European Commission

Science for Environment Policy

15 November 2018
Issue 516

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Source: Zanoletti, A., Bilo, F., Depero, L., Zappa, D., and Bontempi, E. (2018). The first sustainable material designed for air particulate matter capture: An introduction to Azure Chemistry. *Journal of Environmental Management*, 218: 355–362.

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To cite this article/service: "Science for Environment Policy": European Commission DG Environment News Alert Service, edited by SCU, The University of the West of England, Bristol.

Innovative seaweed-based gel coating for urban homes able to capture harmful air particles

Air pollution via small particulate matter (PM) from diesel fumes and other sources is of growing concern in urban areas, and contributes to poor air quality. In European urban areas, PM pollution often exceeds World Health Organization (WHO) safe levels for human wellbeing. In response to this, the European Commission has encouraged researchers to develop a low-cost, sustainable material that captures these particles in order to clean the air[1]. This study created a new PM capture material using sustainable chemical processes where the carbon footprint and energy use of the production process of the remediation material is taken into account. The newly developed porous material is called 'SUNSPACE' (an acronym derived from '(SUstaiNable materials Synthesized from By-products and Alginates for Clean air and better Environment').

The European Environment Agency report on air pollution[2] from 2016 noted that a large portion of the urban population was exposed to amounts of PM exceeding WHO recommended levels, and that in 2013, 467 000 premature deaths in Europe were attributed to $PM_{2.5}$ (fine particles with a diameter of 2.5 micrometres or less). These particles can be especially harmful as they are fine enough to penetrate human bronchi and lungs, and there is a need for low-cost, and sustainable building materials necessary to capture them. The engineered materials currently available either produce environmental pollution themselves, use toxic chemicals in their production, require refrigeration, or are made from petroleum — so there is a need for a greener approach to designing a suitable material. The material should be capable of capturing a range of particle sizes with a special focus on micro- and nanoparticles, given that fine particles are potentially the most damaging to human health.

'SUNSPACE' was created using sustainable chemistry principles — the researchers say it is low energy, long lasting, and easily regenerated, using minimal amounts of material in its design. Pores were created from the decomposition of sodium bicarbonate at low temperatures to create bubbles of CO_2 gas. Sodium alginate was extracted from several types of brown seaweed and used to form an insoluble gel with positively charged calcium ions from either calcium iodate or calcium chloride. Silica fume, a by-product of silicone metal alloy processing, was used in the preparation of SUNSPACE. A method to calculate the sustainability of the material was based on embodied energy — the energy required to produce one kilogram of the material — and its carbon footprint (compared to materials such as bamboo, cement, and others).

To create the capture material at room temperature, the gel-forming sodium alginate was dissolved in solvent; calcium iodate/chloride was then added, followed by silica fume and, finally, sodium bicarbonate, to create a slurry. The slurry was warmed on a heating plate at 60–70°C for one hour, and the carbon dioxide released during this process resulted in the material being porous.

Continued on next page.

1. Horizon prize on materials for clean air: http://ec.europa.eu/research/horizonprize/index.cfm?prize=clean-air

2. Air quality in Europe Report, 2016. European Environment Agency: https://www.eea.europa.eu/publications/air-quality-in-europe-2016. (Accessed 23 February 2018).

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Innovative seaweed-based gel coating for urban homes able to capture harmful air particles *(continued)*

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Porous discs of SUNSPACE of 2.3 cm in diameter and 5 mm in thickness were created for use in tests. Three tests were devised to check the capability of SUNSPACE to trap air PM. In the first test SUNSPACE was exposed to diesel fumes from a car exhaust for 15 minutes at a distance of 15 cm from the pipe; the SUNSPACE disc was made using white silica to better highlight any change in colour resulting from PM capture. The used material was washed afterwards to remove the trapped PM, and dried for reuse. The second test involved a SUNSPACE sample with an area of 20 cm^2, placed 30 cm from an incense stick. In the third test a SUNSPACE sample with an area of 4.15 cm^2 was positioned 30 cm away from six incense sticks being burned in succession. The researchers suggest that SUNSPACE saturation depends on the air quality — when it is poor (i.e. the concentration of PM10 and PM2.5 is high) the material traps more PM, compared to better air conditions.

Analysis of SUNSPACE found it to have ink-bottle-shaped pores that trap fine particles effectively. The samples exposed to diesel fumes darkened in colour and were shown to contain a greater weight of carbon after their exposure — diesel fuel PM has a carbon core coated with metals, polyaromatic hydrocarbons, and quinones (a class of compounds derived from aromatic compounds, such as benzene and naphthalene). The SUNSPACE diesel test disc was washed with water to mimic rainfall, and returned to almost original capacity. This ability to be regenerated by rainfall makes it suitable for PM capture in urban areas[3].

The second and third tests, involving incense sticks, showed that PM was captured at a slightly lower amount sequentially after each of the six incense sticks was burned. The material adsorbed 2407 mg/cm^2 of air PM with diameters lower than one millimetre — scaling this up equates to 24 g/m^2 of air PM (about two orders of magnitude more than the PM that can be trapped by leaves). The researchers estimate that if SUNSPACE was used to cover the 92 million m^2 of roof tiles in New York, about 2 200 tons of air PM would be captured by the roofs alone, until rainfall. This estimate was calculated on the basis of the trapping capability of the new material and the surface area of New York roofs. The SUNSPACE would also regenerate after rainfall; the researchers suggest that the discharge water could be collected by the urban wastewater collection system. The researchers add that PM adsorption might also depend on factors such as wind direction and intensity.

The researchers aim to implement the patented material at industrial level with the support of an appropriate partner. They suggest that it would be necessary to invest about €150,000, to cover all start-up costs.

The 2008 ambient air quality Directive[4] set limits for the concentrations of major air pollutants that impact public health, such as PM and nitrogen dioxide (NO_2). As $PM_{2.5}$ poses a risk at any level, the Directive suggests that approaches should aim at generally reducing these concentrations in urban areas. Air quality standards are presently not being achieved in several air quality areas, as shown in the Air Quality in Europe 2016 report[2], and current air-filter materials — such as polyethylene— are not produced sustainably. SUNSPACE offers an innovative sustainable solution to both improve air quality and lower PM levels in the urban environment.

3. More recent research demonstrates the possibility of SUNSPACE regeneration by washing: Zanoletti, A. *et al* (2018). SUNSPACE, a porous material to reduce air particulate matter (PM). *Frontiers in Chemistry*: *https://www.frontiersin.org/*

4. The 2008 ambient air quality Directive (2008/50/EC)