Biodiversity restoration and conservation of inland water ecosystems for environmental and human well-being

BioReset

BiodivRestore-406

2020 - 2021 Joint Call
Joint COFUND Call on “Conservation and restoration of degraded ecosystems and their biodiversity, including a focus on aquatic systems”

Deliverable 2.3.1

Microplastic removal using industrial by-products

Lead Beneficiary	Work package	Delivery month
IFE	1	24

1. Executive Summary

BioReset proposes to advance treatment processes (chemical, physical, biological and their combination) to promote ecosystem recovery and conservation and to develop assessment strategies. Diatoms will be used to model ecosystem conservation and restoration since their communities show high levels of biodiversity. The diatoms will provide an expeditious method to compare different recovery strategies and water treatment processes, allowing to address timescale and key conservation/restoration questions. The full environmental, economic, and social viability of the upgraded and innovative treatment technologies will be assessed. Based on this knowledge, scale-up studies in geographically different sites (Portugal and Spain) will be performed to ascertain the technical and economic feasibility at a larger scale and recommended action guidelines will be issued.

BioReset also envisages the creation of a representative space-time picture of the presence of emerging contaminants in inland waters and its correlation to effects on diatom communities. For this, powerful analytical techniques, such as gas- and liquid chromatography, will be used. Besides these methods, and to obtain real-time information, miniaturized analytical platforms that can perform fast, and on-site monitoring will also be employed.

Deliverable 2.3.1 provides details about the removal of microplastics from water using natural flocculants and biocarbon-based filtration.

2. Task description

WP2 regards Improving the effectiveness and upscaling of wastewater treatments for the removal of emerging contaminants (EC, pharmaceuticals and microplastics). Within this WP, Task 2.3 "Technological approaches for the removal of microplastics", involves the testing of innovative solutions based on the valorisation of industrial by-products as filtrations systems. In this task two novel approaches for microplastic removal from water bodies were explored: nature-based flotation chemicals and biocarbon filtration columns. The first approach involved utilizing nature-derived flotation chemicals such as alginate, carrageenan, starch, and their combinations. These biopolymers might possess inherent properties that enable them to selectively adhere to microplastics, facilitating their separation from water through flotation. Research has suggested the effectiveness of these natural compounds in removing microplastics across various water sources [1]. The second approach focused on filtration columns packed with biocarbon derived from diverse waste sources, including woodchips, coffee water, and wastewater sludge. Biocarbon, generated through pyrolysis processes, offers a porous and adsorbent medium capable of capturing microplastics as water passes through the column (3-5 µm particle size). The choice of waste sources for biocarbon production introduces sustainability and resource efficiency to the microplastic removal process. The content of microplastics were quantified before and along the treatment using the GC-Pyr-MS/MS method developed in Task 1.1.

3. WP1 - Task 2.3.1 team members

The Team members in WP2, Task 2.3, regarding microplastic removal using industrial by-products, were:

Name	Organization	Role
Laura Ferrando Climent	IFE	Task coordinator and researcher

4. Developed activities

Coagulant/flocculant approach with natural substances

The experiment aimed to evaluate the effectiveness of natural flocculants in removing MPs from water under controlled conditions. The study employed chemical coagulation using single dosages of selected reagents. A synthetic landfill leachate (SLL) was used as the test medium to simulate realistic contamination conditions.

Reagents

Four reagent systems were tested:

1. Carrageenates combined with calcium chloride
2. Alginate combined with calcium chloride
3. Starch
4. Combinations of the above

Experimental design

- Type: Batch experiment
- Apparatus: 1 L stirring tank
- Mixing Conditions: Controlled agitation at 40–150 rpm
- Exposure Time: 10 min

Dosage

- Calcium Chloride: 100–200 mg/L
- Natural flocculants:
  - Carrageenate: 2–10 mg/L
  - Alginate: 2–10 mg/L
  - Starch: 3% solution

Microplastics characteristics

- Polymer types: PE, PP, PET, PS, PU, Nylon 6, Nylon 66
- Particle size: 5 µm
- Nominal MP amount tested: PE: 160 µg, PP: 40 µg, PS: 8 µg, PU: 4 µg, PET: 16 µg, N6: 5 µg, N66: 18 µg

Column filtration using biocarbon materials

The experiment investigated the efficiency of biocarbon-based filtration columns for removing MPs from water. The study uses both SLL and real landfill leachate (RLL) spiked with MPs as test matrices. The company "Scandinavian Water Technology AS" provided the biocarbon materials.

Filtration system (Figure 1)

- Column Dimensions: 30 cm length, 3 cm internal diameter
- Packing Material: Biocarbon (50–100 g per column)
- Flow Rate: 2 mL/min
- Experiment Duration: 24 h
- Total Volume Processed: 1 L per experiment

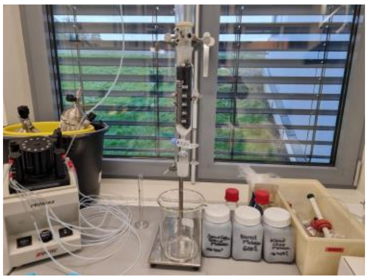

Figure 1. Filtration system with biocarbon materials

Biocarbon Types

Three types of biocarbon derived from pyrolysis of different waste materials were tested:

1. Pyrolyzed **coffee waste:** Density: 1.4 g/cm³ | Particle size: 3.5–5 µm
2. Pyrolyzed **wood briquette waste:** Density: 1.3 g/cm³ | Particle size: 3.5–5 µm
3. Pyrolyzed **sewage sludge:** Density: 1.4 g/cm³ | Particle size: 3.5–5 µm

The **microplastics characteristics** were the same as for the coagulant/flocculant approach.

5. Results

Coagulant/flocculant approach with natural substances

Table 1. Results from the coagulant/flocculant approach with natural substances for the removal of MP from a synthetic landfill leachate.

Reagents	Concentration	PE (µg)	PP (µg)	PET (µg)	PS (µg)	PU (µg)	N6 (µg)	N66 (µg)
Carragenate **Calcium chloride**	2 mg/L 100 mg/L	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Carragenate **Calcium chloride**	10 mg/L 200 mg/L	11 (± 10)	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Alginate **Calcium chloride**	2 mg/L 100 mg/L	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Alginate **Calcium chloride**	10 mg/L 200 mg/L	8 (± 6.5)	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Starch/pH 7	1%	<LOD	<LOD	<LOD	<LOD	<LOD	1 (± 1.2)	<LOD
Starch/pH 7	3%	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Carragenate **Alginate** **Calcium chloride**	5 mg/L 5 mg/L 200 mg/L	9 (± 8.5)	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Column filtration using biocarbon materials

Table 2. Results from column filtration using biocarbon materials for the removal of MP from synthetic and real landfill leachates.

Material	Type of water	PE (µg)	PP (µg)	PET (µg)	PS (µg)	PU (µg)	N6 (µg)	N66 (µg)
Pyrolised **coffee waste**	SLL	9 (± 8.5)	27 (± 17)	<LOD	<LOD	<LOD	<LOD	<LOD
Pyrolised wood **bricket waste**	SLL	<LOD	34 (± 32)	<LOD	<LOD	<LOD	<LOD	<LOD
Pyrolised **sewage sludge**	SLL	<LOD	33 (± 29)	<LOD	<LOD	<LOD	<LOD	<LOD
Pyrolised **coffee waste**	**RLL**	<LOD	44 (± 42)	<LOD	<LOD	<LOD	<LOD	<LOD
Pyrolised wood **bricket waste**	**RLL**	<LOD	46 (± 39)	1.5 (± 1.1)	<LOD	<LOD	<LOD	<LOD
Pyrolised **sewage sludge**	**RLL**	<LOD	47 (± 39)	<LOD	<LOD	<LOD	<LOD	<LOD

6. Conclusion

Both approaches showed promise for mitigating microplastic pollution in water bodies (synthetic and real landfill leachate) for PP, PE, PS, PU, PET, Nylon 6 and Nylon 66. Nature-based flotation chemicals offer a low-cost and environmentally friendly solution, harnessing the inherent properties of biopolymers to target microplastics selectively. On the other hand, biocarbon filtration columns offer versatility and scalability, leveraging waste materials to create effective filtration media. The results obtained highlight the importance of innovative, circular-based and natural-inspired solutions for addressing microplastic contamination in water, paving the way for sustainable water management practices and safeguarding the health of aquatic ecosystems and communities.

Take aways:

- All the natural-based coagulants showed up to 90% removal of PE and 100% removal of PP, PS, PU, N6 and N66
- Separation of MPs using biocarbon as filtration material showed almost 95% removal for all the MPs except for PP that was almost not removed. Further investigations on potential contamination are being carried out into this MP.
- Natural-based coagulants are presented as a low-cost sustainable approach to remove MPs from wastewaters unlike separation with biocarbon filters that was less efficient.
- Further investigations are needed into different particle sizes.
- Based on deviations found in the analytical results, and the necessity to run several replicates of the same sample, it can be concluded that analytical methods for MP analyzes in water compartments still require improvement in sample preparation for further quantification of MPs.

References

[1] César Cunha, Laura Silva, Jorge Paulo, Marisa Faria, Natacha Nogueira, Nereida Cordeiro, Microalgal-based biopolymer for nano- and microplastic removal: a possible biosolution for wastewater treatment, Environmental Pollution 263 (Part B) (2020) 114385. https://doi.org/10.1016/j.envpol.2020.114385