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Holistic air purification for future space exploration missions. What can we already use now?

In preparation of future exploration missions to Moon or Mars, Environmental Control Life Support Systems (ECLSS) are crucial for the survival of humans in space. In particular, the generation and preservation of a controlled atmosphere is of key importance and should not only rely on the regular supply of oxygen tanks or water electrolysis. A robust and reliable solution has been developed, tested and optimized for small habitable areas with maximum recycling of carbon dioxide and covering all aspects of controlled air quality: composition, fine particles, volatile organic matter, odors and even airborne viruses.

Currently, about 50% of oxygen is recovered from carbon dioxide on the International Space Station (ISS) with NASA's advanced oxygen generator. Oxygen tanks are uploaded regularly to the ISS to be mixed with capsule air and various air purification systems have been uploaded and tested to improve the air quality on the ISS with various success rates.

The GreenLung® is a photobioreactor based technology to purify air in confined areas. The initial development started with a focus on CO2 conversion to oxygen by microalgae and has been gradually refined in the past years. The efficiency was improved by adding preprocessing steps to accelerate gas transfer to the liquid phase, improved.

The photobioreactor and gas transfer systems were characterized by determining volumetric mass transfer coefficient (kLa). The dynamics of the microbial consortium include specific growth yield and the carrying capacity. The lighting system of the reactor is optimized to maximize the utilization of light energy by aligning the spectral out of the lamps and radial illumination from the center of the reactor.

Long term continuous operation tests were performed to validate the performance in real-life scenarios.

CO2 to O2 conversion
Volumetric mass transfer coefficient (kLa) for CO2 measured in the photobioreactor is equal to 75 1/h. The CO2 conversion efficiency is 500 g per day for a reactor volume of 100 liters. The average light intensity in the reactor is equals to 250 µmol PAR/m².s.

VOC reduction
The reduction of Volatile Organic Carbons (VOCs) was measured in a laboratory tests chamber. Acetaldehyde and toluene were used as model components because of their abundance in indoor spaces and the components are representatives for VOCs groups with specific physical-chemical properties. The specific absorption rate for acetaldehyde is 0,25 1/h. This results in a removal capacity of 0,015 mg acetaldehyde per liter reactor volume per hour.

Airborn virusses
The removal of air-born viruses from the ambient air by capturing them in the liquid phase is evaluated in ongoing research. Quantitative analyses are performed using the MS2 phage as a model for virus particles allowing to establish mass balances and removal rates. First results indicate that MS2 phages are deactivated. The destruction of phages and virusses in the photobioreactor will be investigated in the next steps.

The prototype GreenLung® has been fully elaborated and tested in the frame of a space demonstrator, but its functionality is also suitable for many terrestrial applications. By making use of biological processes, the GreenLung® technology shows excellent performance on a wide range of potential criticalities of indoor air control.

Primary authors: Mrs LUTHER, Amanda (Redwire Space); Mr DEMEY, Dries (Redwire Space)

Co-authors: Mrs DE RIDDER, Malika (Redwire Space); Prof. SAELENS, Xavier (VIB - UGent)

Presenter: Mr DEMEY, Dries (Redwire Space)