Optimization of Filtration Rig for Evaluation of Amazon Cartridge Fiber Filter for Manganese Removal in Drinking Water Treatment

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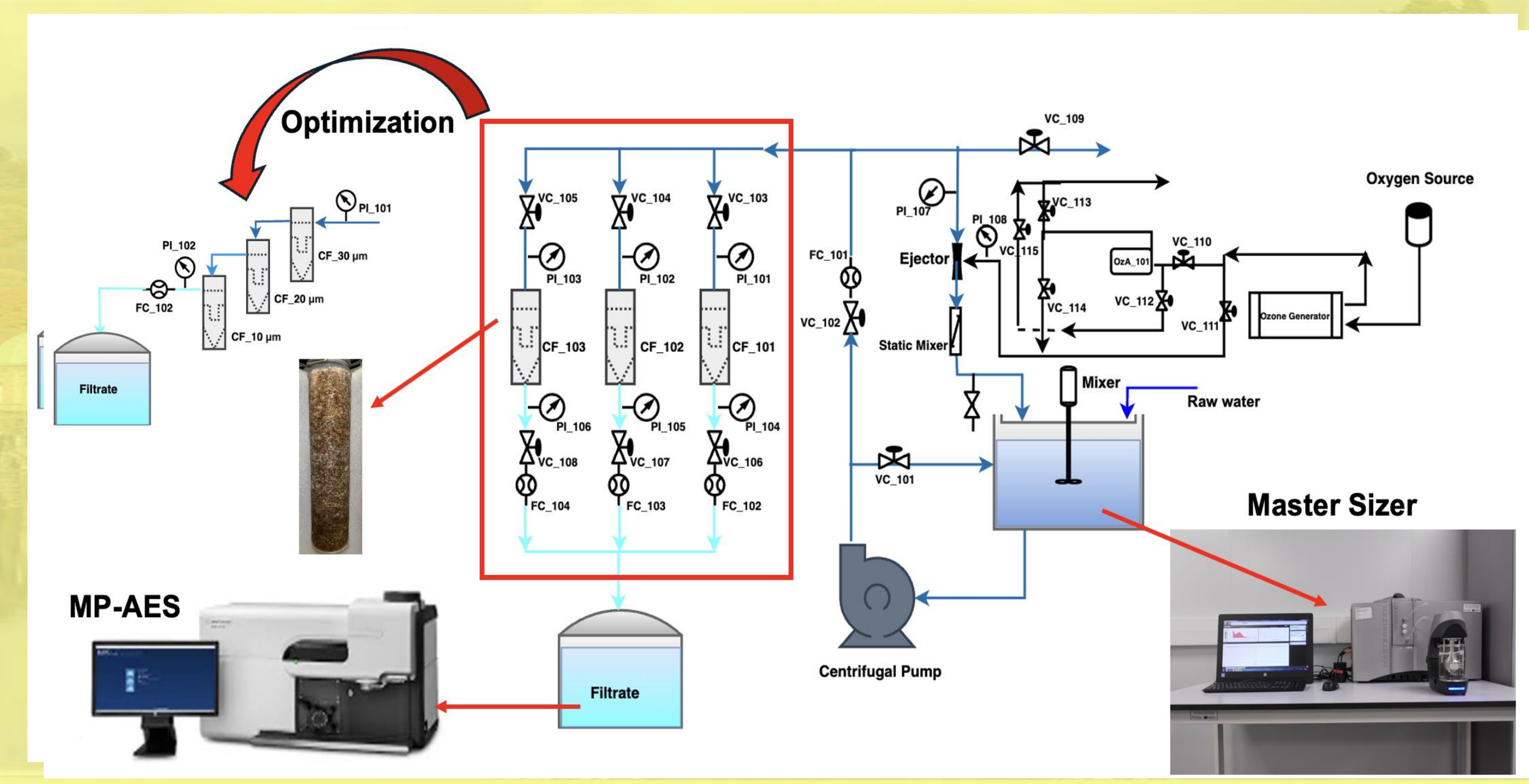
Introduction

- **Manganese** is a natural element in water (0.1% of Earth's crust) and can cause discolouration, stains, and deposits in water systems.
- The Welsh Water target for Mn in final water is 2 µg/L (**50 µg/L** by WHO).
- This study aims to **design a filtration unit** and assess the **Amazon cartridge fibre filter** for manganese removal in drinking water.

Method

- Cartridge Filter placed in filter housing was used at sizes of 10 (F10), 20 (F20) and 30 (F30) µm provided by Amazon Filter.
- The filtration unit included a pump, a 100-litre tank, and an ozone system.
- 3 Different oxidants were used to precipitate manganese: Permanganate, ozone, and hypochlorite.
- Analysis and characterization:
  1. SEM. 2. FT-IR
  3. MP-AES 4. UV-VIS
  5. TOC. 6. Master Sizer



Results

1. Manganese Removal

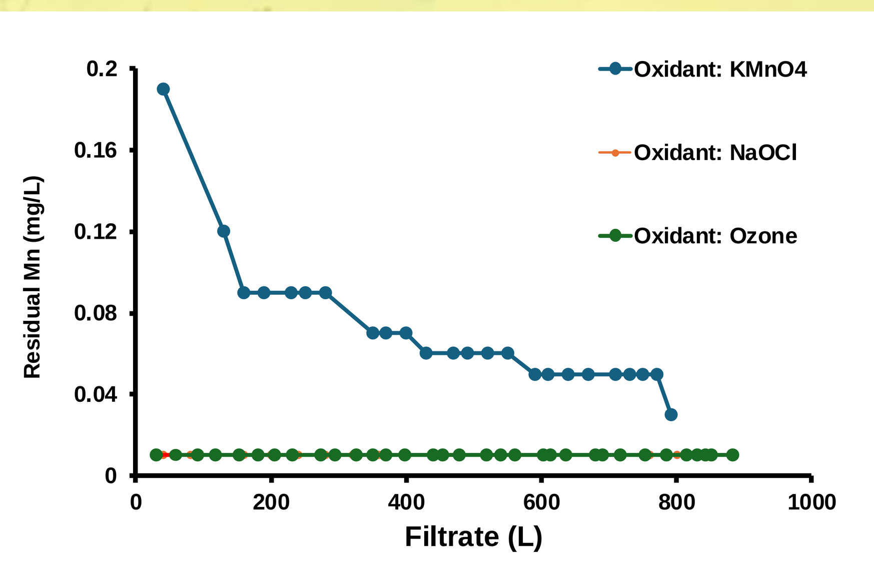


Fig.3.Mn removal using three different oxidants

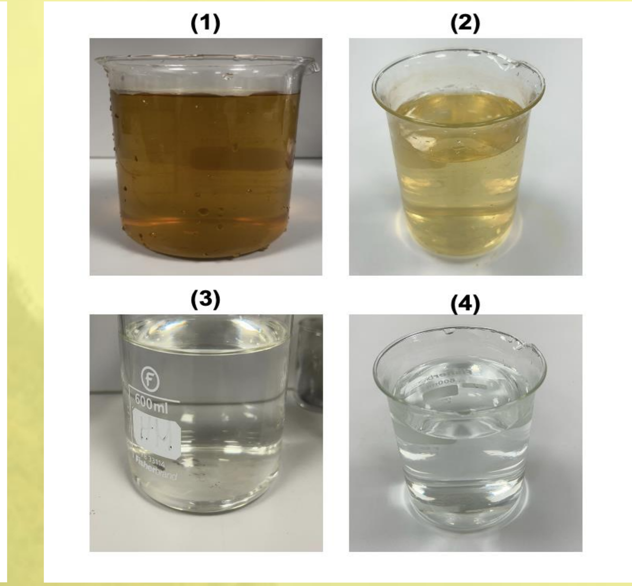


Fig. 2. Filtrate from: 1) 30 micron, 2) 20 micron, 3) 10 micron, 4) Optimized unit.

- **Mn removal was carried out based on stoichiometric molar ratios:**

$$3Mn^{+2} + 2KMnO_4 + 2H_2O \rightarrow 5MnO_2(s) + 2K^+ + 4H^+ \quad (1)$$

$$Mn^{2+} + ClO^- + H_2O \rightarrow Cl^- + 2H^+ + MnO_2(s) \quad (2)$$

$$Mn^{2+} + O_3(aq) + H_2O \rightarrow MnO_2(s) + O_2(aq) + 2H^+ \quad (3)$$

- **The developed Rig showed high efficiency for Mn removal, which reached ≥0.002 mg/L.**
- **The size of the particles was measured for each oxidant used as follows:**

O_3: 9.90 (µm), NaOCl: 11.21 (µm), $KMnO_4$: 13.45 (µm)

- **Particles penetrated and passed through 20 and 30-microns, as shown in Fig 2.**
- **TSS for 30, 20, and 10 microns and the optimised rig was 4.6, 1.6, 0 and 0 mg/L respectively**

2. Evaluation of pressure drop across filters

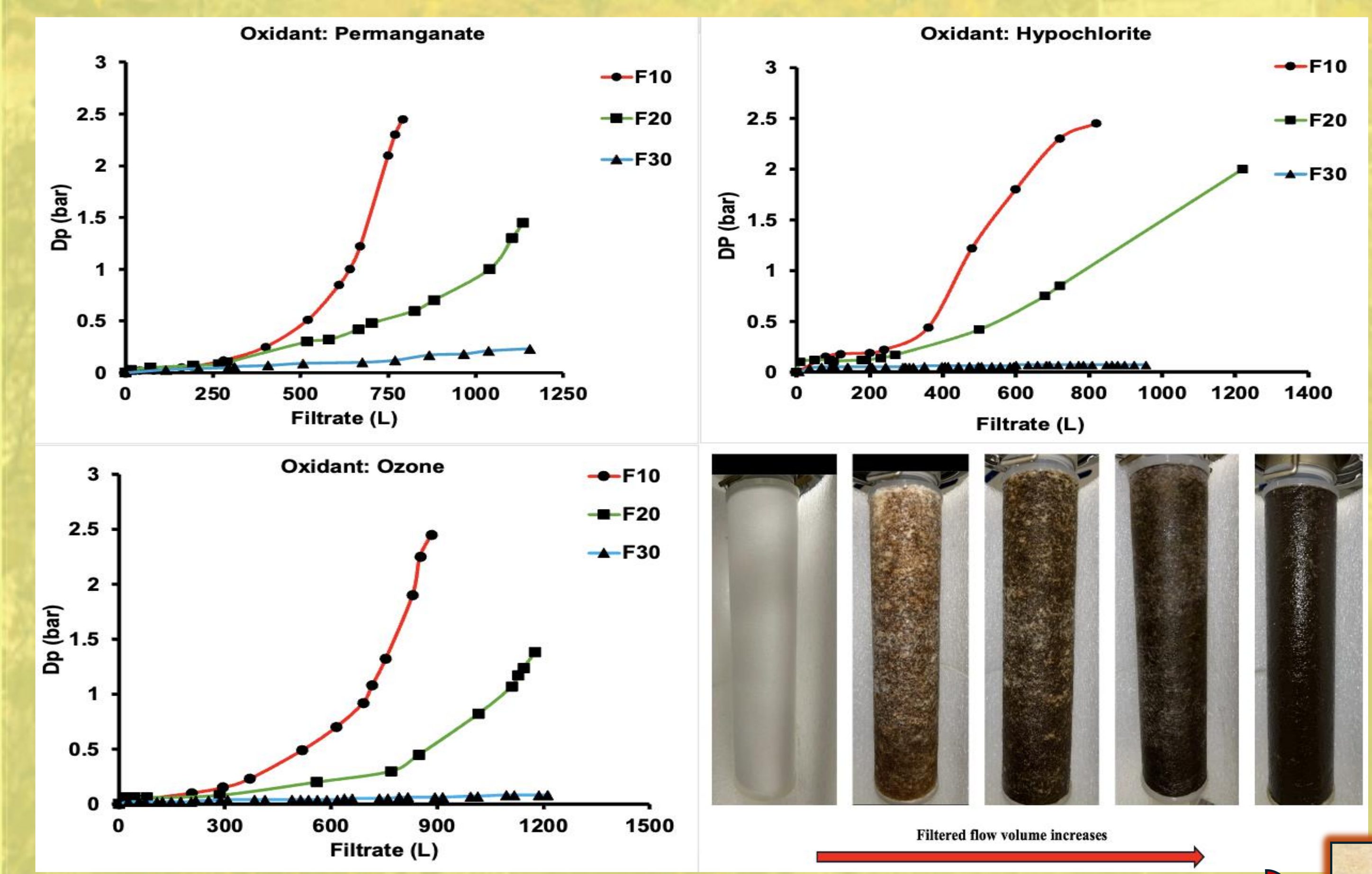


Fig.3. Pressure differential across filter media as a function of filtrate volume: 10, 20, and 30- microns using different oxidants (single filtration)

The pattern of particle deposition on filter's surface.
As more filtrate collected particles accumulation starts from bottom to top.

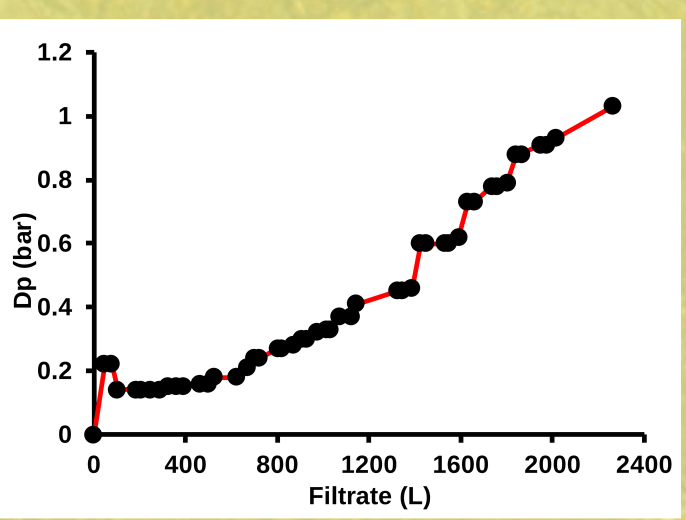


Fig.4. Pressure differential across filter media as a function of filtrate volume: series filtration (Optimised)

Table 1. Summarized data of Fig.3.

oxidant	Dp (bar)	V (L)_F10	Dp (bar)2	V (L)_F20	Dp (bar)3	V (L)_F30
KMnO4	0.4	430	0.4	630	0.04	208
NaOCl	0.4	442	0.4	760	0.04	292
O3	0.4	478	0.4	790	0.04	307
KMnO4	1	640	1	1013	0.06	311
NaOCl	1	671	1	1081	0.06	351
O3	1	679	1	1089	0.06	382
KMnO4	1.8	670	1.2	1085	0.08	420
NaOCl	1.8	793	1.2	1115	0.08	692
O3	1.8	843	1.2	1140	0.08	1094

- **The filter's fouling behaviour as the Mn particles retained is shown in Fig. 3&4.**
- **Pressure drops across F10, F20 and F30 were different depend on pore size, oxidant and particle size.**
- **F10 showed greater Mn removal, however, faster blockage.**
- **The developed Rig showed high efficiency for Mn removal, which reached below the Welsh Water target of 2 µg/L (Fig 5), with a significantly lower pressure drop. In addition, full Mn removal was achieved when humic acid was presented in water**

3. Filter characterization and cleaning

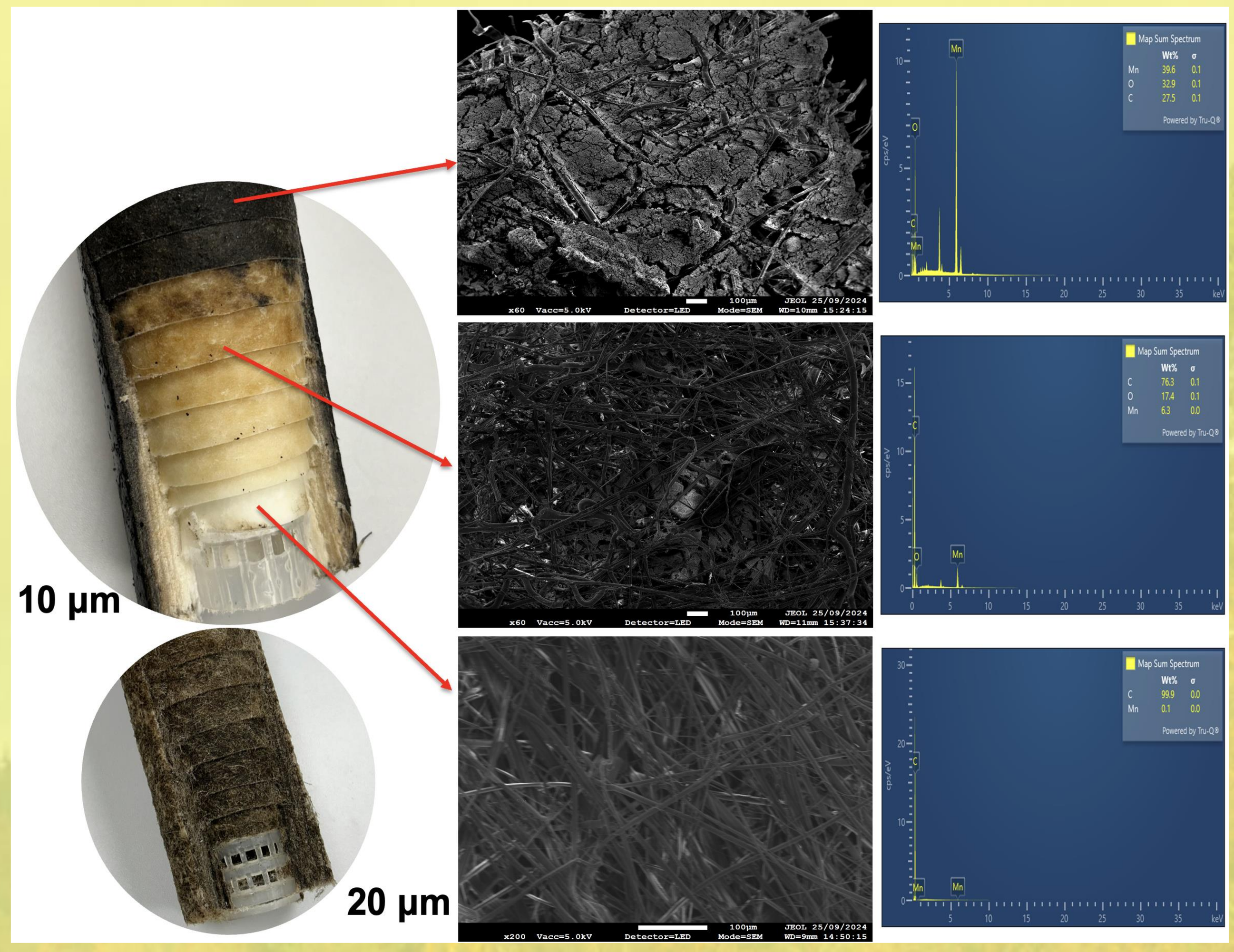


Fig.5. Morphology of the fibre filter by SEM-EDS

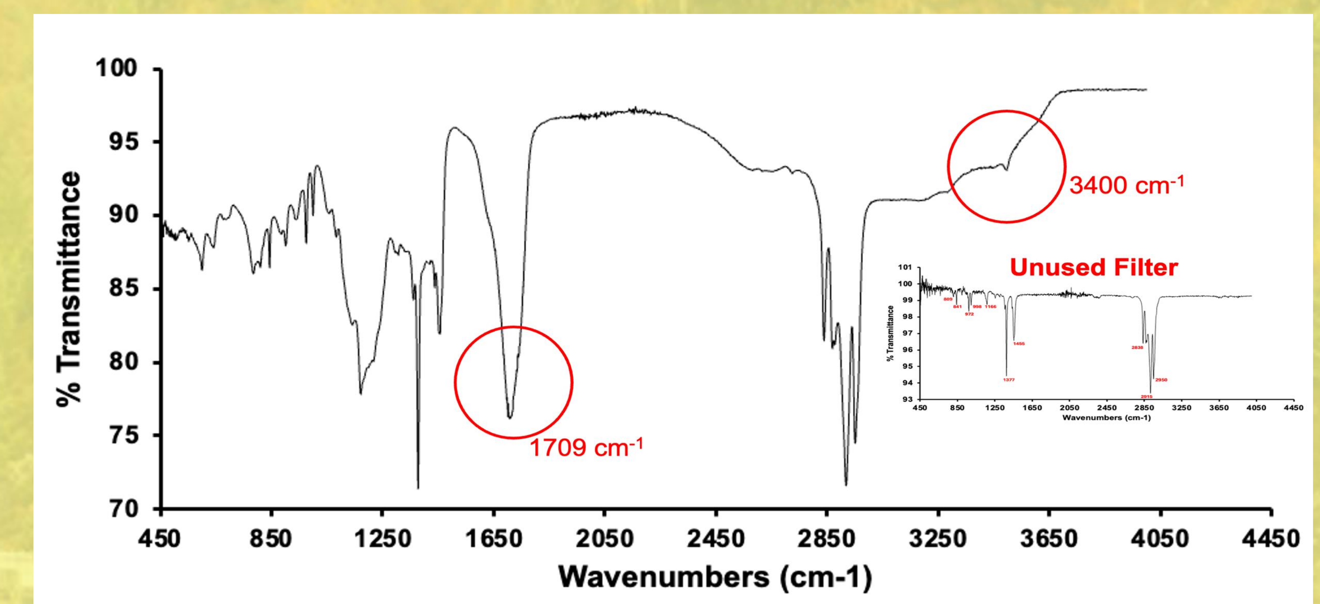


Fig 7. FTIR analysis of filter after cleaning

- **The peak between 1700-1710 cm^{-1}: absorption of a carbonyl (C=O) group**
- **The intensity of carbonyl peaks increased with decreasing carbon content. These results indicate the degradation of the filter over a long period of time during cleaning.**
- **In addition, the filter material was not affected by exposure to O_3.**
- **The appearance of O-H stretching of the hydroxyl group at 3400 cm^{-1}**

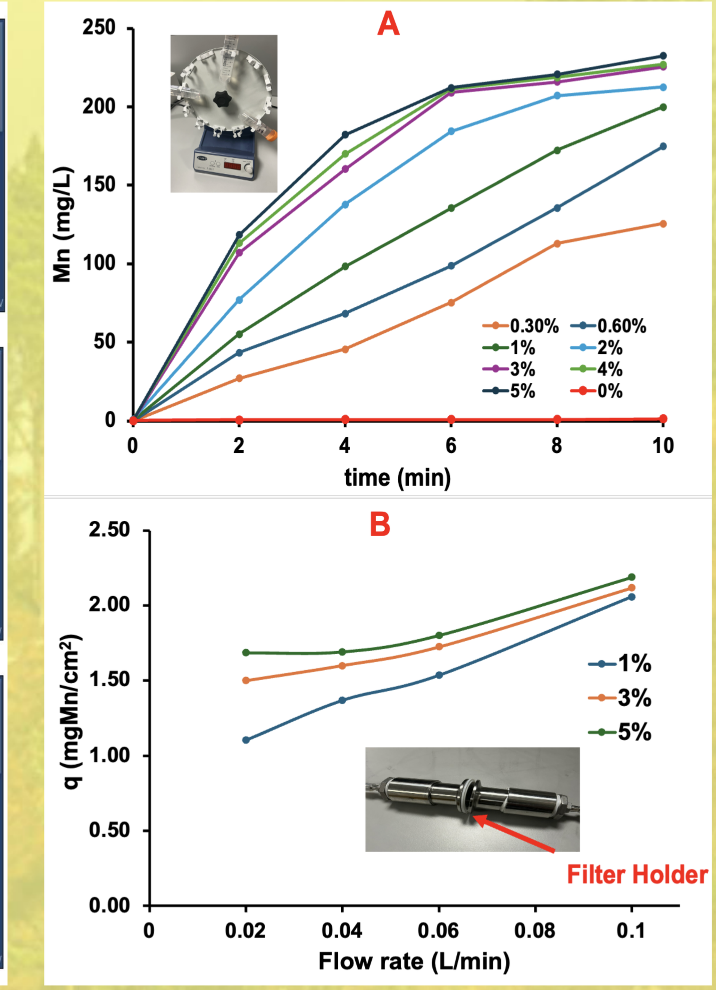


Fig 6. A) Dissolution of Mn particles into different acid concentrations using a rotator, B) retention capacity at different flow rates

- **A higher % of citric acid led to a fully clean 4 cm² filter in a short time.**
- **Adsorption capacity had a high value when the acid passed through 4 cm² at a higher flow rate.**
- **Particle trapping by the filter was analysed (Fig 5).**
- **It was observed that all particles will be retained by F10 while most deposited and fewer penetrated into the inner layer of the particle media.**
- **Particles penetrated the inner layers in F20 and F30.**

Conclusion

- **The 10-micron cartridge fiber filter showed greater efficiency in removing manganese from drinking water.**
- **Optimisation of the rig helps to increase the lifespan of the filter, which leads to reducing the cost.**
- **Ozone proved to be an appropriate oxidant for Mn removal even at low pH.**
- **Welsh water target for dissolving Mn in final water was achieved (<2 µg/L).**
- **Cartridge filters can be re-used as the cleaning procedure was successful. However, it is recommended to evaluate other chemical cleaning regimes and carry out more tests on material degradation of the filters.**

Acknowledgement

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