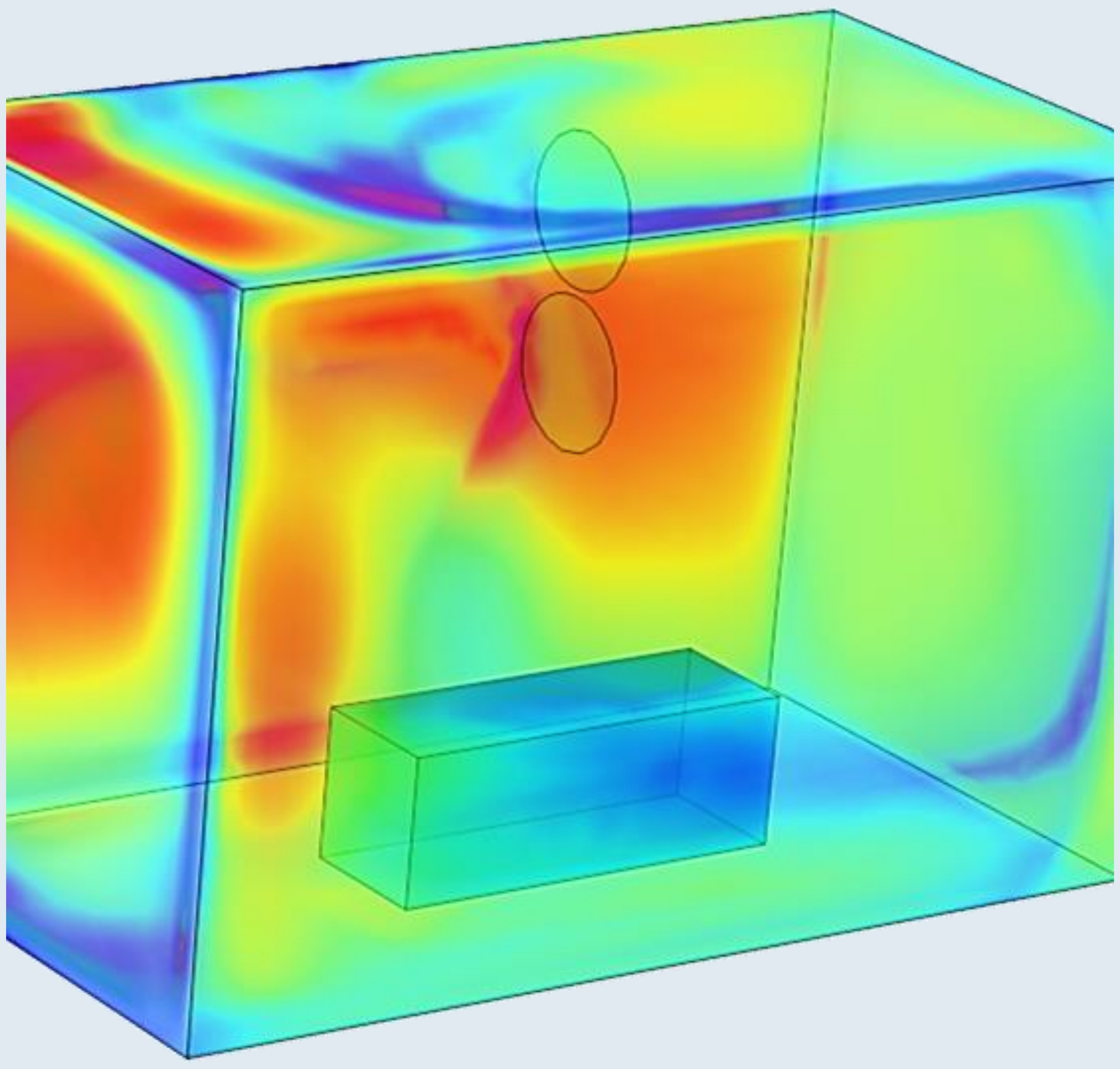

Modeling Botanical Biofiltration for Indoor VOCs Purification

Botanical biofiltration is an indoor VOC-purification technique that biodegrades VOCs due to plants-bacteria, often neglected in models. Multiphysics modeling is a tool for a comprehensive analysis.

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Introduction

Botanical biofiltration is a novel, more robust and versatile technology for indoor volatile organic compounds (VOCs) purification. The technology combines multiple VOC-removal mechanisms: physical-chemical (diffusion, convection) and biological (biodegradation). Previous research has focused on experiments in climate chambers to evaluate its efficiency. Yet very little is understood regarding the modeling of the system, and subsystems: botanical and substrate compartments.

Previous studies have neglected the biodegradation occurring in the botanical compartment, thus applying only a conventional biofiltration model. Nevertheless, research has shown that bacteria and plant cells can likewise remove VOCs, and therefore, need to be considered. A model that considers an indoor environment with the botanical biofilter as a VOC-sink (batch reactor) offers an approximation to understand the efficiency and potential of the system.

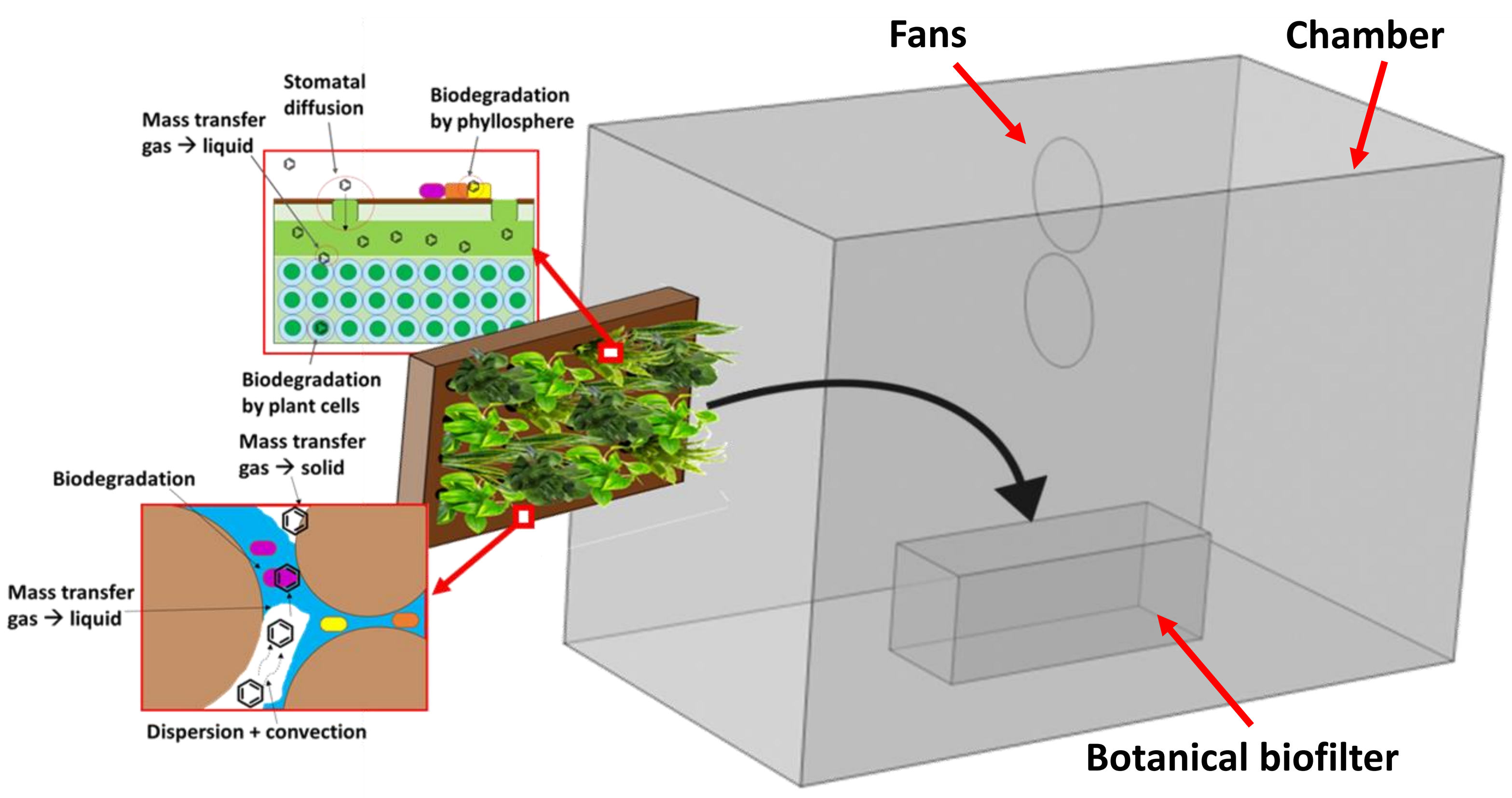

FIGURE 1. Translation of botanical biofiltration phenomena into a multiphysics model for a passive system.

Methodology

A preliminary model was built upon biofiltration and bioremediation phenomena. Turbulent flow in porous media was coupled with transport of diluted species, and sink terms for the VOC biodegradation. The model vas validated against experiments (r=0.98).

Turbulent Flow-Porous Medium:

$$\frac{1}{\varepsilon}\rho(u\cdot\nabla)u\frac{1}{\varepsilon} = \nabla\cdot[-pI+K] - \left(\mu\kappa^{-1} + \beta\rho|u| + \frac{Q_m}{\varepsilon^2}\right)u + F$$

Transport Phenomena: $-(D_{D,i} + D_{e,i})\nabla C_i + u\cdot\nabla C_i = R_i$

Multiphysics: $J_{T,i} = -\frac{\mu_T}{Sc_T}\nabla C_i$ **Sink Term:** $R_i = \theta_l \mathrm{k} C_i$

Results

The passive botanical biofilter removed 5.0E-04 mol of VOC from the chamber (10 ppm; 1.2 m^3) in 67 min, via a first-order reaction, with a decay constant (k) of -5E-02 s^{-1}. The mean velocity through the passive biofilter was low, as expected (1.0E-03 m s^{-1}), and total VOC flux of 1.8E-06 mol m^{-2} s^{-1}. The porosity (ε), liquid saturation (θ_l) and decay constant were experimentally obtained. A parametric study confirmed that higher θ_l values increased the removal speed since VOC-degradation occurs in the liquid phase.

Future work will parameterize the sink term for the substrate considering the bacterial concentration; for the plants, the leaf area density, stomatal number and bacteria in the leaves (phyllosphere).

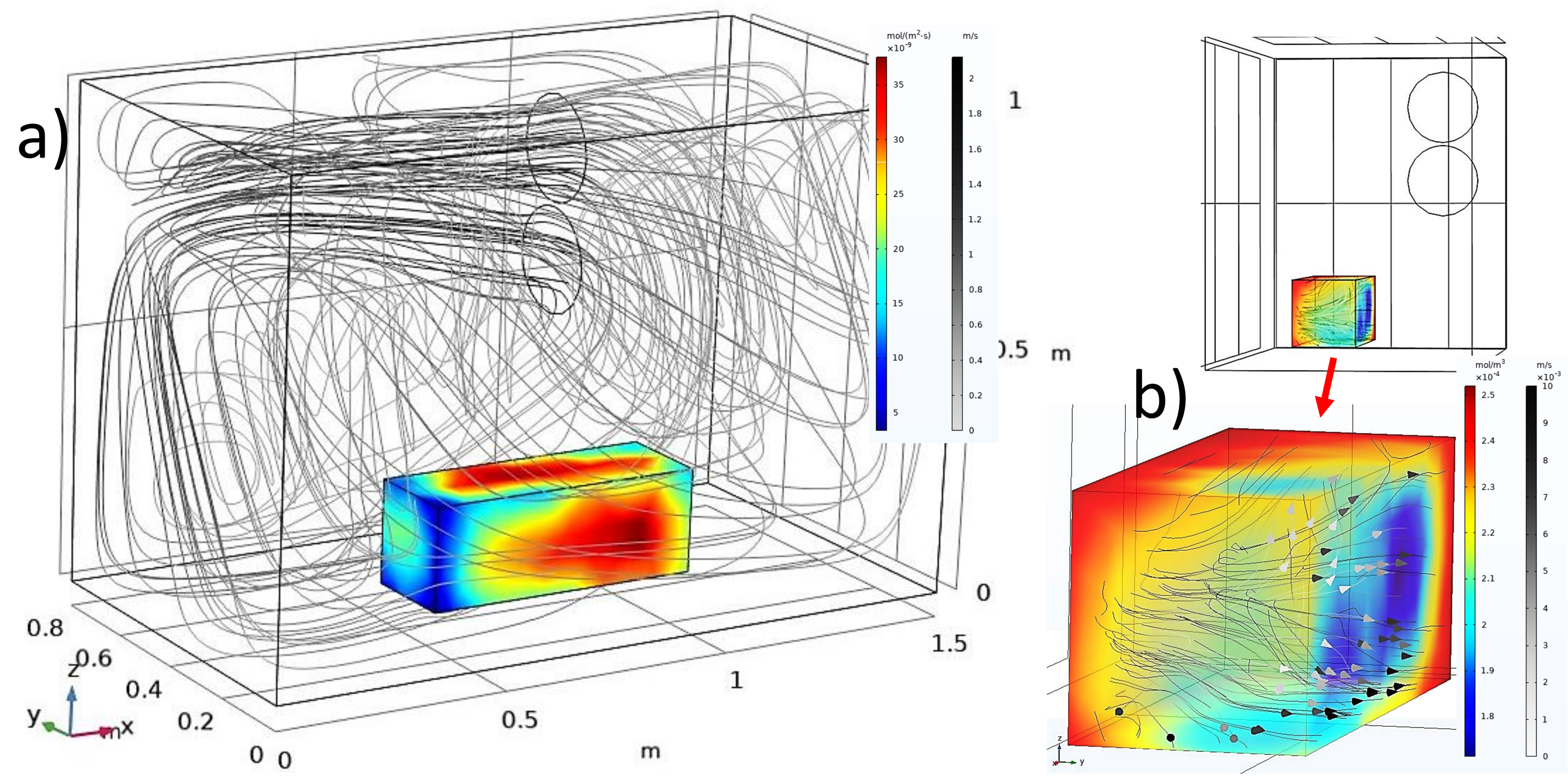

FIGURE 2. (a) Dispersive flux in the b. biofilter; velocity in the chamber. (b) VOC concentration and velocity in the b. biofilter.

REFERENCES

Masi, M. *et al.* (2022) 'Modelling botanical biofiltration of indoor air streams contaminated by volatile organic compounds', *Journal of Hazardous Materials*, 422. Available at: https://doi.org/10.1016/j.jhazmat.2021.126875.

Wang, Z., Pei, J. and Zhang, J.S. (2012) 'Modeling and simulation of an activated carbon-based botanical air filtration system for improving indoor air quality', *Building and Environment*, 54, pp. 109–115. Available at: https://doi.org/10.1016/j.buildenv.2012.02.011.

Wolverton, B.C., Mcdonald, R.C. and Watkins, E.A. (1984) 'Foliage plants for removing indoor air pollutants from energy-efficient homes', *Economic Botany*, 38(2), pp. 224–228. Available at: https://doi.org/10.1007/BF02858837.

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