SCHWEIZER JUGEND FORSCHT
LA SCIENCE APPELLE LES JEUNES
SCIENZA E GIOVENTÙ
SCIENZA E GIUVENTETGNA

GENIUS Olympiad

New and Sustainable Method for Water Purification Using Cellulose Nanofiber Filters

Luca Schaufelberger, Switzerland

Introduction

Clean water is a valuable resource for humanity. In the future, it will be of upmost importance to provide clean water in a sustainable and resource-friendly way. This is precisely what I endeavoured to achieve in my work. My goal consisted of producing a sustainable cellulose nanofilter made from waste generated by the paper industry. The filtration process should be based on electrostatic interactions between negatively charged pollutants and a chemically modified, positively charged filter (adsorption). Such a procedure might eliminate the clogging often observed with mechanical membranes.

In addition, I wanted to develop a new method to clean the used filters by means of desorption, which would allow the filters to be regenerated and reused multiple times. The sustainability of the water purification can be increased dramatically through such recyclability. This method combines sustainability with the high efficiency of nano materials thanks to their large surface area. In my experiments, I focused on the water pollutant *humic acid*, a product of biodegradation.

In order to achieve my goals, I posed three core questions:

1. Is it possible to create a porous adsorption filter suitable for the filtration of humic acid?
2. Can these filters be cleaned and reused in an efficient way?
3. What are the underlying mechanisms responsible for the experimental results?

Methods

In a first step, I adsorbed the humic acid onto the cellulose-nanofibers and evaluated which conditions are suitable for the desorption process. It was important for me to use cheap and readily available substances. Therefore I only adjusted pH value and the NaCl concentration. These optimisations were performed in a *model environment,* in which the cellulose nanofibers are in suspension.
The second step involved producing a filter suitable for efficient water purification by means of freeze-drying. Such a cationic filter made from cellulose nanofibers has never been used for the filtration of humic acid. With these filters I was able to test the results from the first step under practical conditions.

These two inherently different approaches to the problem provided not only important insights into the fundamental nature of the processes, but also an opportunity to test the filters in relation to their potential future applications.

Results

My experiments showed that a NaCl concentration of 1 M in combination with a basic pH value of 11.8 is perfectly suitable for the cleaning of the filters. By optimizing the process, it was possible to remove up to 97% of all humic acid from the used filter. In addition, I successfully identified the mechanisms responsible for this desorption. The proposed explanations are strongly supported by the empirical results.

After the desorption process, I was able to reuse the water filters several times. The efficiency of the filter only decreased by 4% per cycle. The flux decreased by 10% every cycle. This is a minor decrease compared to mechanical membranes, which tend to clog very easily.

Discussion

My work demonstrates that the cellulose nanofilters have a much higher adsorption capacity for humic acid than any other material described in scientific literature up to the present day. This is mainly due to the large specific surface area of 252m^2 per g and the large pores. By using a freeze-dried filter, I was able to bring the process one step closer to practical applications.

Additionally, I was able to develop a highly efficient and simple procedure to clean the filters. This is very promising as it reduces the overall energy consumption and cost of the method by eliminating the necessity of producing a new filter every time. In comparison to other methods of water purification, for example those based on fossil materials or dependent on high temperatures, the procedure has the advantage of being environmentally friendly as well as highly effective.

Conclusion

To conclude, I was able to develop an environmentally friendly method for water purification by regenerating the filters in an efficient way.

To follow up, the present concept of using such chemically modified functional cellulose nanofibers could further be extended to encompass removal of other negatively charged water pollutants, such as viruses or toxic nanoparticles. In addition, one could modify the filters differently, which may result in a universally-applicable method for purifying water – our most valuable resource.