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A Transport Canada Plastics Challenge

Department of Chemical Engineering

Removing Microplastics from Ship Greywater

- Introduction -

Microplastics

- Small plastic pieces less than five millimeters in length.
- Primary microplastics exist in microfibre and microbead form. Secondary microplastics derive from a larger plastic source.

Greywater

- Drainage from dishwater, sinks, shower, laundry, bath and washbasins.
- Contains organic nutrients and chemical contaminants like oil, fat and grease; food particles; detergents; flame retardants; pharmaceuticals and cosmetic products; disinfectants; fecal coliform; and microplastics.

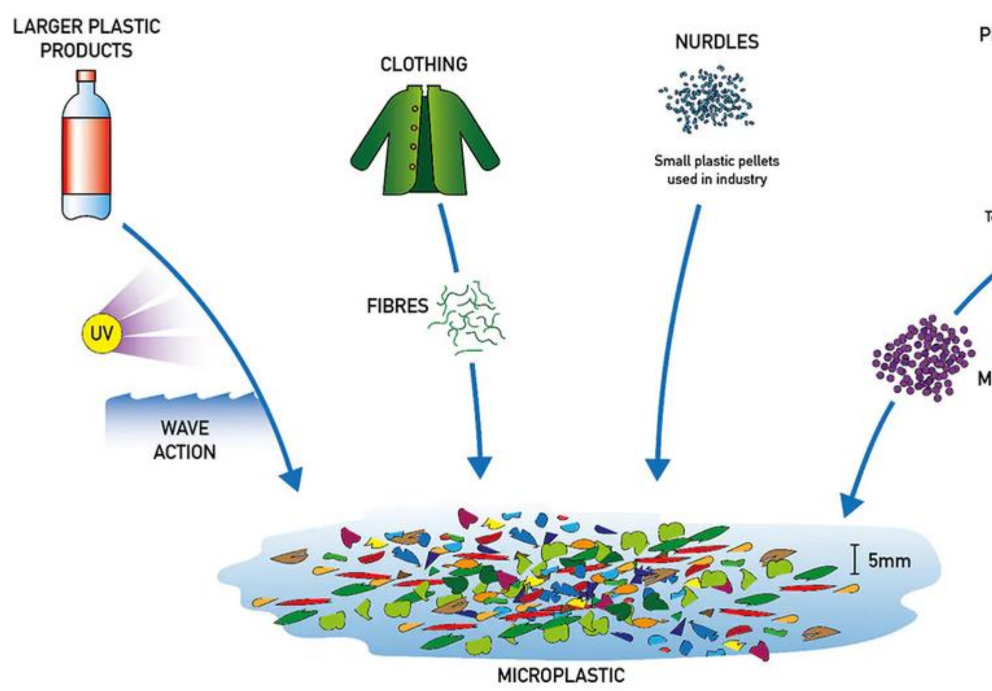


Figure 1: Common sources of microplastics

- Design Process -

- Design objective to capture 90% of microplastic particles, and approximately 98% by mass of microplastics.
- Cruise ships were selected as the target vessel. By using an average water production of 125L/person/day and a capacity of 3500 people, a flowrate of 400 L/h baseline was selected. A peaking factor of 2 was used for high flow conditions.
- Common microplastic removal techniques such as sieves, clarifiers, ferrofluid, ultrafiltration, membrane bioreactors (MBR), and dynamic membrane filtration were researched and evaluated using a decision matrix.
- Cost (1), space required (2) , effectiveness (3), environmental effects (1), engineering maturity (1), and ease of operation (2) were used as selection criteria (criteria weight).
- A **membrane bioreactor followed by ultrafiltration** was selected.
- Detailed designs of the screening system, MBR, and membrane filtration were completed.

- Details of Design -

Microplastic Size Distribution and Pollution Issue

- The average microplastic size is 606µm in length.
- Once they enter aquatic ecosystems, microplastics suspend in the water, 'disguising' themselves as food.
- Microplastics are consumed by aquatic life that mistake them for food. This can have severe effects and can drastically impact human health, as well as the aquatic species that consume the microplastics.

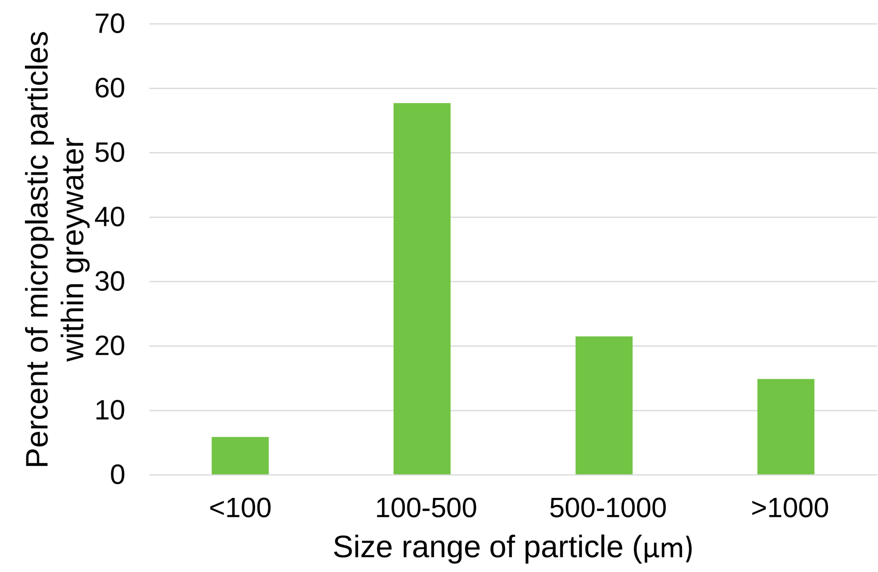


Figure 2: Microplastic distribution within greywater

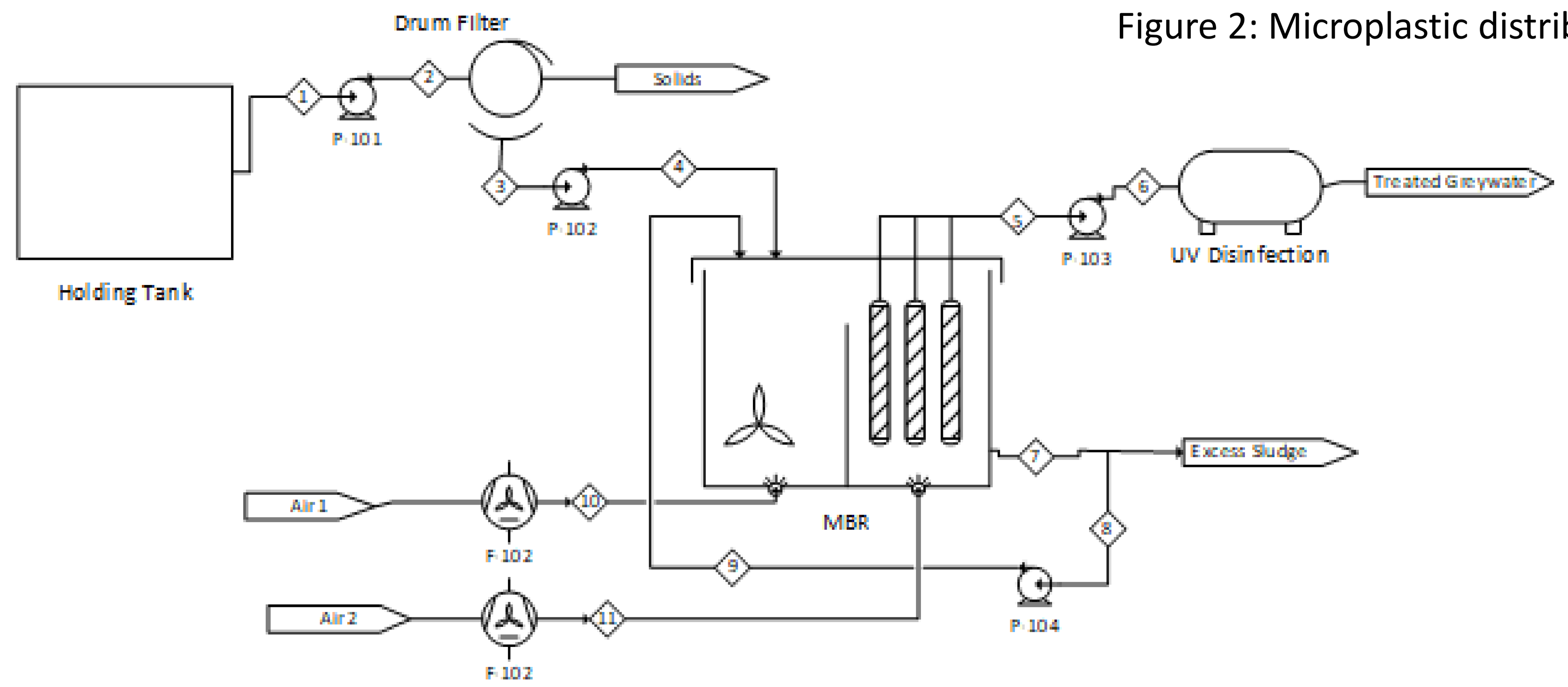


Figure 3: PFD of the design system

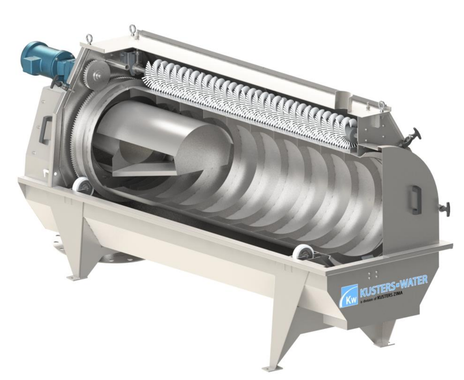
Treatment will consist of greywater being pumped from a holding tank to a rotating drum filter.

The greywater is then sent to a MBR with a submerged hollow fiber filter.

Water is then sent to UV disinfection before it is discharged

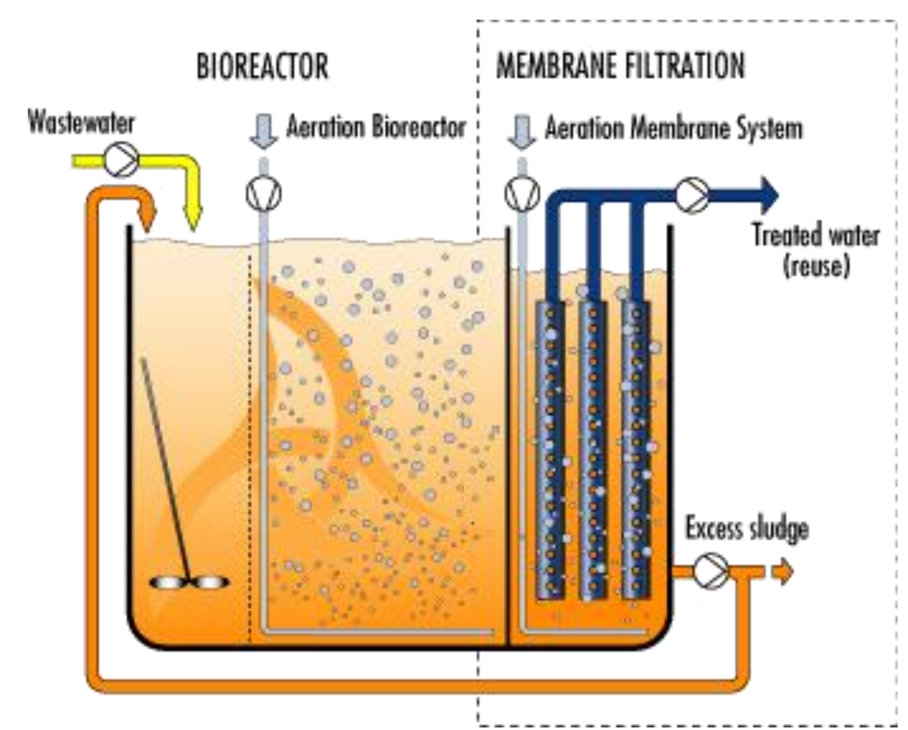
Step 1: Initial Screening

The initial screening consists of a holding tank and a rotary drum filter. As the drum rotates, water passes through the mesh filter and solids are entrained inside



Step 2: Biological Treatment

The bioreactor decreases the compositional complexity of the inlet greywater by consuming organic material and decreasing the BOD and COD of the slurry.



Step 3: Membrane Separation

The MBR system utilizes a submerged ZeeWeed Ultrafiltration (UF) membrane to filter 98% of detectable microplastics and produce a high-quality, low-turbidity effluent.

Step 4: UV Disinfection

Uses prebuilt TrojanUVfit. The 8 lamp system is easy to maintain and can satisfy the flow requirements.

Discharge!

- Conclusions and Recommendations -

Potential Hazards

- Greywater and microbe mixture released from bioreactor vessel.
  - Mitigate by equipping containment guard and pressure monitoring system
- Electricity in the presence of water containment
  - Mitigate by keeping electrical sources of the ground and away from potential water pooling locations
- Leaks
  - Mitigate by implementing a surrounding containment guard and an efficient/effective shut down procedure
- MBR gas release and buildup in confined ship haul
  - Automatic gas analyzers and alarms

Costs

- High initial capital cost investment
  - Includes materials, assembly, and purchased prebuilt components
  - Upwards of 150,000$
- Operational costs
  - Air
  - Power for pumps, fans, and motor
  - Part replacement (UV lamps, filters, drum mesh)
  - MBR microbe replacement
  - Labor and maintenance

Recommendations for Future Design Iterations

- Investigate ways to quantify the amount of microplastic removed without using laboratory testing
- Investigate applicability for small commercial vessels
- Create a system contained within one unit for easier operation

- Project Related References -

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