Sponsored Thesis Project Competition on

"RE-IMAGINING URBAN RIVERS"

Season- 3

Project Title : Device for Removal of Microplastic pollution from river, Pawna
Creator : Kriti Mada, Dept. of Geology (B.Sc.)

National Institute of Urban Affairs

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Preface

This project investigates the separation of microplastic from riverine systems using iron oxide filings and electromagnets. For the study of the effects, microplastics were first defined and categorised. Then the creation of microplastics were done for each type of microplastic that was identified, keeping in mind the required size that fit the definition.

For the purpose of analyzing the efficiency, a crude photo-spectrometer was made, which was used to analyze spectrums of the solutions with microplastic and after treatment to compare and understand the separation efficiencies for different microplastic particles. It has been shown that this method to remove microplastics is efficient for fragmented and irregular shaped particles more than film or rounded particles.

Furthermore, the use of iron filings has proven to treat water polluted with oil as well, which was previously known (Dina Ewis et al, 2020, https://doi.org/10.1016/j.jwpe.2020.101583).

Acknowledgements

The idea of doing something for the environment was always an active thought, it was due to the 'Student Thesis Writing Competition Season 3' organized by NIUA and Namami Gange that I got an opportunity to translate my thoughts into actionable ideas and plans.

I thank my guide Dr. Devdutt Upasani for encouraging and helping me whenever I felt stuck, always coming to my aide at a moment's notice.

I would also like to thank my Geology departments HOD Prof. Shyam Mude and our retired principal Dr. Ravindrasinh Pardeshi of Fergusson College.

And the pillars of strength, my family, supported me throughout the execution of this project.

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1. Introduction

In today's world a life without plastic seems impossible. While plastic has proven more useful and diverse in application than any other material, they come bearing serious environmental, social, economic and health consequences. From the 1950s to the 1970s, only a small amount of plastic was produced, and as a result, plastic waste was relatively manageable. However, between the 1970s and the 1990s, plastic waste generation more than tripled, and now the amount of plastic waste we generate has risen more in a single decade than it had in the previous 40 years. [1]

Studies have increasingly shown that all the plastic pollution in the oceans largely stems from rivers that serve as conduits from the mainland to the oceans. It has been estimated that 1,000 rivers are accountable for nearly 80% of global annual riverine plastic emissions into the ocean, which range between 0.8 and 2.7 million tonnes per year, with small urban rivers amongst the most polluting. [2]

Plastics including microplastics are now ubiquitous in our natural environment. They are becoming part of the Earth's fossil record and a marker of the Anthropocene, our current geological era. They have even given their name to a new marine microbial habitat called the "plastisphere".[3] (figure from Lourens J. J. Meijer et al. DOI:10.1126/sciadv.aaz5803)

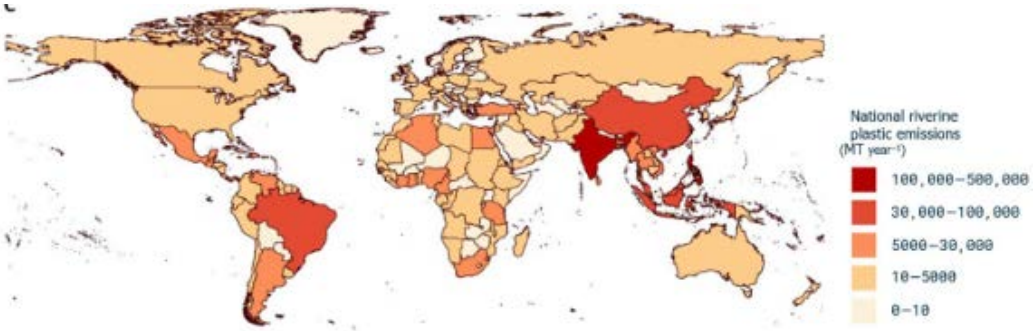


Figure 1 National Riverine Plastic Data

Keeping the increasing plastic problem that pollutes riverine environments, this project is an effort to investigate a possible solution to remove microplastics [4]. The method of extraction is by the use ferric oxides and electromagnets.

2. Approach Used

2.1 A look at Microplastic Properties

Due to its wide variety of application, plastics can be classified based on each type of use. There are definitions used by industry, medicine, science et cetera. While they vary slightly they share the fact that it concerns solid materials that can be molded and that consist of polymers. The International Organization for Standardization (ISO) defined plastic as "a material which contains as an essential ingredient a high polymer and which, at some stage in its processing into finished products, can be shaped by flow". (5)

- Basic Classification:

Base material	Description/examples	Typical products	Plastic?
Petro-based polymers	Polystyrene Polyethylene Polyurethane	Insulation Packaging, abrasives Swimwear,floors, matrasses	Yes
Bio-based polymers	Analogues of petro-based polymers made from renewable resources	Same as petro-based	Yes
Mineral-based polymers	Silicones	Breast implants Cookware Hair conditioners	Yes or no?
Natural biopolymers	DNA, proteins, wool, silk, amber, cellulose, natural rubber		No
Artificial biopolymers	Non-natural analogues of biopolymers		No
Modified natural polymers	Nitrocellulose, vulcanized rubber	Printing ink, laquers Car tyres	Yes Yes or no
Composites	Fibre-reinforced plastics	Boats, automotive, aircraft, clothing and fabrics	Yes
Elastomers	Rubber, silicones	Car tyres, roofing, toys, kitchenwear,	Yes or no ?

Table 1 Proposed assignment of base materials as sources of microplastic as proposed by Verschoor (2015) [5]

On heating a solid usually changes into its liquid state. Plastics are divided into thermoplasts (melt at heating), thermosets (disintegrate at heating). Elastomers are a particular group of elastic synthetic materials, which are excluded from the plastic definition by ISO [2]

For the project we will concern ourselves with petro/bio based plastic types.

- Solubility:

A **low solubility** is a common plastic property. The solubility depends on their polarity, molecular weight, branching, crosslinking degree, and crystallinity. Polar macromolecules like polyethyleneglycol (PEG), polyacrylic acid, polyacrylamide and polyvinyl alcohol (PVA) among others, are soluble in water. Conversely, nonpolar polymers or polymers showing a low polarity such as polystyrene, polymethyl methacrylate, polyvinyl chloride, and polyisobutilene are poorly soluble in water. [5]

We will concern ourselves with low solubility polymers, which are hydrophobic in nature.

- Persistence:

Plastics tend to survive for long, with residence times estimated from 100 to 1300 years [7]. Persistence is the resistance against degradation. Although some degree of degradation slowly takes place [8].

- Vertical Distribution:

Most microplastic distribution is till the first meter below the waters' surface [10]. This due to their lowered density, although over time they may sink and are known to behave like other lightweight sediment particles[11].

- Microplastic form and shape:

The microplastic data can be segregated based on particle shape and form. The dominant forms are fragments and lines[10], alongwith film and foam type.
For the project we shall create a minimum of 1 of each of these 4 categories defined above keeping in order size specifications of <5mm defined previously.

- Iron Oxides

Iron oxides are hydrophobic, like plastics and form stable emulsions with oil another hydrophobic agent. Studies have shown that hydrophobic NPs have the ability to keep water in oil emulsion stable due to the formation of the adsorbed layer of NPs at the oil–water interface (12)

And plastics are important agents in the transport of hydrophobic contaminants. (13)

From the above research it was hypothesized by the author that plastics would adsorb iron particles, which could thus be used to segregate it using the magnetic properties of iron oxide.

2.2 Materials for tests

2.2.1 Iron filings: Commercial iron oxide filings were used. Citric acid solution using lemons was made to use on iron to create corroded oxides.

2.2.2 Making of microplastics:

The plastic treatment consisted of "simulated" secondary microplastic materials (in the sense that they were not produced in the environment), which were processed for this experiment from commercially available products similar to the work of Lehmann et.al. [14].

1. For microfibers, polyamide (PA-nylon) was chosen obtained by manually cutting ropes.
2. Microplastic films were produced by manually cutting polyethylene terephthalate (PET) from plastic packaging.
3. For microplastic foams, we used polyethylene (PE), expandable polypropylene (EPP) and polyurethane (PU) products from packaging materials and domestic cleaning equipment for cleaning.
4. Microplastic particles were produced from polyethylene terephthalate (PET) sourced from water bottles, polypropylene (PP) sourced from talcum powder product container, high density polyethylene (HDPE) sourced from bottle caps and low density polyethylene (LDPE) sourced from containers.

The materials thus sourced after sanding and cutting were then scrutinized for their size. Below are the images of the created microplastic types. All 4 fragment types are photographed under microscope with 100x power.

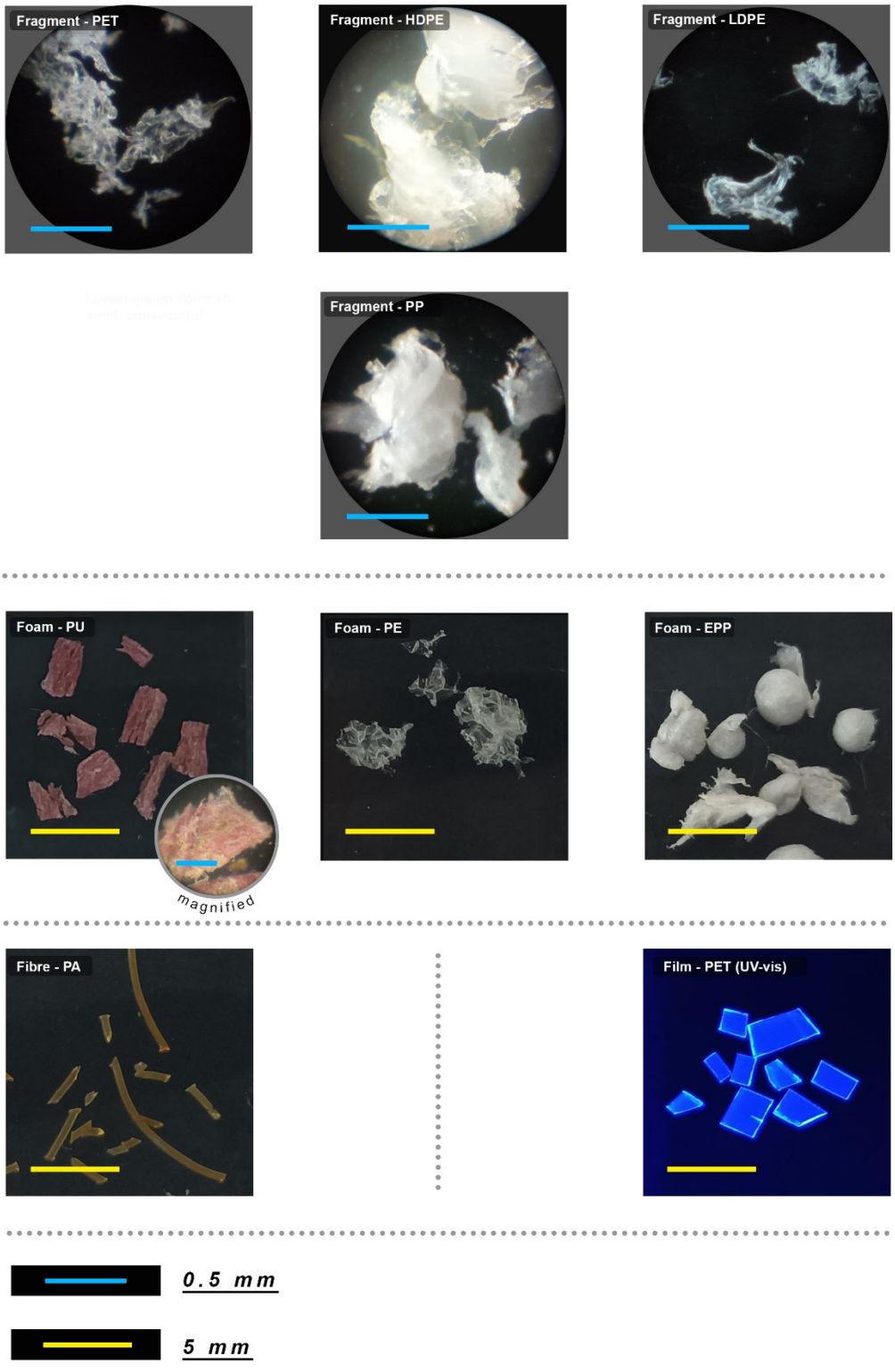


Figure 2 Microplastic Image used for testing. Fragment types are under 100X magnification

2.3 Concept of testing:

The idea is to use iron filings, and disperse it in water polluted with plastic. The iron particle which will then be adsorbed and will aid in the separation of the microplastics by means of a magnetic force. Additionally iron forms emulsions with oil, which in case of oil spills can also be treated. But the scope of this project will focus on microplastic removal.

Figure 6 Addition of PET fragments

Figure 5 Addition of iron filings and stirring

Figure 4 Removal of iron and PET using magnet

Figure 3 Iron filing and microplastic mixture after segregation

3. Results and Discussion

3.1 Spectrometer: To test the Efficiency

The Beer-Lambert law relates the attenuation of light to the properties of the material through which the light is traveling.

The absorbance of a solution:
For each wavelength of light passing through the spectrometer, the intensity of the light passing through the reference cell is measured. This is usually referred to as Io- that's I for Intensity.

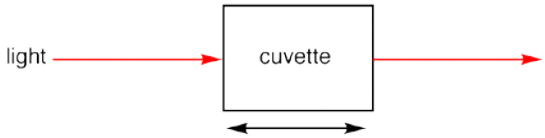


Figure 7 Light absorbed by sample in a cuvette (diagram from LibreTexts Chemistry page)

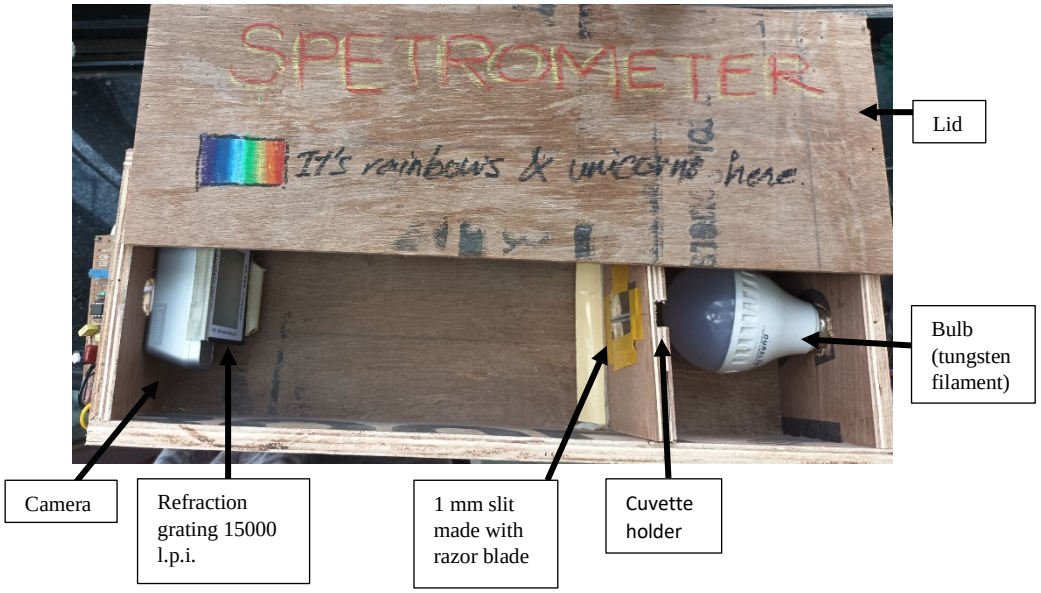
The intensity of the light passing through the sample cell is also measured for that wavelength - given the symbol, I. If I is less than Io, then the sample has absorbed some of the light (neglecting reflection of light off the cuvette surface). A simple bit of math is then done in the computer to convert this into something called the absorbance of the sample - given the symbol, A. The absorbance of a transition depends on two external assumptions.

1. The absorbance is directly proportional to the concentration (c) of the solution of the sample used in the experiment.
2. The absorbance is directly proportional to the length of the light path (l), which is equal to the width of the cuvette.

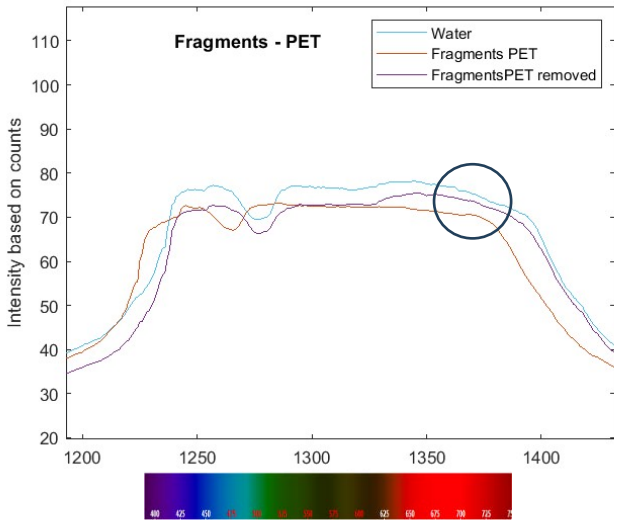
Keeping in mind point 1, it can be determined that photo-spectrometer graph of a solution with microplastic particles will record lesser intensity of light as compared to clear water for a particular wavelength. This spectrometry is done for 3 types of samples for each plastic particle type:

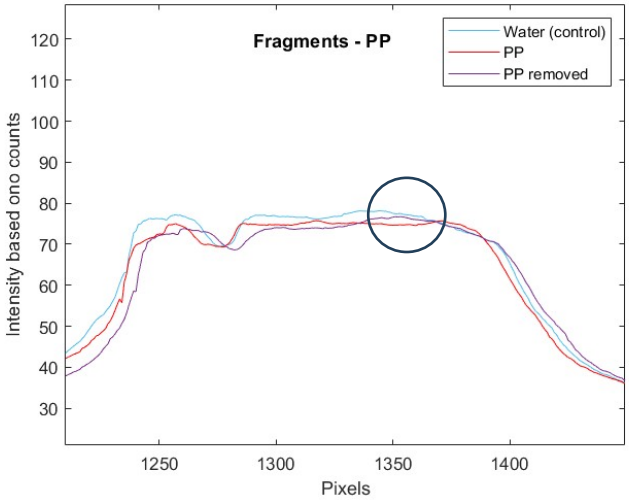
A. Water (control)
B. Sample with particulate matter
C. Sample after using iron filings for cleaning process

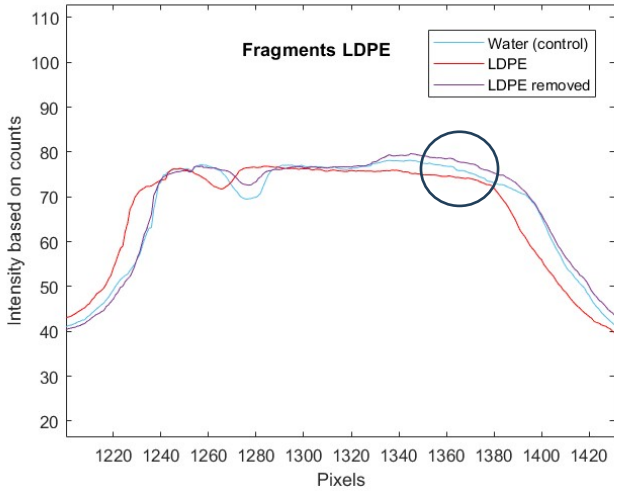
Figure 8 Crude Photo-spectrometer

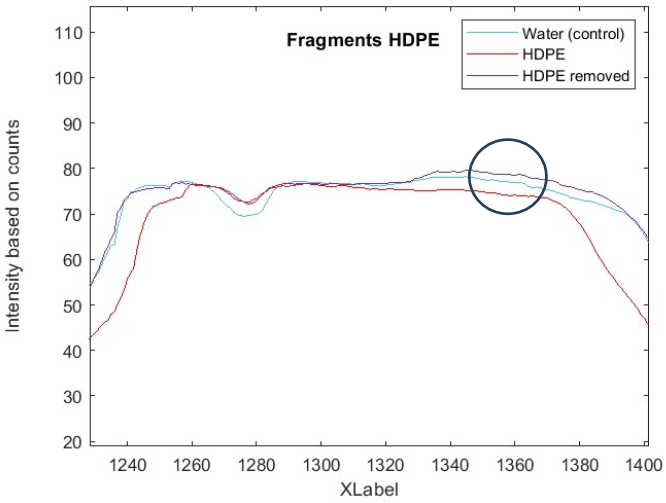


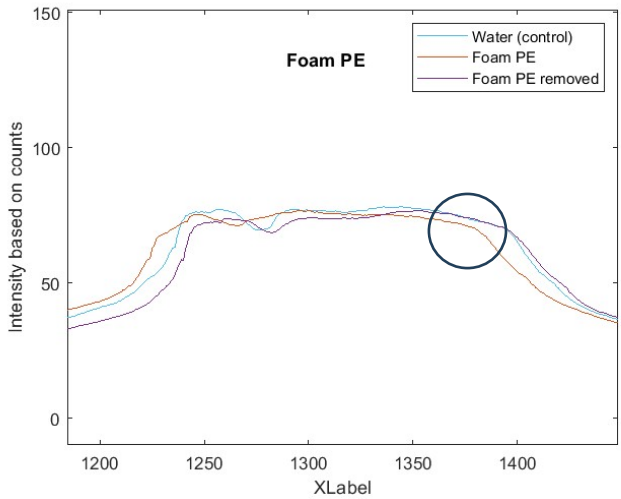
3.2 Photo-spectrometry data: For each microplastic type 10 samples were tested for which graphs were plot. An average of these has resulted in the final plot.
The concentration of plastic used was exceeding 38 particles/m^3 minimum [16].

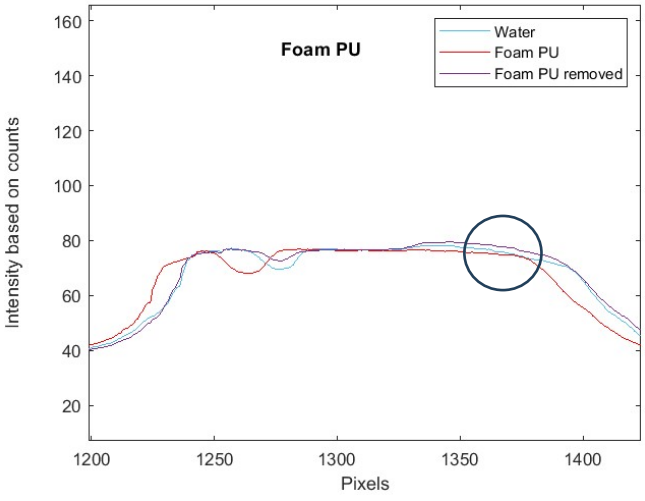


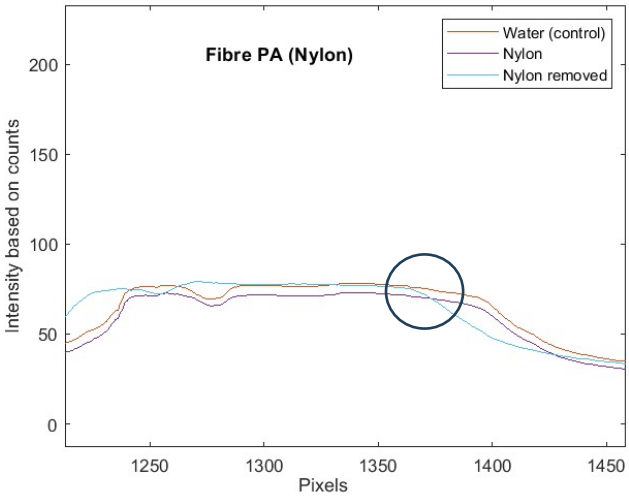


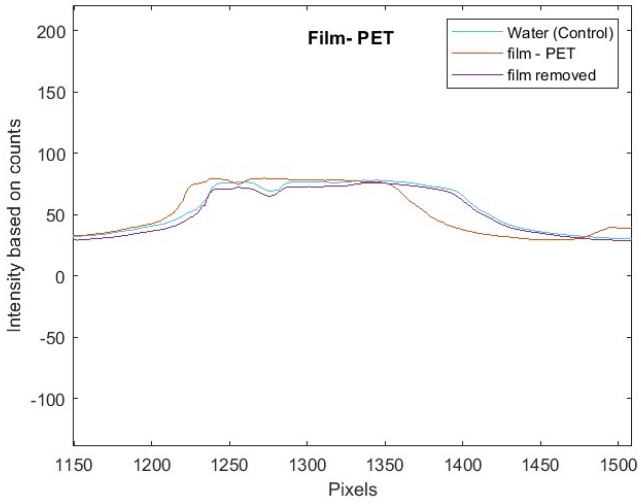












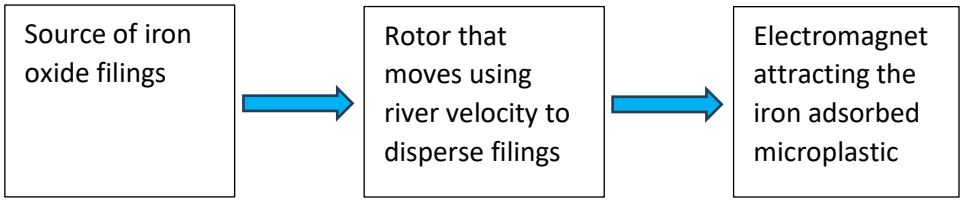
3.3 Data inference:

From the above data, we can interpret that using iron filings and a magnet is efficient in extracting microplastic particles in almost all the above plastic types, although its efficiency is very low for PET film, and more efficient for fragment type particles.

3.4 The Device:

The idea of a device that can introduce iron filings in the water which will then be adsorbed by the microplastic particles and then separated using electromagnets seems ideal.

Key thing to keep in mind would be that such a device would be used in a river system with continuous water flow.



Some key features to note:

- **Important feature of design should be to keep marine organisms safe and as undisturbed as possible.**
- **Utilize the rivers flow to power the electromagnet**
- **Use minimum space, and the form of small units so as to allow boats and other traffic.**
- **It will also be key to ensure that no large objects entangle in the rotor blades**
- **The electromagnet core with a casing should also be detachable for removal of collected particles.**
- **A casing is important to making collection of particles easy because the core may contain residual magnetism after removal of power.**

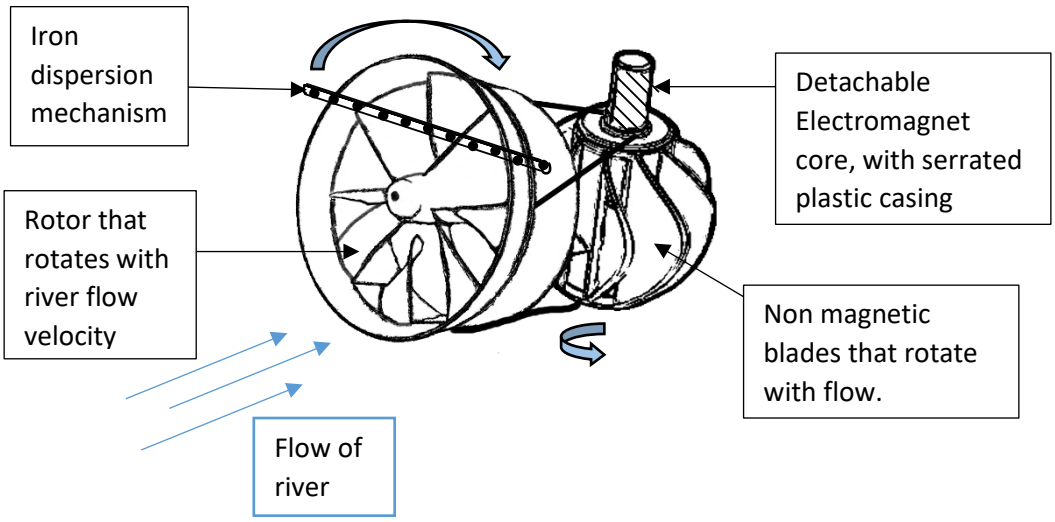
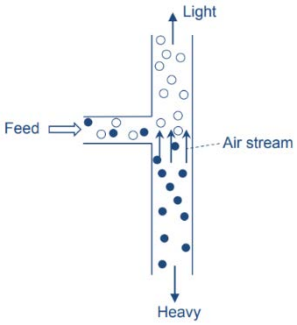


Figure 9 Design of microplastic separating machine

3.5 Discussion**:**

The retrieved plastic and iron filing mixture need to be separated. Currently no methods were found in the literature study done for the project. A ballistic separator which is based on a simple principle, that is, the different movement characteristics of particles of different size, shape, and weight can be separated. Other chemical alternatives need to be explored. [17]



For separation amongst plastic material much material exists like eddy current separation, magnetic separation etc. [18]

Figure 10 Schematic representation of ballistic sepperator

4. Conclusions

From the above results and study conducted it is apparent that iron filings are good adsorbents for microplastic. But the key feature to be noted is that the shape of particles should be more angular and jagged like the sanded fragments that were created.

The following method can be used for removal of oils from water as well.More research needs to be done for on ground results.

Microplastics will always remain despite our best efforts, but the results are hopeful.If we mitigate microplastic at the rivers our oceans will be protected from more damage.Further investigation is necessary in microplastic and iron seperation and their secondary use.

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CERTIFICATE OF COMPLETION

This is to certify that this thesis project titled "**Thesis Title**" was carried out by Sh./Smt. **Name of Student**, a student of **Name of Course**, at the **Name of Institute**. The research for this project was undertaken under the guidance of the afore-mentioned institute and completed during the period of **Start Date** to **End Date**.

This project was shortlisted under the *Sponsored Thesis Project Competition on "RE-IMAGINING URBAN RIVERS" (Season- 3)* hosted by the National Institute of Urban Affairs (NIUA) and the National Mission for Clean Ganga (NMCG).

This report has been submitted by the student as a final deliverable under the competition. All parts of this research can used by any of the undersigning parties.

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Signature	-	

2. Institute

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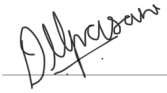
Department	-	Geology
Authorized Representative	-	Dr. Devdutt Upasani
Signature	-	

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