Development of a Smart Water Pre-Treatment System For Controlled Environment Agriculture Using Micro-Plasma And Nanomaterial-Based Filtration Stacks

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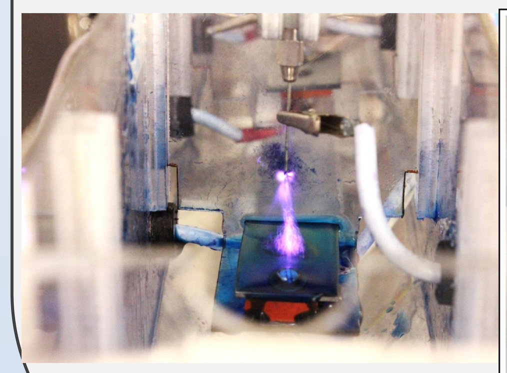
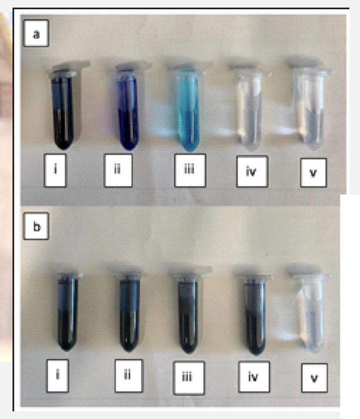
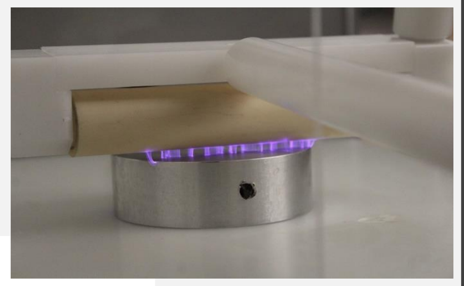
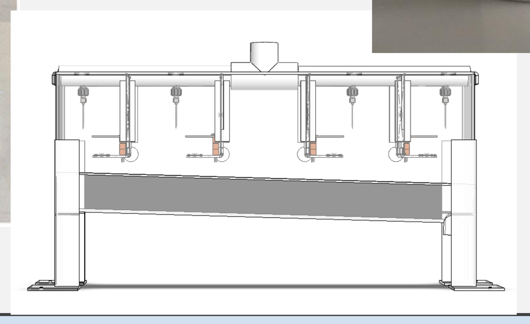
Abstract

To address water scarcity, MXene-based composite filtration stacks are being developed to advance water treatment technologies, with a focus on removing harmful contaminants such as PFAS and recovering valuable nutrients from wastewater. This research involves the creation of a nanofiltration system that integrates activated carbon, graphene, and a Ti3C2 matrix, which has been tested using methylene blue solutions across three filtration cycles. Additionally, a consumer-ready filter has been designed using activated carbon, graphene nanoplatelets, and MXene. Water quality is assessed through conductivity, TDS, and pH measurements, complemented by UV-Vis spectrometry and electron microscopy to evaluate the filtration process.









Nanofiltration using activated carbon, graphene nanoplatelets, and Ti3C2 MXene

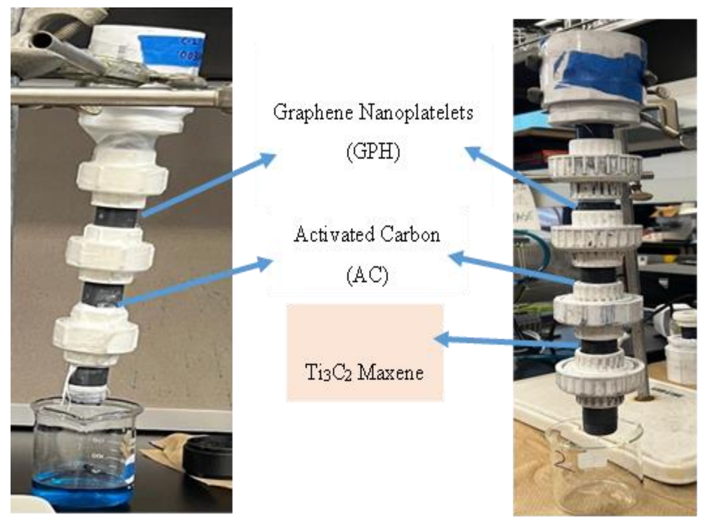


Figure :1 Nanofiltration system

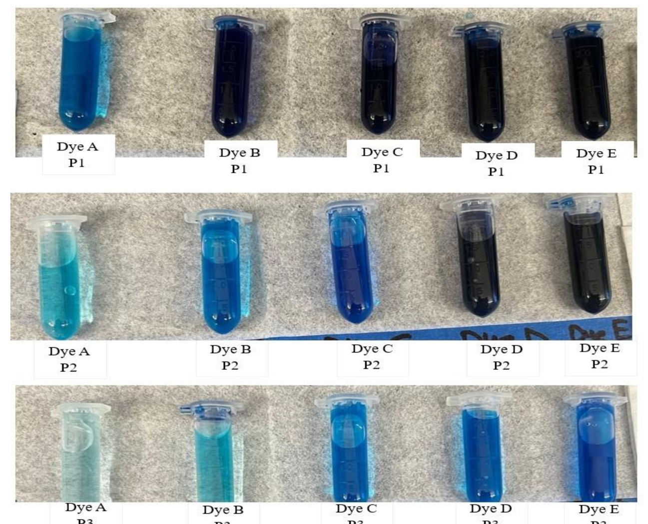


Figure:2 Samples after Nanofiltration

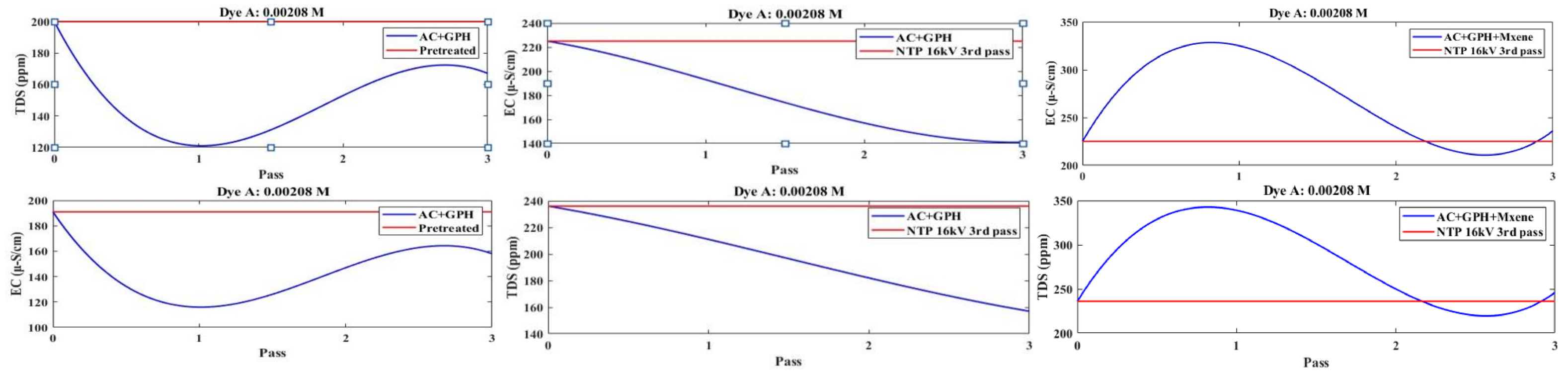


Figure 3 Comparison of TDS and electric conductivity for different Nanofiltration systems.

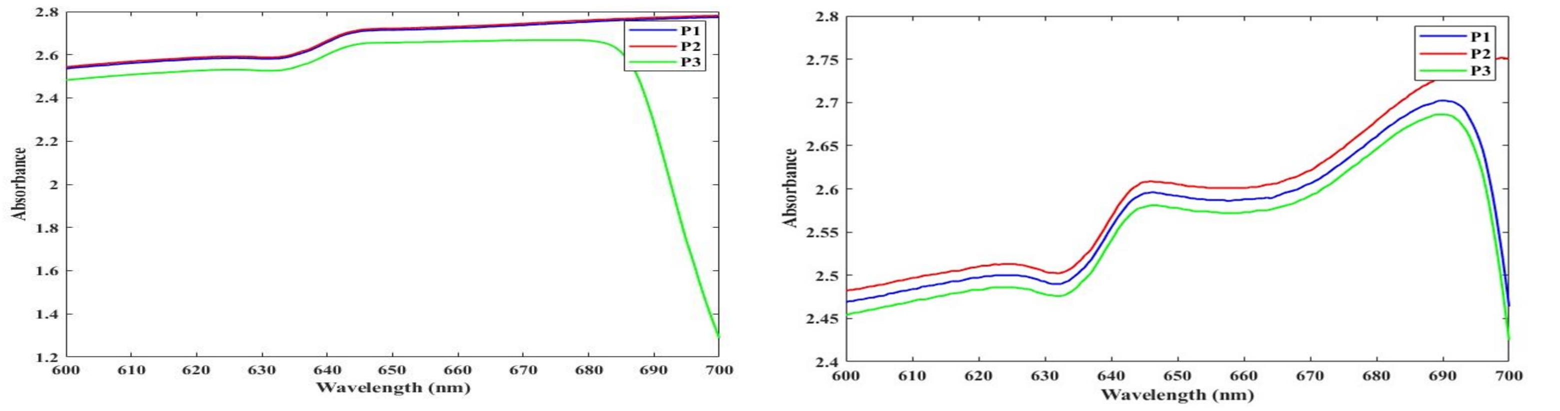


Figure: 4 Comparison of the absorption spectrum for different nanofiltration systems.

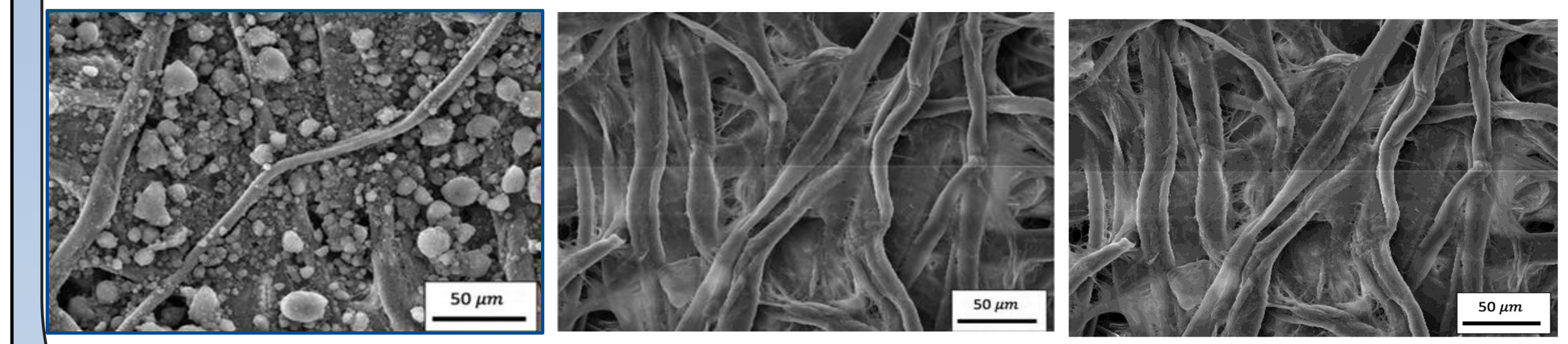


Figure 5: Scanning electron microscope images of the filter paper after the 1st pass (a), second pass (b), and third pass (c)

[1] Hoff, H. (2011). Background paper for the Bonn2011 Conference: the Water, Energy and Food Security Nexus. *Understanding the Nexus*. Stockholm Environment Institute. Thiloka Edirisooriya, E. M., Wang, H., Banerjee, S., Longley, K., Wright, W., Mizuno, W., & Xu, P. (2024). Economic feasibility of developing alternative water supplies for agricultural irrigation. *Current Opinion in Chemical Engineering*, *43*, 100987.

Corona Discharge System

A voltage source electrifies a plate and needle, enabling a pump to propel water through the needle, initiating corona discharge that aggregates particles for improved carbon and graphene filtration. UV spectroscopy measures the water's absorbance, indicating Methylene Blue reduction after successive passes. Experimentation adjusts voltages and iterates the process to determine the best and most consistent operating conditions.

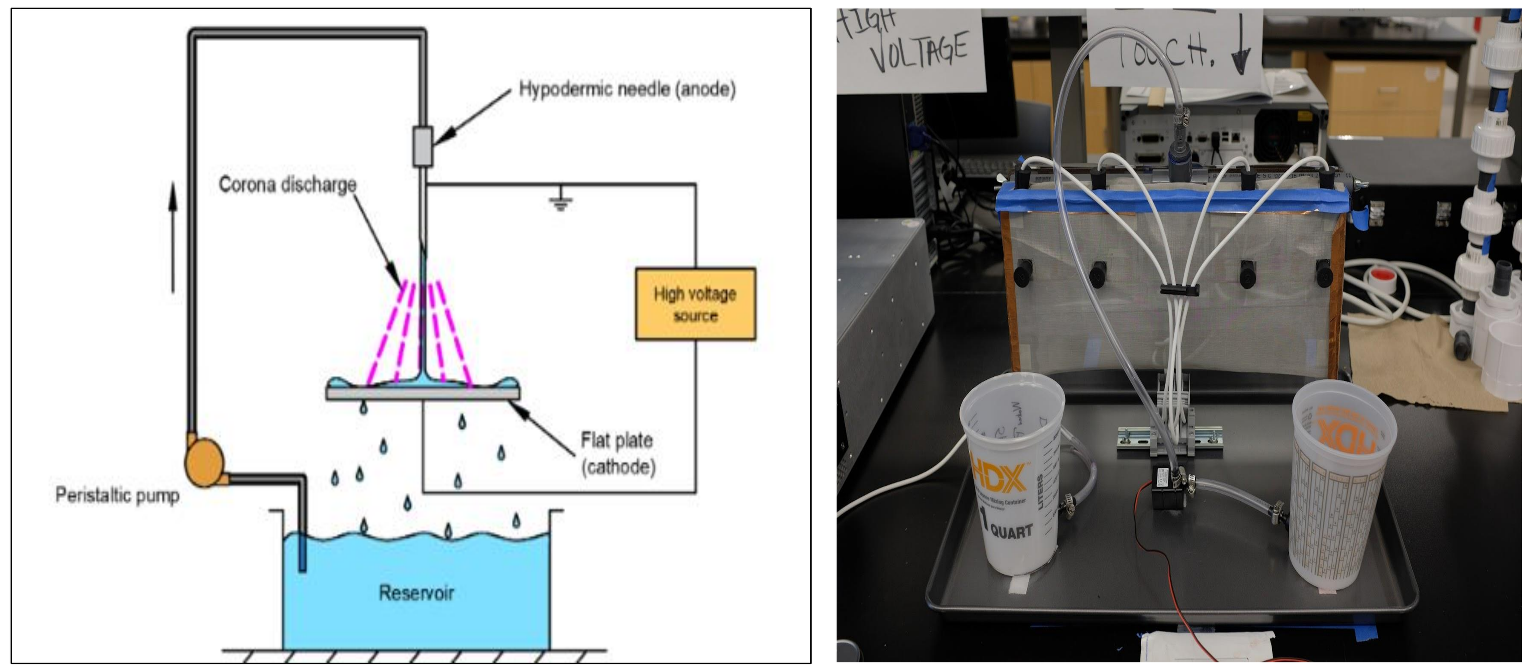


Figure:6 (a) Corona Discharge system (b) Room temperature-based plasma treatment system

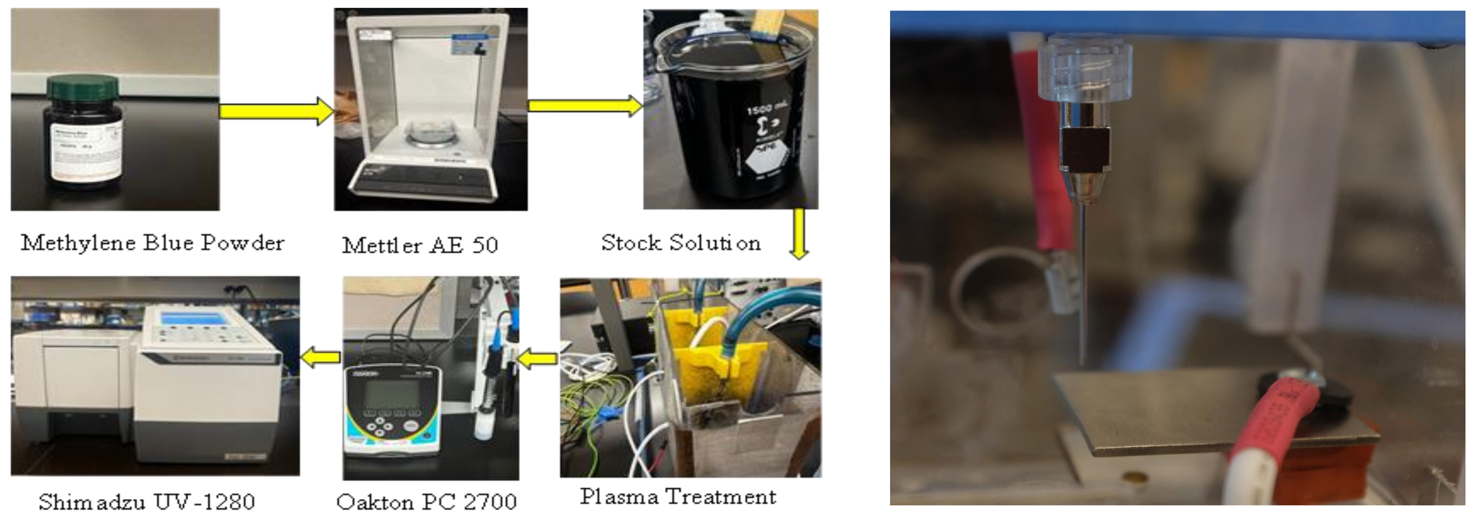


Figure:7 (a) Schematic for complete non-thermal plasma treatment (b) plasma treatment

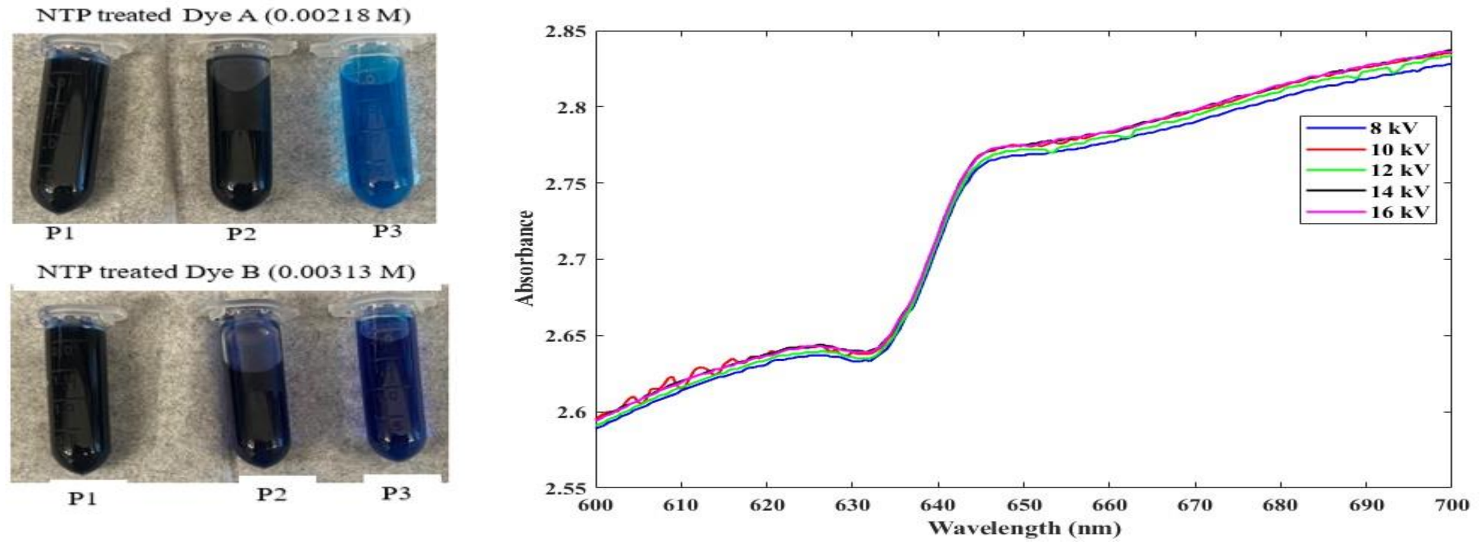
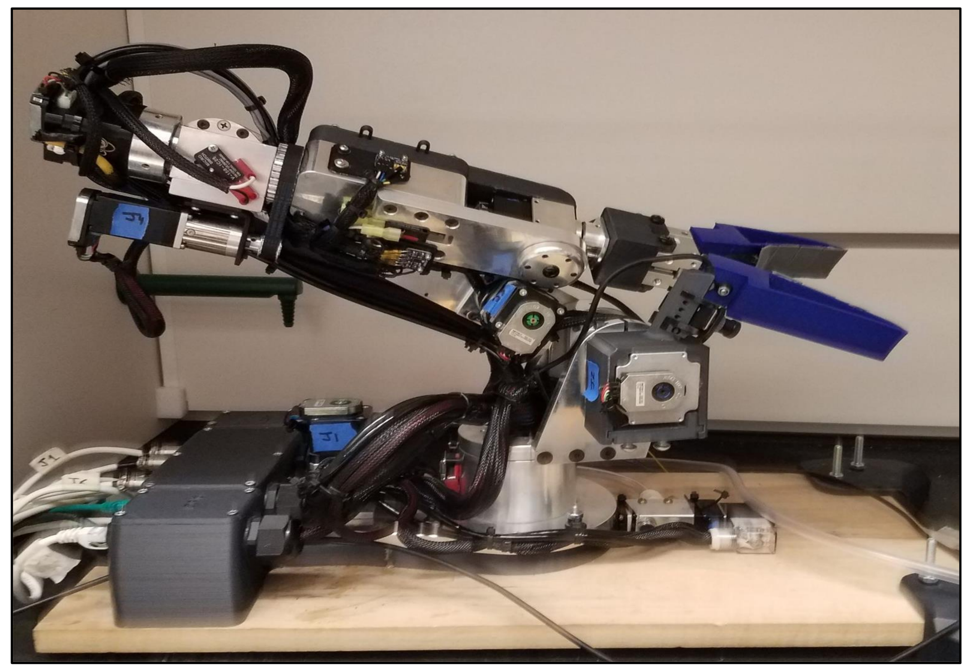


Figure: 8 (a) Samples after NTP treatment (b) Absorption Spectrum after NTP Treatment



The Advanced Robotics Control Software (ARCS) calibrates and controls the robotic arm shown in Figure 5. The two cameras operate through an Arduino Mega. The camera will locate the test samples and give coordinates to the robotic arm to move them.

Figure: 9 AI-Powered System Monitoring with IR-Based Sampling

[2] Zhao, M., Yang, M. T., Singh, M., Overturf, T., Gao, Y., Silva Hernandez, G., Ahmed, S., & Banerjee, S. (2021). Fabrication and characterization of a water purification system using activated carbon and graphene nanoplatelets: Toward the development of a nanofiltration matrix. Water Environment Research, 93(9), 1530–1542. https://doi.org/10.1002/wer.1535

Result and discussion

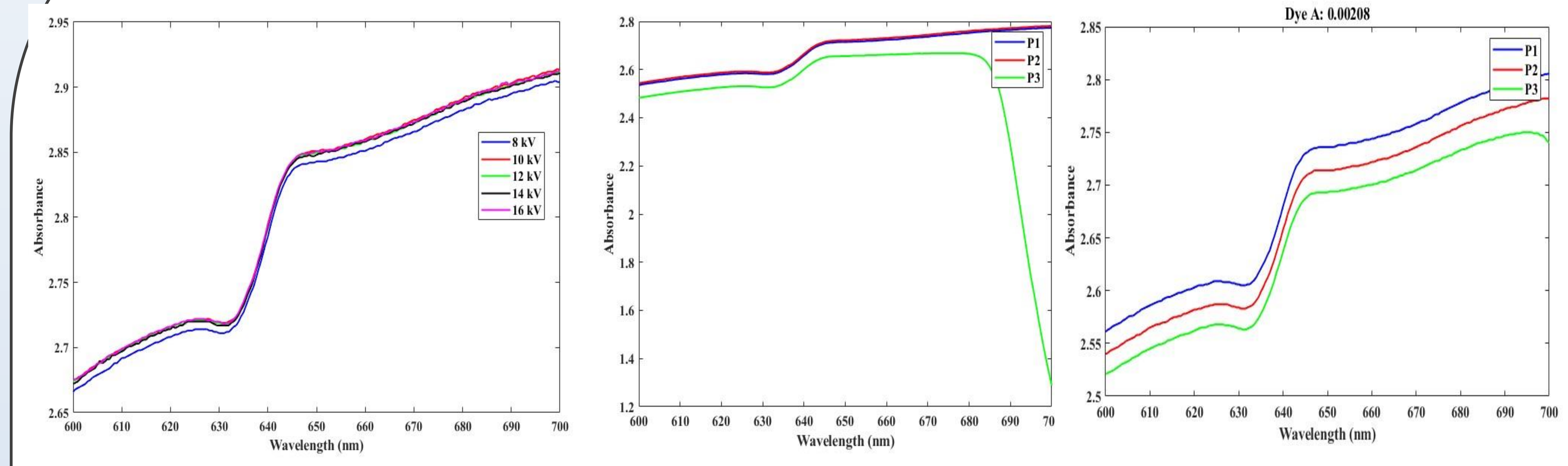


Figure:10 Absorption spectrum (a) NTP treated (b) Non-treated Nanofiltration (c) NTP treated Nanofiltration.

The water treatment system will also be integrated with an autonomous sensor network using both real-time sensors such as optical probes and ion-selective electrode (ISE) sensors, as well as grab-sample methods using AI machines. The system will also be supported by existing data analytics tools for understanding and analyzing the data gathered by the sensor network and sample collection-based water quality testing.

Future Work

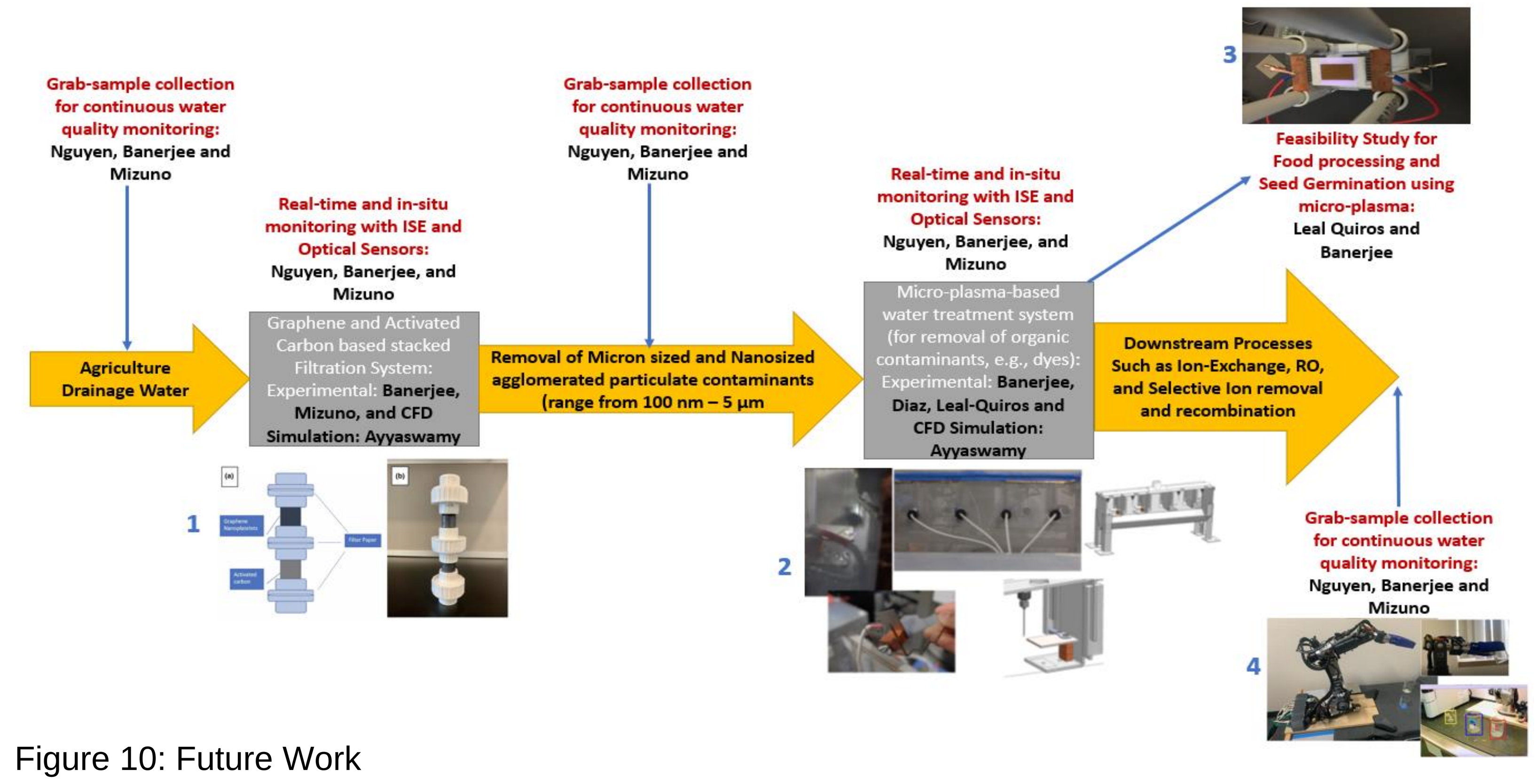


Figure 10: Future Work

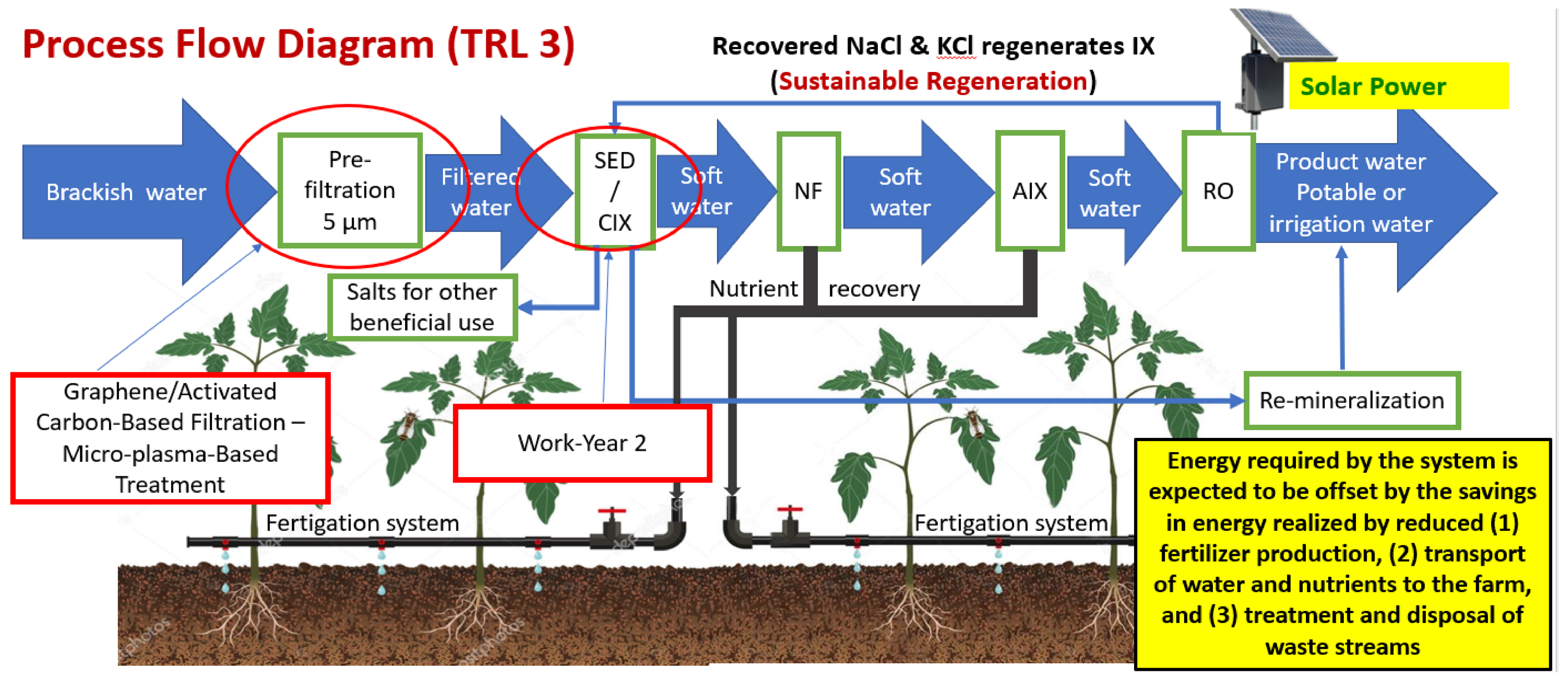


Figure: 11 Process Flow Diagram

Acknowledgements

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