Master of Science HES-SO in Life Sciences

Development of a water filter based on Moringa Oleifera proteins to purify water

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CHEMICAL DEVELOPMENT & PRODUCTION

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DESCRIPTION

Moringa Oleifera tree, also call the miracle tree, is a plant found in many countries in the world. Surprisingly, its distribution corresponds to the area where access to drinking water is more difficult. The seeds, which have strong coagulant and antibacterial properties, have long been used in crushed form by tribes to purify water. Main problems come from the fact that a lot of organic material is added to the water by the seeds powder. This increase in organic material favors the regrowth of bacteria. In the past two decades, research has highlighted and confirmed some of Moringa's water treatment properties comes from a protein named M. Oleifera coagulant protein (MOCP). More recently, the possibility to bind the protein to solid filtering media has been explored and look to be a promising way to use it.

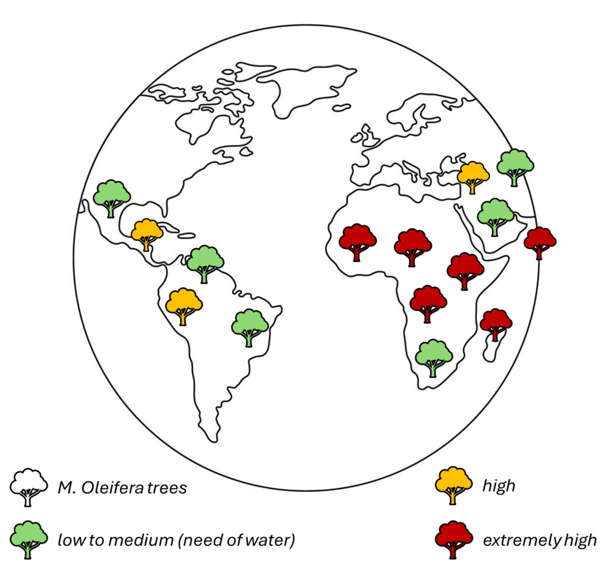

Fig. 1 : Map of the M.Oleifera tree dispersion around the world, color indicate the potable water need

Fig. 2 : Make a M.Oleifera filters. Environ. Sci. Technol. 2019, 53, 12706−12714.

Watalux SA is a society operating in the field of water purification in rural area. Wata™ offers technologies to produce chlorinated solution who could be easily operated and maintained by users with small formation. They want to extend their offer with the development of a global water purification system. Thus, Wata™ would like to explore the possibility to develop a water filter based on the protein coming from *M.Oleifera* seeds extract. The special feature here is the use of this coagulant protein on functionalized media, eliminating the need for prior coagulation to treat turbidity.

OBJECTIFS

As said in the previous section, the aim of the project is to develop a filter functionalized with *M.Oleifera* proteins which, coupled with chlorination, would enable the production and storage of drinking water. Due to these operating conditions, the filter must be easy to operate and, if possible, repairable on site. To achieve this goal, the following objectives have been set :

- Extraction, characterization and adsorption of protein on different media (sand & cotton)
- Quantification of the performance of the filtering media at lab-scale for the treatment of :
  - Turbidity
  - Arsenic
  - Bacteria
- Regarding the previous results & the scale-up feasibility, choose the final filtering media
- Flow direction experiments and wash.
- Pilot building and testing

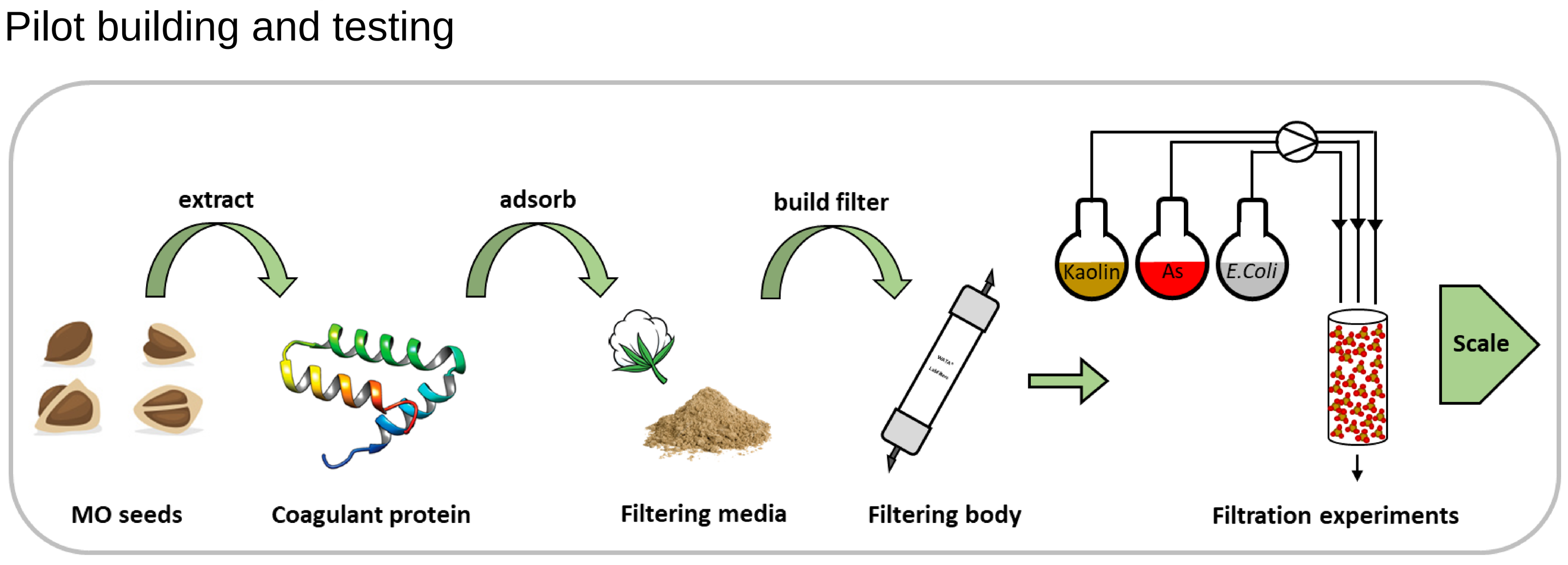

Fig. 3 : Resume of the project principal steps. Extraction, adsorption & test of filtering media/body then scale-up

RESULTS

M.Oleifera coagulant protein

Proteins were successfully extracted from seeds powder of different origin. The BCA quantification shows a total amount of protein between 7 to 22% was found, depending the origin and pretreatment. MOCP was purified by heat and by SPE with cationic resin. Results of the two methods are closed and conclude that the interest protein represent an amount of 14 ± 2% of total proteins. Adsorption experiment leads on cotton and sand show a capacity of 5.28 ± 0.22 and 0.45 ± 0.04 mg of protein per gram of media, respectively. It was demonstrated that a 600mM NaCl solution could desorb them from the supporting media.

Laboratory filtration

A six filters setup was built with PVC tubes of 10x1.5cm and rubber cap. The ability to treat turbidity was demonstrated for functionalized sand and cotton filters. They achieve >99% removal of turbidity operated at maximal flowrate of 2mL*min^{-1} and 10mL*min^{-1} respectively. Arsenic treatment was trickier, sand and cotton shows ability to treat highly concentrated arsenate solution but these efficiency rapidly decrease with the decrease in arsenic concentration. *E.Coli* filtration experiments in cotton at various flowrate with 30cm filters and 10^8 CFU*mL^{-1} influent solution confirm the results read in studies : an LRE >4 equivalent to a 99.99% treatment efficiency.

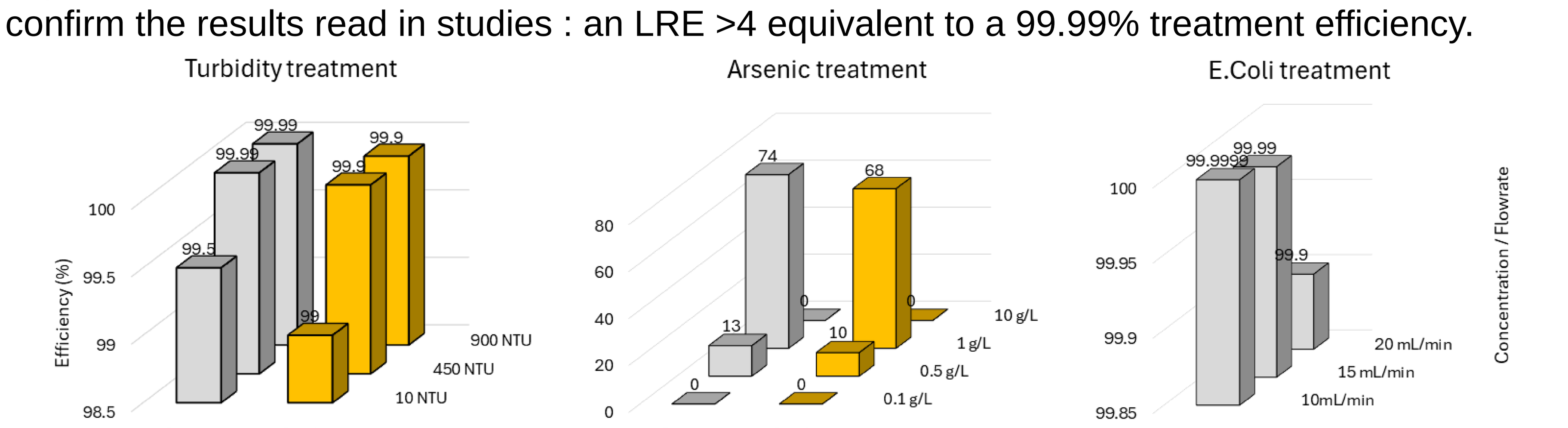

*Fig. 4 : Efficiency of turbidity and arsenic treatment for sand filters and cotton filters of 10x15cm. E.Coli treatment was done in 30x1.5cm filter with an influent solution containing 108 cfu*mL-1. All experiments are made in triplicat.*

The breakthrough of the filters was reached for sand and cotton with kaolin solution containing 2µm particles. A maximal adsorption capacity of 13 ± 3 and 612 ± 38 mg of kaolin per gram of media and a covered surface of 4.22% and 84.44% for the sand and cotton respectively. Closed look on efficiency, flowrate and pressure loss of the two media, cotton seems to be a new and promising technology. To improve the turbidity treatment with cotton and help to choose the height of filter, a 17 experiments (Box-Benkhen design) was conducted with flowrate, filter height and pH as factors. Results shows a possible exploitation of the filters at 20mL*min^{-1} with column height of 30cm for pH from 5.5 to 8.5.

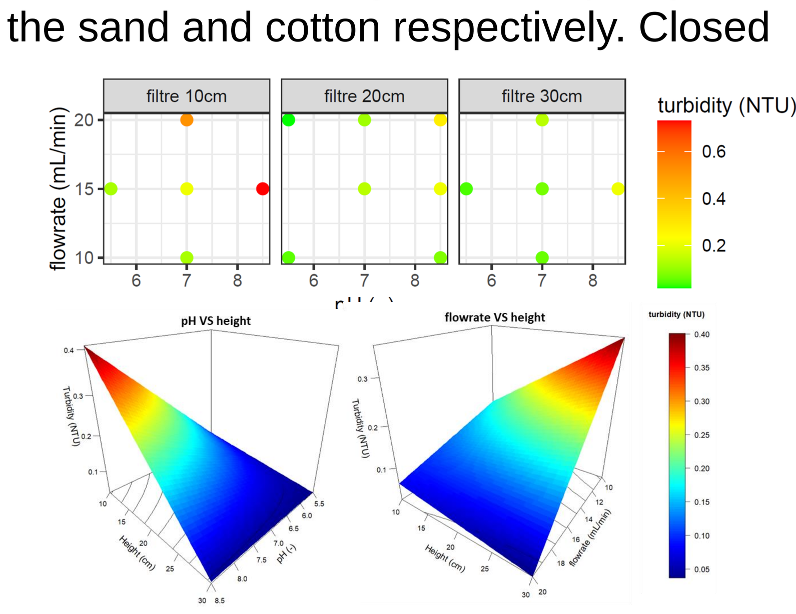

Fig. 5 : Results obtain from the BB design for turbidity treatment

Prototype

Prototype is built to have a minimal flow of 30L*h^{-1} who's a standard set by UNICEF organization for household or small communities. Scale-up calculation based on the experiment at lab-scale shows that a 7.5cm diameter filter containing a 30cm cotton bed is sufficient to achieve these goal. Filters are built with standards DN7.5cm pipe and dispenser, and collector are in PET-G. Pieces were designed with fusion360® and are print with a commercial 3D printer, making it easy to replace or modify on site. The filters could theoretically treat 11'000L of a turbid influent water of 10 NTU. These capacity even if the lifetime of the filters in real use is cut by two, is sufficient for a 5 people yearly water supply or for 20 people community with monthly wash.

Fig. 6 : Assembled prototype for 30L/h with 20mL/min flowrate, 11'000L filtration capacity, usable for household or small communities

CONCLUSION

A promising prototype has been built based on the results obtained at laboratory scale. Its performance looks after prior testing to be close to the one seen with smalls laboratory filters. A great efficiency, >99.9%, to deal with turbidity even at high value and to catch gram negative bacteria as E.Coli (99.99%). These capacities of treatment are in line with standards dictated by the WHO and allows to hope a field used for small community or medical dispenser. The BB design shows that the filter prototype could operate with a large secure marge allowing for variation in the inlet flow rate (10 to 20mL*min^{-1}) or influent concentration (1-800 NTU) without losing effectiveness. The filter is sufficient for household of 5 people drinking 20L/day of water or for communities of 20 people with maintenance operations. Protein extraction is easy and could be done on site with different raw materials as fresh moringa seeds or seed cake obtain after oil extraction. Likewise, materials for building the filter are easy to find and the 3D-printed parts make it easy to repair. However, protein binding to the filters need to be further explored. During that study, the protein stays bind to the media during a 3 months time without losing effectiveness. The wash of it needs to be further explored and optimize, principally the possibility to wash it without disturbing the protein. These additional steps could increase the robustness and the ease of use of the technology. Treatment of metallic ions like arsenic is not efficient, way to treat that kind of pollutant must be explored. Finally, the filter shows a possibility to catch micro-plastics an interesting property for today who should be investigated.