Æther : Bio-inspired indoor air purifying device

æther

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ABSTRACT

Air pollution is a major issue in both interior and exterior spaces. Most people spend over 80% of their time indoors. Aether is an air-purifying device which can tackle particulate matter carrying poly aromatic hydrocarbons, molecules that are harmful endocrine disruptors. The degradation process relies on the activity of an enzyme cocktail. We demonstrate their activity using *Escherichia coli* produced proteins on anthracene. Public engagement and information on this issue has required on our part multiple actions ranging from a worldwide survey, to a particulate matter chase game organized with the help of associations for lung disease and air quality authorities. Our device is modeled by industrial design principles, and a 1:1 scale unit is presented. The notion of clean air is by law a right that every citizen should enjoy, Aether aims at meeting this challenge.

Figure 1: *Particulate matter. PM 2.5 and PM 10 are composed of organic and inorganic compounds. The particles can stay in suspension for long periods and enter the lungs. Most of the organic components are Poly Aromatic Hydrocarbons (PAHs).*

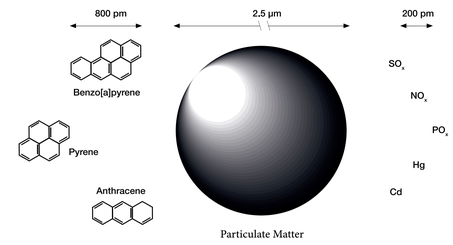
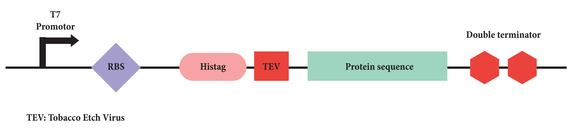


Figure 2: *Schematic representation of our standardised construction.*



SCIENCE METHODOLOGY

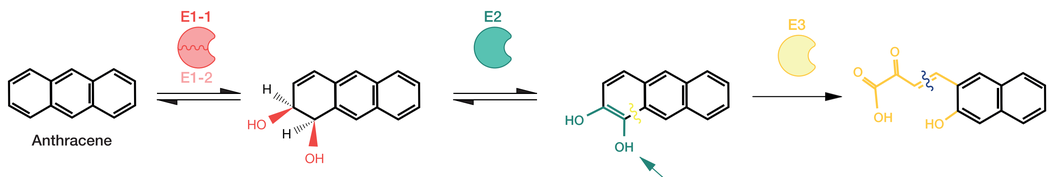


Figure 3a: *Schematic representation of the enzyme degradation pathway for poly-aromatic hydrocarbons. Anthracene degradation: (E1-1/E1-2: BBa_KB2198000/001), E2: BBa_KB2198002, E3: BBa_KB2198003, E4: BBa_KB2198004). The green arrow represents a possible cycling of the reaction to iteratively degrade the remainder of the rings, due to the non-specific substrate specificity of E3.*

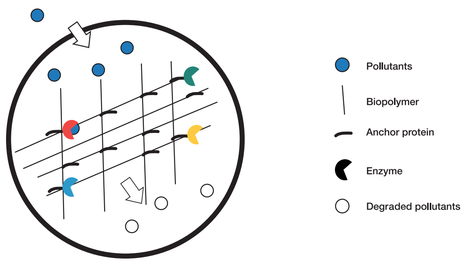


Figure 3b: *The scaffold of our device. The substratum of the device is composed of a network of spider-silk and enzyme molecules. Organic pollutants (PMs) are trapped by the water condensing property of the spider-silk S1 (MaSp1, Major Spindroin protein of Euprosthenops australis). The enzymes E1-E4 cocktail then proceed following Fig 2a. to their degradation.*

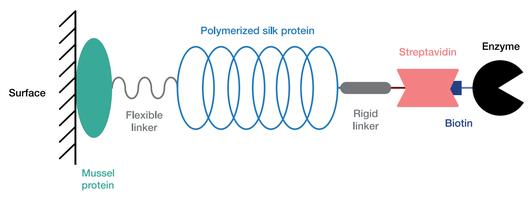


Figure 4: *Molecular scaffold. Future work will produce a molecular scaffold composed of the fusion of mussel protein Mfp5 (Mytilus californianus) with S1. A tiered layer of S1 (BBa_KB2198005) will create a variable density film. The termination of polymerization will be provided by S1-Strepavidin. The capping of the structure will be with the biotinylated enzyme cocktail by streptavidin-biotin interaction.*

RESULTS AND CONCLUSIONS

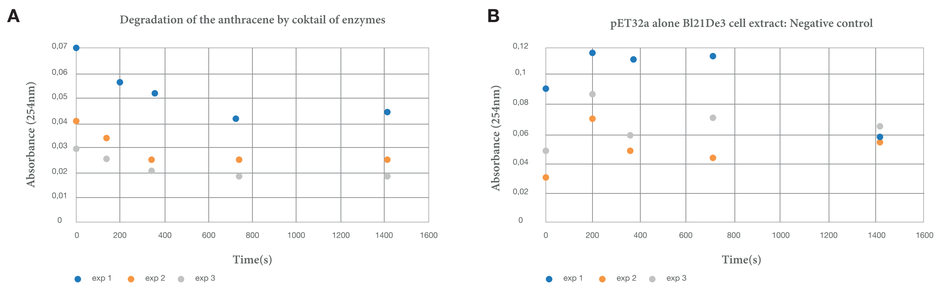


Figure 5: *Kinetics of the degradation of PAHs by the E1-E4 enzyme cocktail.* **A.** *Time plot of the change in absorbance as a consequence of the addition of the enzyme cocktail to anthracene (Abs: 254 nm, prepared in 80% glycerol v/v) in 120 µl reaction buffer (Tris-Cl 50 mM, pH 7.4, NaCl 50 mM) at RT (22°C). The mean of three technical replicates are plotted, with SD as error bar. Enzymes are provided as bacterial extracts and expressed from a pET32a vector after induction with IPTG 0.5 mM in Escherichia coli.* **B.** *Control reaction is performed with empty pET32a transformed E. coli induced for the same time period (3 hrs at 37°C).*

The capture and especially degradation of poly aromatic hydrocarbons is a key step in the fight against PM pollution. We have demonstrated that an enzyme cocktail composed of E1, E2, E3 and E4 is able to degrade anthracene within minutes. We will in the future set our reaction on a silk-protein based scaffold. This is a proof of concept for attacking other members of the PAHs, which cannot be easily degraded by other methods, namely benzo[a]pyrene.

We were also able to assemble our prototype filter based on applied design methodologies, integrating air flow modeling data and usage scenarios for indoor applications. We present our 3D printed pre-prototype on a 1:1 scale, with its associated peripherals; an app, after sale services and usage scenarios. The unit will be based on the use of printed organic Grätzel power cells, and contain both a bio-filter and activated charcoal filter. In addition, based on data from surveys and a worldwide questionnaire, we have fully integrated the public's perception of our device, its application in improving health and their daily environment. Finally, we produced an analysis of regulatory directives and their societal impact (Polluters, citizens) in a report on Air pollution. The right to breath clean air stands as stated, and will be more so with Aether.

DESIGN METHODOLOGY

In order to bring this innovative solution to fight air pollution to users, we designed an affordable and energy self-sufficient air purifier containing this bio-filter, surrounded by a user friendly service and a dedicated app. Design methods (brainstorming, benchmark, user scenario, user experience roadmap) and tools (2D and 3D CAD software), as well as prototyping tools (3D printing, laser cutting) have been used to produce scale 1:1 model of the product and app. We also established a graphic charter to go along with our object so as to have a coherent visual environment.

Figure 6.

INTEGRATED HUMAN PRACTICES

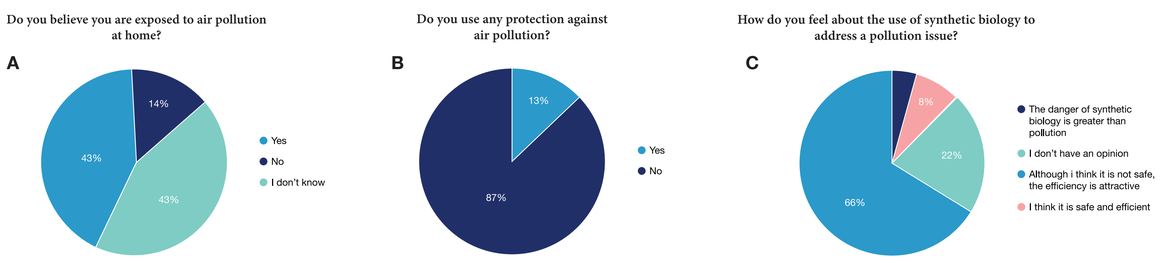


Figure 7: *A global investigation about air pollution and synthetic biology (2297 answers).* **A. Awareness about indoor air pollution.** *According to our survey, 63% are aware to be exposed to air pollution at home.* **B. Means used for protection.** *However, only 14% of them protect themselves against this plague (excepted in Asia where people use masks or air purifiers).* **C. Synthetic biology as a solution to air pollution.** *We also observed that 64% of respondents are interested in a synthetic biology solution but think it is not a safe science.*

Summary of our global study: We identified a problem of lack of information about indoor air pollution. This questionnaire also confirmed the need for our solution, especially in Asia and Africa, and influenced our application scenario. While most participants are interested in the potential of synthetic biology, many ask for safety guarantees. Thus, we conducted further investigations and engagement to sensibilize people about the issue whether it was through a scavenger hunt, workshops with students or meetings with French institutional actors in the fight against air pollution.

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SCHOOLS

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LAW

The right for all to breath an air which is not harmful to one's health.
« Article 1 Law n°96-1236 on the Air and Rational Use of Energy 1996. France. 2017.igem.org/Team:Pasteur_Paris/HP/Law

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