little more oil if it is too thick; add more powder if too runny.
- Test with a magnet—the fluid should move, form spikes, or follow the magnet.

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

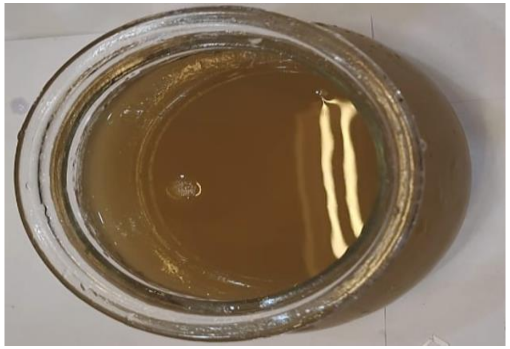
- **Effluent water**
- **Ocean water**

Effluent water

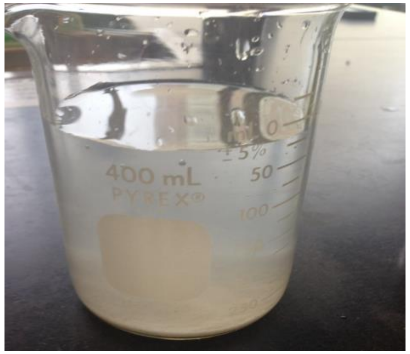
Steps

- Add 250 ml of effluent water to a petri dish
- Add 15 ml of ferrofluid to the petri dish
- Mix them thoroughly with a wooden stick
- Then use a magnet to remove ferro fluid which coats around the

Effluent Water



Ocean Water



Ocean water

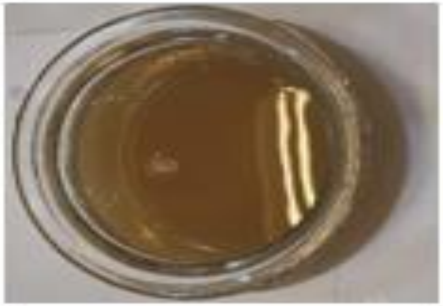
Steps

- Add 250 ml of ocean water to a petri dish.
- Add 15 ml of ferrofluid to the petri dish.
- Mix them thoroughly with a wooden stick.
- Then use a magnet to remove ferro fluid which coats around the microplastic.

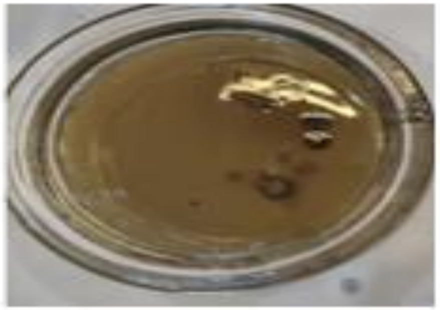
Data tabulation

Effluent water :

Before



After

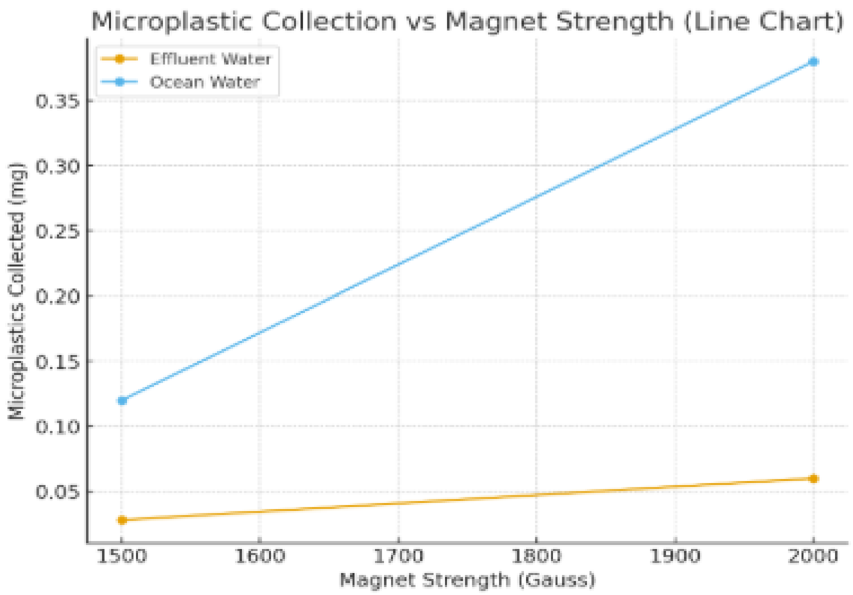


Ocean water:

Before

After

Type of water	Magnet Strength (Gauss)	Duration of Magnet Application (min)	Microplastics Collected (mg)	PH LEVEL
Effluent Water	1500	3	3	7.4
Effluent Water	2000	5	4.5	7.1
Ocean Water	1500	3	1.2	8.1
Ocean Water	2000	5	2	8.0



Result

Based on the experimental observations, ferrofluid demonstrates clear potential for the removal of microplastics from both effluent water and ocean water. Higher magnet strength and longer exposure time resulted in greater quantities of microplastics being captured, indicating that magnetic extraction using ferrofluid is an effective method under controlled conditions. Although performance varied between water types—likely due to differences in salinity, pH, and microplastic composition—the overall results confirm that ferrofluid-assisted magnetic separation can successfully reduce microplastic levels. Further optimization of ferrofluid concentration, recovery methods, and environmental safety considerations will strengthen its applicability for large-scale water treatment.

The results support the hypothesis: **as ferrofluid concentration or magnetic intensity increases, microplastic removal also increases**, but the improvement begins to level off, indicating a saturation point where most available microplastic surfaces are already coated. Beyond this point, adding more ferrofluid or using stronger magnets does not significantly increase removal efficiency.

Overall, the findings confirm that ferrofluid can effectively remove microplastics from water, with its performance depending on concentration, magnet strength, and water characteristics. This suggests that ferrofluid-based magnetic separation is a promising technique for microplastic remediation when optimized for environmental conditions.

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.