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Membrane technology: Removing contaminants in wastewater

A team of researchers in Singapore have developed a robust free standing TiO_2 nanofibre membrane which, they believe, could be a cost and energy efficient way of cleaning wastewater.

With ongoing rapid industrialisation – especially in countries such as India and China over the past two decades – the demand for drinking water has increased tremendously in terms of quantity and quality. The scarcity of such a precious resource has increased the need for water reclamation, for the preservation and recovery of drinking water.

However, the presence of contaminants such as natural organic matter (NOMs) and trace organics accumulating in raw water creates a major problem. The coagulation/flocculation and chlorination technology has been widely used for the removal of the contaminants. However, this technology is unable to completely removal it, and generates extra volumes of sludge which requires further treatment and disposal. In addition, aluminium exposure is suspected to play a part in the onset of Alzheimer's disease. NOMs have been shown to react with the major disinfectants (chlorine, ozone, chlorine dioxide, chloramines) to produce a host of disinfection by-products, such as trihalomethanes (THMs), haloacetic acids (HAAs), bromoform (CHBr3), dibromoacetic acid (DBAA), and 2,4-dibromophenol (2,4-DBP), etc which are carcinogenic compounds.

Progress has been made with regard to the use of micro/ultra filtration (MF/UF) membranes as an advanced water treatment process for producing high quality drinking water with a small footprint size. However, the commercial filtration membranes have a high fouling tendency caused by the deposition of contaminants such as NOMs as well as trace organics and microorganisms, which is one of the major problems in using filtration membranes for producing high quality drinking water. There is an urgent need in searching for new generation membranes which will be able to overcome the existing problems of membrane fouling and leaking of contaminants within the membrane pore.

Nanotechnology

Nanotechnology has great potential in molecular separation applications by offering more precise structural controlled materials for such needs. Titanium oxide (TiO_2) nanosized particles are a popular photocatalyst which attract much attention from both fundamental research and through the practical application of removing HA from water. However, the nanosized TiO_2 photocatalyst has an inherent and significant drawback – that is, the difficulty in separation and recovery. In order to increase the photocatalytic activity of TiO_2 and concurrently solve the problem of separation and recovery, it is important to re-design TiO_2 structured photocatalytic material.

Dramatic effects have been added in this area by our research group. Given the potential of nanofabricated membrane to advance molecular separation and oxidation, we have developed a robust and inexpensive robust and free-standing TiO_2 nanofibre membrane.

The membrane

The robust and free-standing TiO_2 nanofibre membrane as shown in Figure 1 is in the

Figure 1: SEM machines show the TiO_2 nanofibre membrane without the substrate at different magnification.

The presence of contaminants such as natural organic matter and trace organics accumulating in raw water creates a major problem when it comes to providing clean water.

form of a "spider web" nonwoven. The non-toxic TiO_2 nanofibre membrane acts as both filtration membrane and photocatalyst in water technologies.

In the presence of ultraviolet light, the crystalline TiO_2 nanofibre is known to produce strong oxidant and exhibit quantum size effects at nanosize (<10 nm). This material also can be used in solar conditions. These unique properties give rise to various applications particularly in producing cost effective commercial filtration membranes that could dramatically reduce the cost of water production.

The advantages of the TiO_2 nanofibre membrane are:

1. Full surface exposure to UV or solar for self-regeneration, which effectively eliminates the membrane fouling problem;
2. Concurrent membrane filtration for separation purposes;
3. A high surface area, which allows higher adsorption rate of various trace organics and bacteria for improving water quality;
4. A higher acid/basic and temperature resistance;
5. Environmentally friendly and longer membrane life span;
6. Flexible property which enables the membrane to be formed into various membrane modules for larger commercial application.

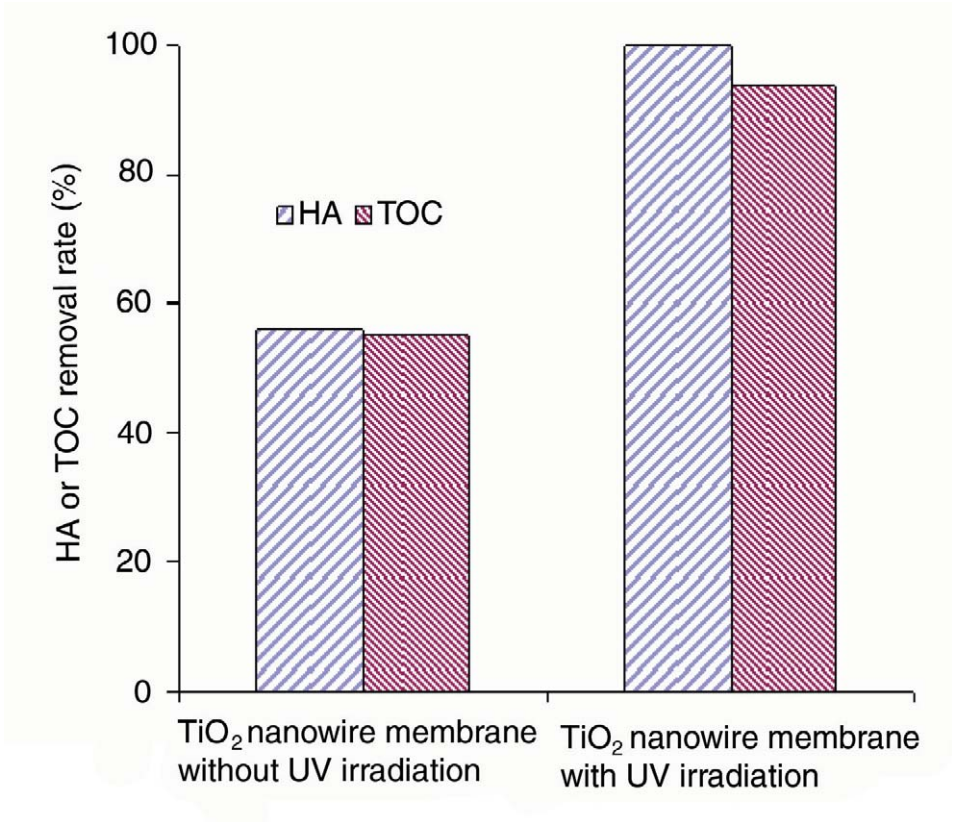

Figure 2: The removal rate of HA and TOC by the TiO_2 nanofiber membrane filtration with and without irradiation.

The results

The photocatalytic activity and anti-fouling ability of the TiO_2 nanofibre membrane were investigated using humic acid (HA) solution as the feed. HA solution of 15 mg/L was filtered using the TiO_2 nanofibre membrane with UV irradiation. The filtration without UV irradiation was also carried out as a reference. The removal rates of HA by the TiO_2 nanofibre membrane filtration are shown in Figure 2. About 57% of HA were rejected using the TiO_2 nanofibre membrane alone. Under the same conditions, with UV irradiation on the membrane, the HA removal rate reached almost 100%. To investigate the mineralisation degree of HA, the concentrations of TOC in the filtrate and feed were also determined. The results are shown in Figure 2. It can be seen that 93.6% of TOC were removed by TiO_2 nanofibre membrane filtration with UV irradiation, which indicates that most of HA were completely degraded into carbon dioxide and water instead of intermediates matter.

The TiO_2 nanofibre membrane has the potential to be applied in a large amount of water and wastewater treatment uses. Using the TiO_2 nanofibre membrane under reduction conditions, it could provide new source of hydrogen; an interesting possibility for clean energy industries.

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