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CERAMPOL

Revolutionising wastewater management with tailor-made filtration systems

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Building better **filters**

Water security represents one of the greatest socioeconomic challenges for future generations. As part of the effort to create lasting solutions, **Drs Izabel Alfany** and **Mirko Faccini** share details of a project that aims to create tailor-made wastewater filtration solutions based on ceramic and polymeric materials

Can you describe the new filtration technology that you are developing under the auspices of the Ceramic And Polymeric Membrane for Water Purification of Heavy Metals and Hazardous Organic Compounds (CERAMPOL) project?

MF: The CERAMPOL filtration technology consists of three major functional parts, including a pre-filter based on polymeric nanofibers, a highly selective nanostructured ceramic membrane and a cleaning system based on piezoelectric materials. Each of these components is considered an independent tool that can be combined to provide a tailor-made solution. Every part will be engineered as a simple cartridge that can be easily placed into and removed from the final CERAMPOL demonstrator module. This allows the same unit to be easily adapted to the specific requirements of different water remediation processes.

Which specific contaminants and industrial wastes are you targeting through this initiative?

MF: CERAMPOL targets two main types of water contaminant: heavy metals and pharmaceuticals.

Wastewater containing toxic heavy metal ions can be produced by a wide variety of industries such as metal finishing, mining, and the manufacturing of batteries, electrical cables and electronics.

Drugs and their metabolites are considered as a new class of pollutants owing to increasing concentrations appearing in European drinking water and streams. Sources include pharmaceutical industries, hospitals, medical facilities and households.

Moreover, we are targeting other foreign matter, such as precious metals and rare earth elements. These are both nontoxic, but are worth recovering due to their high added value. Precious metals and rare earth elements are present in effluents

Shaking up **wastewater treatment**

In a bid to increase wastewater reuse, the **CERAMPOL** project will build an innovative three-tier treatment system using nanomaterials that could potentially revolutionise its management

WHILE OVER 70 PER CENT of the world's surface is covered by water, much of it is unfit for human consumption. One reason for this is the rise in wastewater – water that has been reduced in quality by anthropogenic factors such as the introduction of sewage and by-products of the metallurgic, pharmaceutical and healthcare industries, among others.

The rising number of highly toxic contaminants present in wastewater can cause significant challenges to water supply infrastructure and damage to the ecosystems of lakes, rivers and seas, in both developed and developing countries. Various treatment processes have already been developed to clean wastewater and return it for human use; however, these are not always easy to implement. Common drawbacks include their cost, high energy consumption and lack of durability. Given the increasing demands of agriculture, industry and domestic users, the challenges of managing this precious resource look set to escalate.

DEVISING NOVEL SOLUTIONS FOR WASTEWATER TREATMENT

The multidisciplinary team behind the CERAMPOL project – a four-year venture that began in early 2012 – is responding to traditional barriers facing wastewater treatment by developing innovative nanomaterial-based membranes that will improve purification processes. Bringing together expertise that straddles fields as diverse as chemistry, engineering, biology, electronics and computational modelling, its pan-European consortium includes representatives from academia, R&D and industry.

CERAMPOL is led by Drs Izabel Alfany and Mirko Faccini, both of whom are based at the LEITAT Technological Center in Barcelona, Spain. The EU Seventh Framework Programme (FP7)-funded project aims to produce a tailorfrom fine chemical and pharmaceutical industries, as well as in mining streams.

Are rival technologies in development? What advantages does your technology have over other filtration systems?

MF: The advantage of the CERAMPOL concept is that the integration of various parts exhibiting several functionalities and properties – antifouling, self-cleaning, catalytic activity, affinity to specific species – leads to tailor-made solutions. The project will provide an economic, innovative and versatile toolbox for rapid prototyping, fabrication and implementation of multifunctional nanostructured membranes for solving problems associated with wastewater treatment.

Specifically, the project will focus on manufacturing prototypes for the following industrial applications: removing heavy metals from acid mine drainage water; recovering valuable metals and rare earth elements from wastewater of chemical and mining industries; and catalytic degradation of toxic drugs and metabolites originating from effluents of pharmaceutical industries and hospitals or nursing homes.

We believe that, due to the flexibility of CERAMPOL's approach, our filtration technology will be readily transferred to several other water remediation processes.

Given the increase in nanoparticle use within manufacturing processes and products, will the CERAMPOL technology also be applicable to removing nanoparticles from water?

MF: Although the technology is not designed specifically for the removal of nanoparticles from water, it could be applied for this purpose. Our results clearly show that, thanks to the high surface area and porosity of nanofibre membranes, they are able to remove metal and metal oxide nanoparticles from water.

Is there a risk that the nanomaterials used within this technology could actually cause additional water contamination?

MF: The release of nanoparticles to the environment from nanotech materials and products is always a critical issue.

The human and environmental health risks of the nanomaterial-based membranes developed in this project will be evaluated at the different stages of their life cycle. Our risk assessment will cover the production steps, the use, and the end life (or disposal) stages. During the project, toxicity and ecotoxicity data will be collected, and tailored *in vitro* studies will be performed. The project will also quantify the nanomaterials released within water treatment processes that use our nanomaterial-based membranes.

How important is the worldwide dissemination of your results? What routes of distribution are you utilising?

IA: The sharing of results is a responsibility taken by all partners, and is particularly important within the scientific community. CERAMPOL counts on our detailed webpage and LinkedIn account for online dissemination, and our partners take project leaflets and posters to each conference and event that they take part in.

In January 2015, the Leitat Technological Center will host a Nano4water cluster workshop with the aim of improving the project's visibility and enabling partners to meet experts and stakeholders from different sectors. Finally, at the end of the project, a video containing CERAMPOL's results will be produced and broadcast.

made wastewater solution that comprises three main facets: an antifouling pre-filter, a nanostructured ceramic membrane and a piezoelectric vibration-based self-cleaning system. This system will be dual purpose – as well as removing toxins from water, it will have the capability to extract high value precious metals and rare earth metals that can then be recycled.

USING POLYMER NANOFIBRES IN PRE-FILTRATION

The antifouling pre-filter separates heavy metals from wastewater. This component will utilise polymer nanofibres with a diameter of 50-500 nanometres, which will coat a ceramic membrane and reduce the amount of contaminants that reach the next stage. Polymer nanofibres are attractive to the researchers largely because of their high surface area. They are low density, have high volume pores and the shape and size of these pores can easily be controlled and adjusted – useful attributes in the filtration process.

The scientists are particularly keen to exploit these features to develop polymer nanofibrous membranes specifically geared to the collection of precious metals and rare earth elements while simultaneously cleaning the water. "These nanofibrous mats will exhibit high mechanical and chemical stability, and fast kinetics in metal extraction," Faccini explains.

REFRAMING THE CERAMIC MEMBRANE

A nanostructured ceramic membrane forms another component of the CERAMPOL technology. Already used in many existing water filtration systems, ceramic membranes are renowned for their chemical, thermal and mechanical stability as well as their permeability. In this case, the group's mission is to create a version that is capable of drawing out heavy metal ions, collecting specific valuable elements, and catalytically degrading drugs and metabolites present in wastewater.

The team is developing this membrane in two ways. In one, they use a sol-gel technique to place a ceramic layer with a controlled pore size onto a porous aluminium oxide base. The gel is then dried and heated, resulting in an abundance of rigid and porous solid materials with unique thermal, mechanical and chemical properties. The other mode of obtaining ceramic nanostructures centres on coating the base with silicon dioxide, titanium dioxide and aluminium oxide nanoparticles that have been synthesised by flame spray pyrolysis, which should allow for greater control of pore structure.

INTELLIGENCE

CERAMPOL

OBJECTIVES

The main goal of CERAMPOL is to develop an innovative filtration technology for industrial wastewater purification.

The specific objectives of the project are:

- To contribute to reducing the amount of pollutants such as heavy metals and dangerous organics released into European water supplies
- To contribute to the long-term water quality and availability of water resources
- To allow production of cleaner water with significant lower costs and energy requirements
- To mitigate the risk to human health and the environment such as chronic toxicity and metal-related diseases
- To recover precious metals and rare earths that reduces Europe's dependency on countries rich in these natural resources

PARTNERS

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DR MIRKO FACCINI holds a PhD in Chemistry from the MESA+ Institute for Nanotechnology, The Netherlands, and has a broad experience in materials science, nanotechnology, polymer chemistry and organic chemistry and interest in applied research. Currently, he is a principal scientist in the Advanced Materials Division of Leitat Technological Center.

DR IZABEL ALFANY is International Projects Manager at Leitat Technological Center. She gained her Biology degree from the Universidade Federal de Sao Carlos (UFSCar), Brazil, and her PhD from the Faculty of Biology at the University of Barcelona. Currently, she is responsible for the Health sector at Leitat's International Projects Office.

AN INNOVATIVE SELF-CLEANING MECHANISM

Membrane filtration systems usually rely on energy-intensive practices such as regular cleaning or backwashing to maintain performance, but these are not completely effective. CERAMPOL's piezoelectric cleaning system, on the other hand, represents a more environmentally- and cost-effective method of ensuring filter longevity. Within their system, a vibrating piezoelectric structure made up of a porous layer of a stable lead-free alkaline niobate derivative will sit between the nanofiber and ceramic layers. Vibrations produced by this component are thought to be capable of loosening and detaching solids and foulants from the pre-filter.

What makes these proposed systems especially innovative is the fact that they will systematically monitor water pressure and, if it plummets below an acceptable level, will spring into action to preserve the membrane.

COLLABORATING WITH END-USERS FOR BETTER RESULTS

While the team is designing this system with the wastewater produced by the pharmaceutical, medical and metallurgical industries in mind, its detachable, three-step nature makes it flexible, so other sectors could easily benefit from its implementation.

Fundamental to the successful commercial uptake of their technology will be the researchers' relationship with industrial partners, among which they count a multinational contractor and a public health consortium, as well as producers of both chemicals and pharmaceuticals. "The presence of these end-users within the project will help to guarantee that our outcomes will be of industrial relevance and will make a substantial impact," Faccini enthuses.

ASSESSING EFFECTIVENESS

Industry colleagues and end-users will be particularly vital within CERAMPOL's evaluation processes. As part of this, end-users will test the technology using real wastewater and give feedback as to how its performance fares against that of existing systems. Industrial stakeholders will analyse the product's technological and economic feasibility. In addition, a full life cycle assessment will be performed for each nanomaterial used and the filtration system as a whole. Finally, the group intends to perform a thorough examination of the unit's wider environmental impacts associated with the extra water recovered and preserved.

> Alfany, Faccini and their colleagues believe that the work could open up improved wastewater treatment processes to SMEs and increase demand for nanomembrane systems within Europe

WIDE-RANGING RESEARCH IMPACTS

In line with the call for environmentally-friendly innovations in the EU's Europe 2020 growth strategy, the researchers behind CERAMPOL believe that the project could potentially be a key cog in boosting the green economy in the medium term. Specifically, Alfany, Faccini and their colleagues believe that the work will open up improved wastewater treatment processes to SMEs and increase demand for nanomembrane systems within Europe.

So far, a great deal of emphasis has been placed on planning the project's overall workflow, and that of each of its individual technological aspects. The next step, and a major target for each stakeholder involved in the project, is to achieve a proof of concept in the near future. Once this has been established, the following phase will be to scale this up to a fully operational system.