A new porous hybrid material to reduce air particulate matter (PM)

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Introduction

The work presents a new porous-mesoporous hybrid material (named SUNSPACE), which is a well-designed, affordable and sustainable solution for air particulate matter (PM) capture. The proposed innovative porous material is realized by using industrial by-products and low-cost materials. Foliage represents right now the best low-cost and sustainable solution for PM accumulation (for example, in Chicago urban trees, which occupy 11% of the city area, remove about 234 tons of PM₂.₅ per year). Leaves efficacy in PM accumulation is also due their wide diffusion. Then for SUNSPACE design, it was chosen a low-impact material, that can be applied on wide spaces. It is proposed to apply SUNSPACE, as a coating, on different supports, such as wall, tiles, roof, street borders, and so on, and thus it was designed to be applied by spray and by painting. SUNSPACE contains pores (from micron to nanometer sizes) having ideal shapes and dimensions for ultra-fine PM trap. It is shown that it can accumulate at least 30 g/m² of particles, at the cost of 0.02 € per gram of captured PM. As it happens in nature for leaves, SUNSPACE is designed to be regenerated, after PM capture, simply by rainfall. The discharge water can be collected by the urban wastewater collection system (for example with wastewater deriving from street washing) to be conveyed at the urban wastewater treatment plant, with no additional impacts.

Materials and approaches

- Silica fume + Bicarbonate + Alginates
- Extrusion
- Spray
- 3D printing
- TEM images of Fe₂O₃ nanoparticles located on the border and on the center (see arrows) of SUNSPACE pores.

Outcomes

- Capture of PM generated by diesel
- TEM images of Fe₂O₃ nanoparticles trapped test

Sustainability

- Synthesis process does not require the use of solvents and precipitating agents;
- Reuse of waste materials promotes environmental sustainability;
- To allow the decomposition of bicarbonate it is possible to exploit solar energy (leaving the sample outdoors on a sunny day).

Transferability

Demonstration of a development version of SUNSPACE material, in the operational environment (TRL level 7), realized by deposition of the new materials as a coating.

Application of SUNSPACE onto a roof tile and a part of a wall (a), SUNSPACE sample after 2 months of exposition on the University roof (b and c).

Embodied energy and CO₂ footprint of SUNSPACE (obtained by thermal annealing - SUNSPACE 1, and without thermal annealing - SUNSPACE 2). As comparison also energies and emissions involved in the production of materials used as filters such as polyethylene (PE), polypropylene (PP), poliamide (PA), polystyrene (PS) and glass are reported.

TEM (a, b) and TEM (b) images of SUNSPACE. In red circle a detail of ink bottle shape pore.

SEM (a, b) and TEM (b) images of SUNSPACE. In red circle a detail of ink bottle shape pore.