EXPLORING SUSTAINABLE CULTIVATION OF GALDIERIA PHLEGREA USING URBAN WASTEWATER: INTEGRATION OF IOT-ENABLED PHOTOBIOREACTOR FOR BIOMASS PRODUCTION AND SILICON-RECOVERY APPLICATIONS

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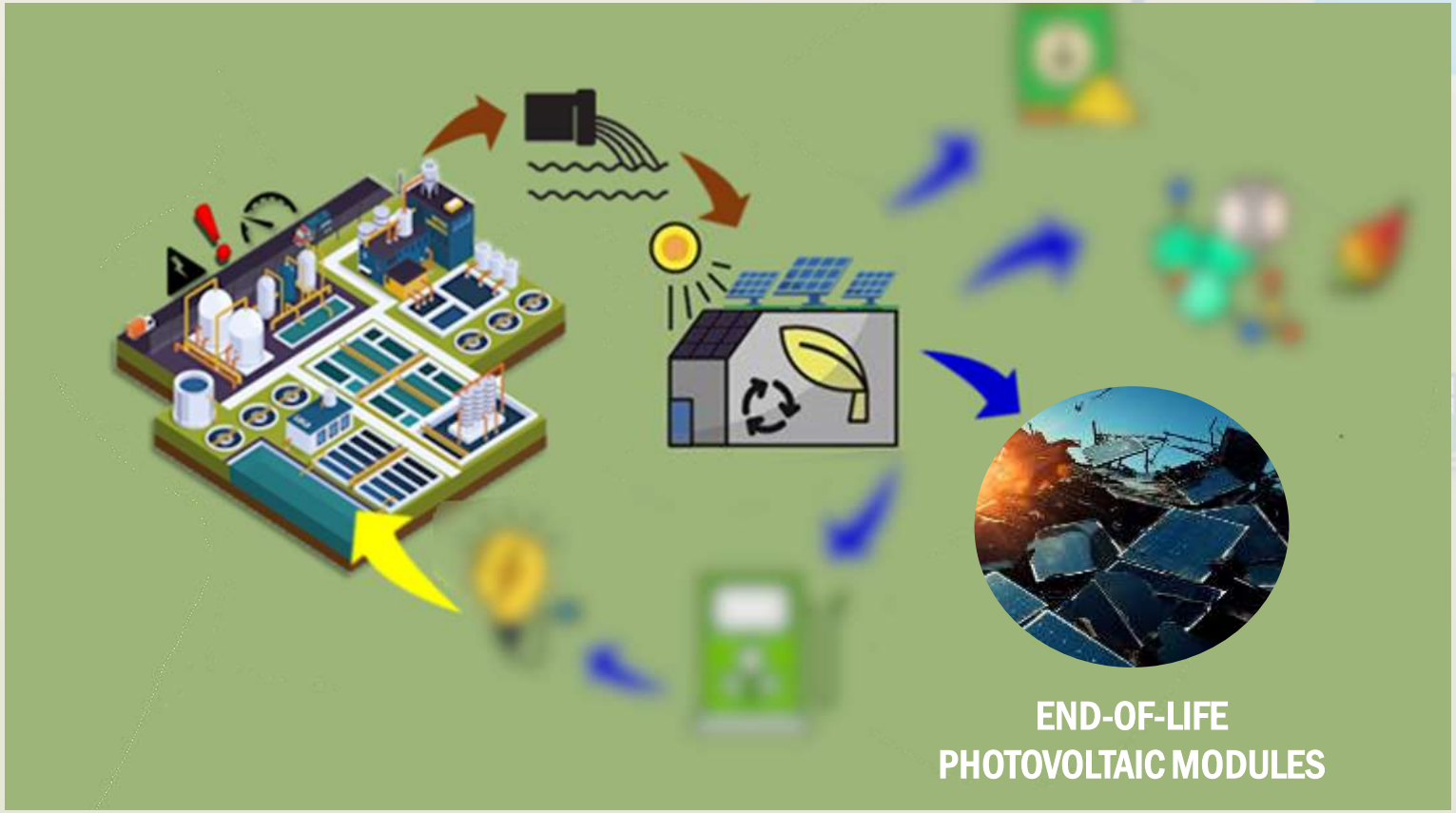
SUM2024 7th INTERNATIONAL SYMPOSIUM ON CIRCULAR ECONOMY & URBAN MINING

THE RESEARCH ACTIVITIES

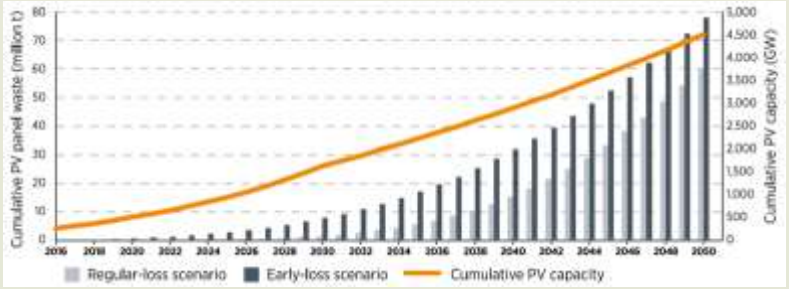
Two main research directions:

1. Development of innovative **IoT-based PhotoBioReactors** for the **cultivation** of microalgae **using municipal wastewater**
2. Reuse of biomass for **biorecovery of Silicon** (and other elements of interest) **from PHOTOVOLTAIC WASTE**



END-OF-LIFE
PHOTOVOLTAIC MODULES

Photovoltaic waste (PV-WEEE)
is a serious environmental problem
and is expected to increase
considerably in the coming decades



Exploring Sustainable Cultivation of G. phlegrea Using Urban WW: Integration of IoT-Enabled PBR for Biomass Production and Si-recovery Applications

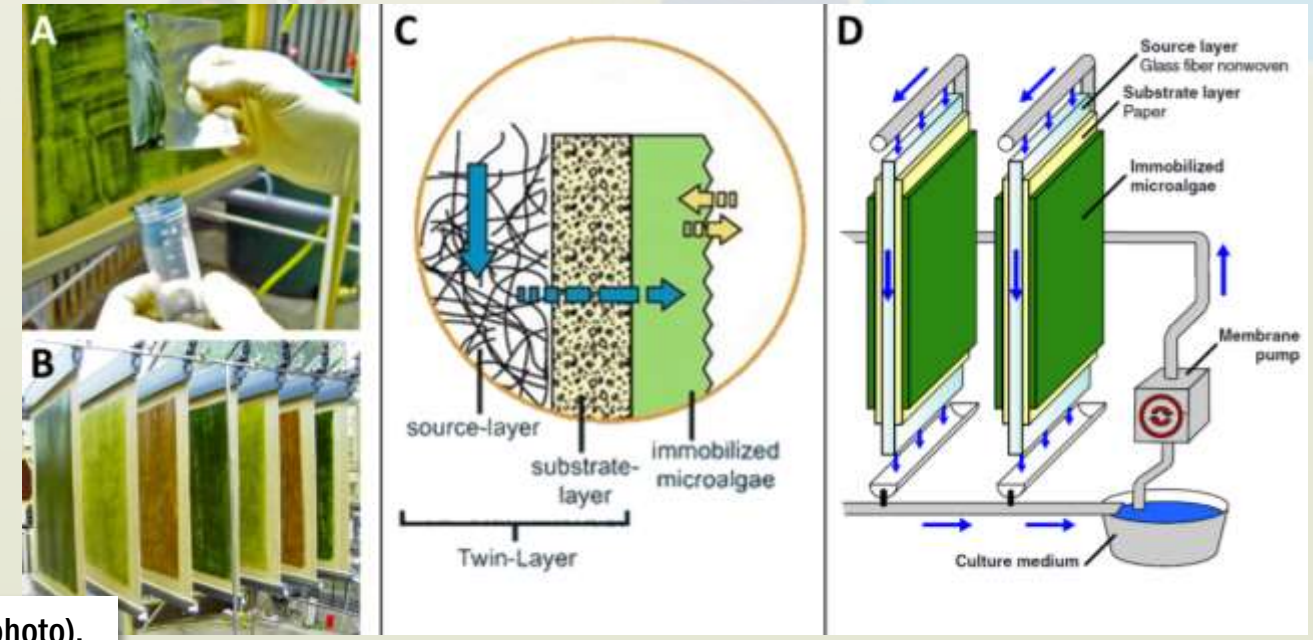
1) ACTIVITY #1: THE PBR PROTOTYPES

We implemented Twin-Layers photobioreactor prototypes with integrated IoT sensors.

The technology uses a layered substrate where culture medium (in this case urban wastewater) circulates for nutrient uptake by the growing biomass.

The prototypes are easily scalable with custom metallic and 3D-printed components.

Twin-Layers prototypes (personal photo).



- ✓ **Optimal growth conditions for the species *G.phlegrea***
- ✓ ***Ready-to-use* algal paste**
- ✓ **Energy-efficient cultivation (absorbed power < 30 W), compensable with solar panel installation**
- ✓ **Minimal material costs**
- ✓ **Easy scale-up**

At an industrial scale, biomass can be harvested manually using spatulas or with low pressure air blasts

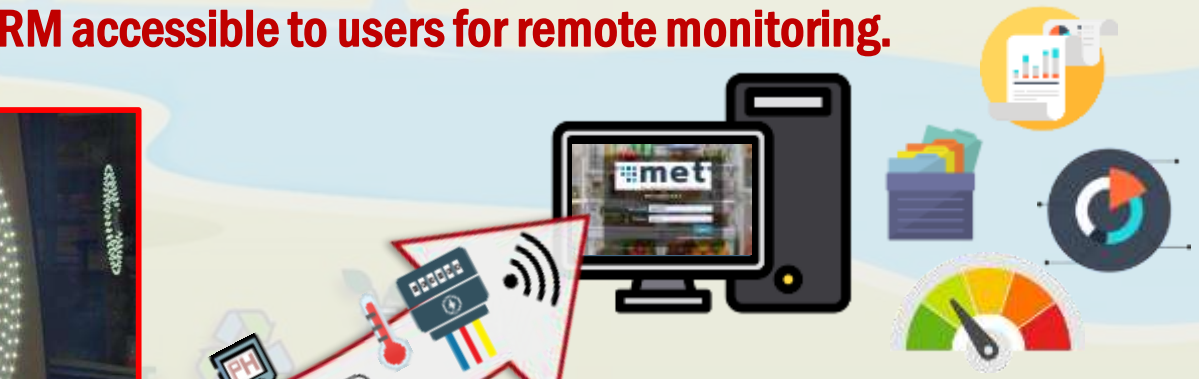
di Cicco, M. R., Palmieri, M., Lubritto, C., & Ciniglia, C. (2022). Microalgae-Based Nutrient Recovery from Urban Wastewater Algal Biorefineries and the Circular Bioeconomy (pp. 115-145): CRC Press.
di Cicco, M. R., Iovinella, M., Palmieri, M., Lubritto, C., & Ciniglia, C. (2021). Extremophilic Microalgae Galdieria Gen. for Urban Wastewater Treatment: Current State, the Case of "POWER" System, and Future Prospects. Plants, 10(11), 2343.
Carbone, D.A.; Olivieri, G.; Pollio, A.; Melkonian, M. Comparison of Galdieria growth and photosynthetic activity in different culture systems. AMB Express 2020, 10, 170.
Naumann, T. et al. "Growing microalgae as aquaculture feeds on twin-layers: a novel solid-state photobioreactor." Journal of applied phycology 25 (2013): 1413-1420.

1) ACTIVITY #1: THE IoT BASED MONITORING SYSTEM

The monitoring system is custom-made too, with probes specifically selected with respect to environmental conditions and the prototype layout. The sensor monitors pH, temperature, lighting conditions, humidity, and volatile organic compounds.

Data is transmitted in real-time to a WEB PLATFORM accessible to users for remote monitoring.

Laboratory-scale Twin Layers photobioreactor prototypes with sensors, polycarbonate discs and attached biomass.



Main Control Unit of the IoT based sensor system

1) ACTIVITY #1: CULTIVATION TESTS AND RESULTS

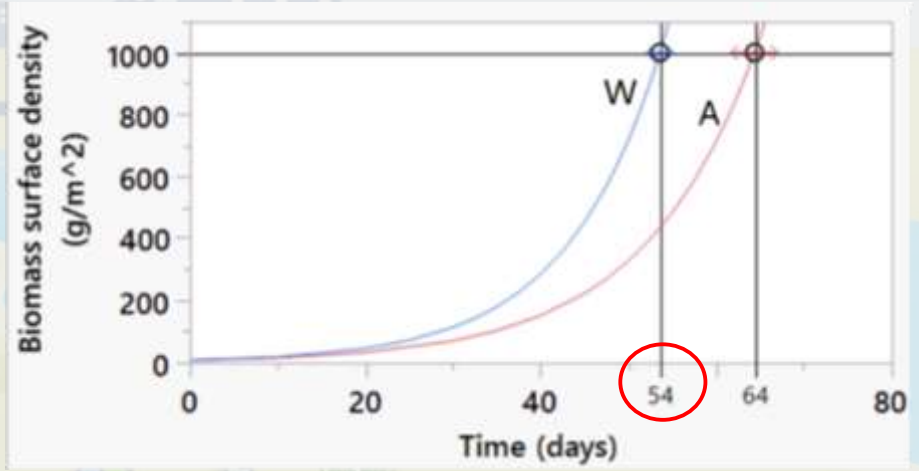
Our experiments involve the strain *Galdieria phlegrea* (ACUF 784.3), which is an extremophilic organisms and thrives in extreme environments (thermal, volcanic)

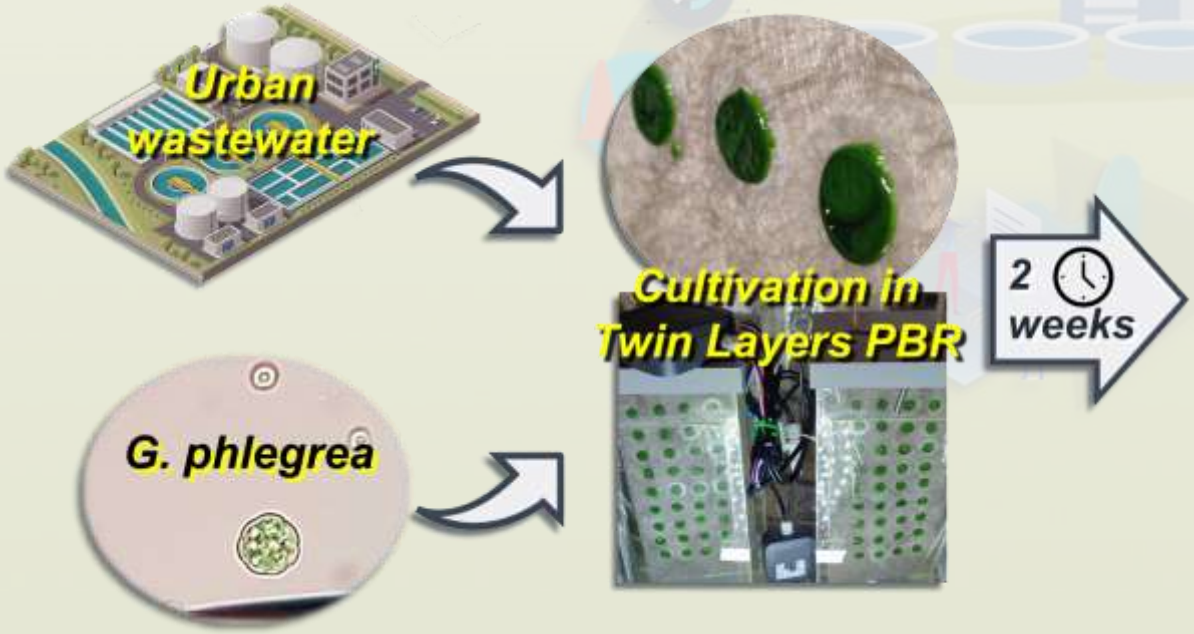
1) ACTIVITY #1: CULTIVATION TESTS AND RESULTS – growth rate

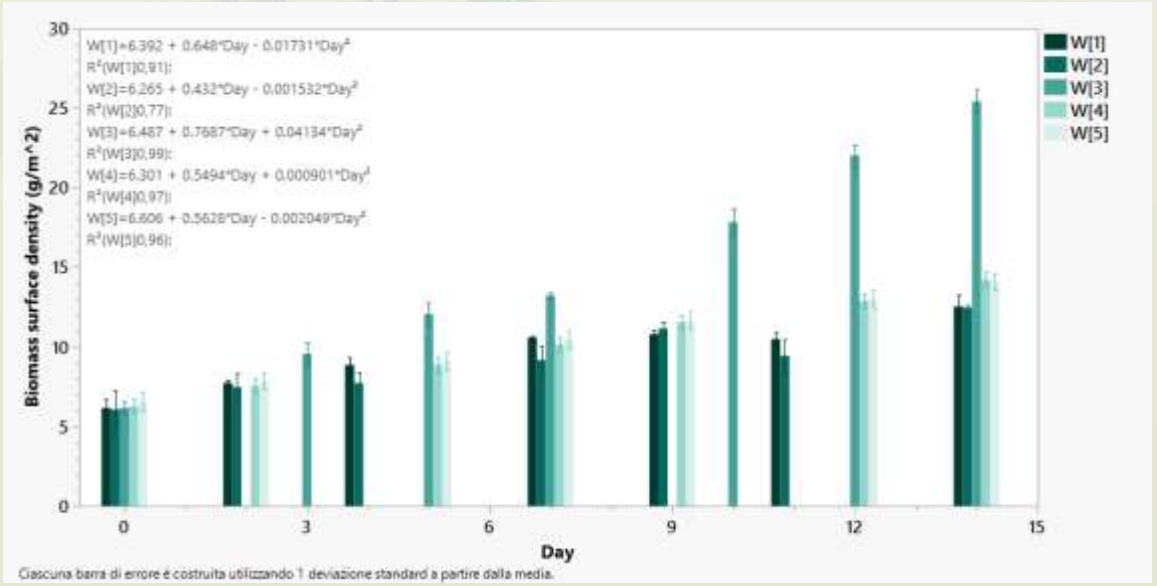
Best fit: exponential growth

Yield: 1kg of dry biomass per m^2 of cultivation surface in less than 60 days

W = Wastewater medium | A = Standard medium



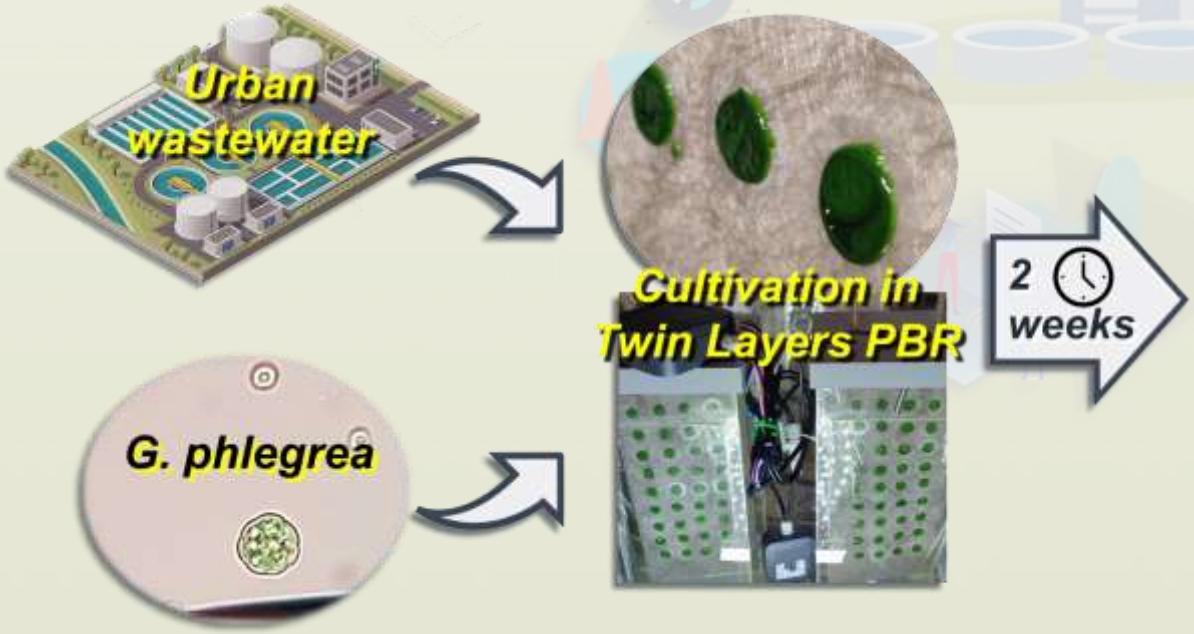


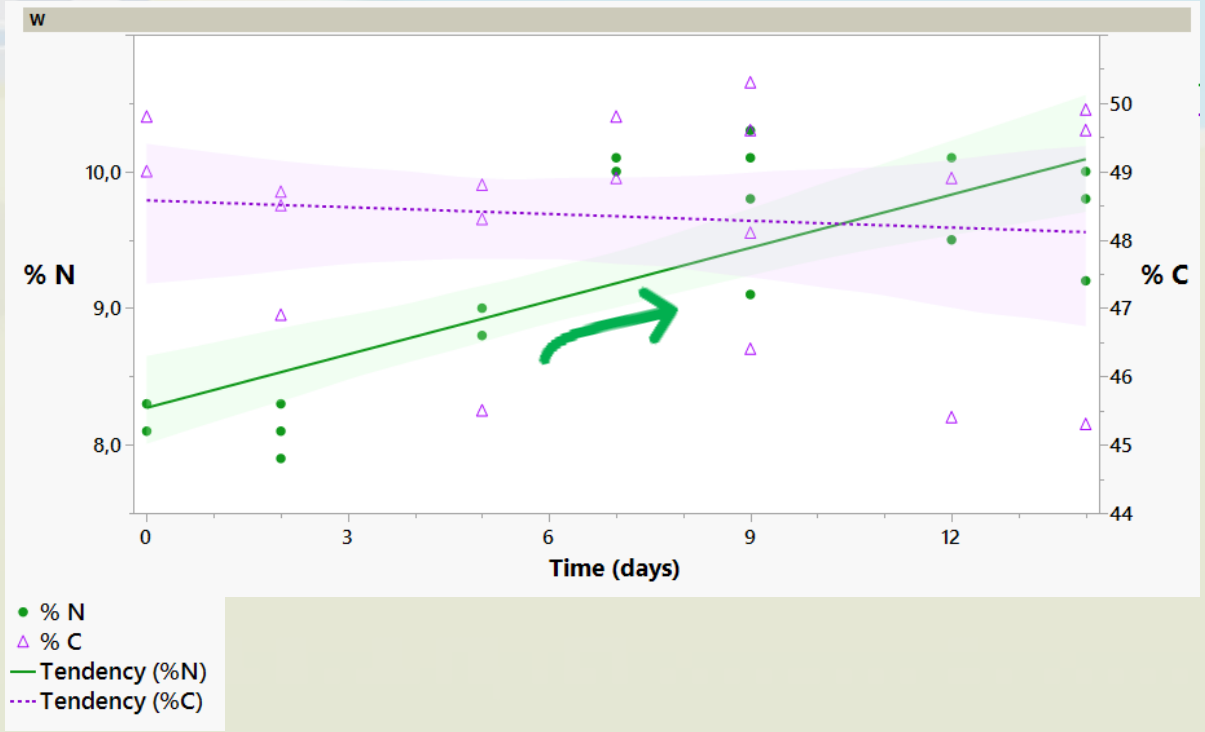


1) ACTIVITY #1: CULTIVATION TESTS AND RESULTS: Isotopic analyses

The total content of N increases over time (from 8% to 10% after 2 weeks).

Moreover, isotopic analyses reveal that N uptaken by the biomass originates from wastewater.

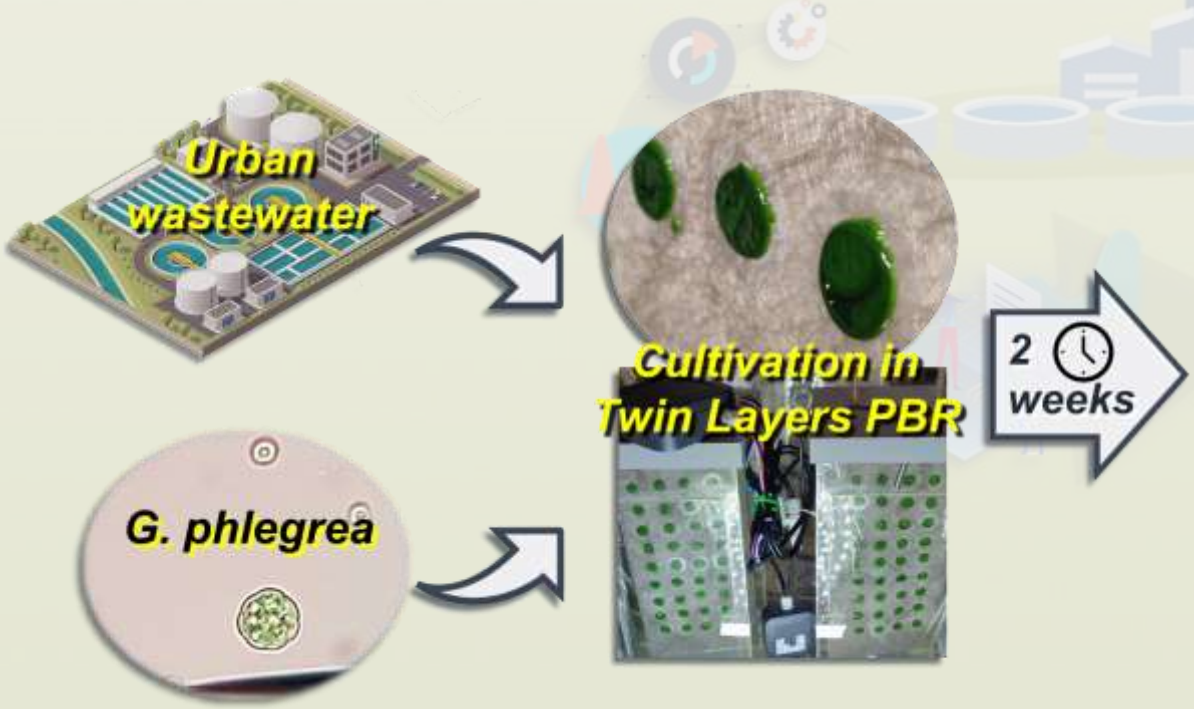




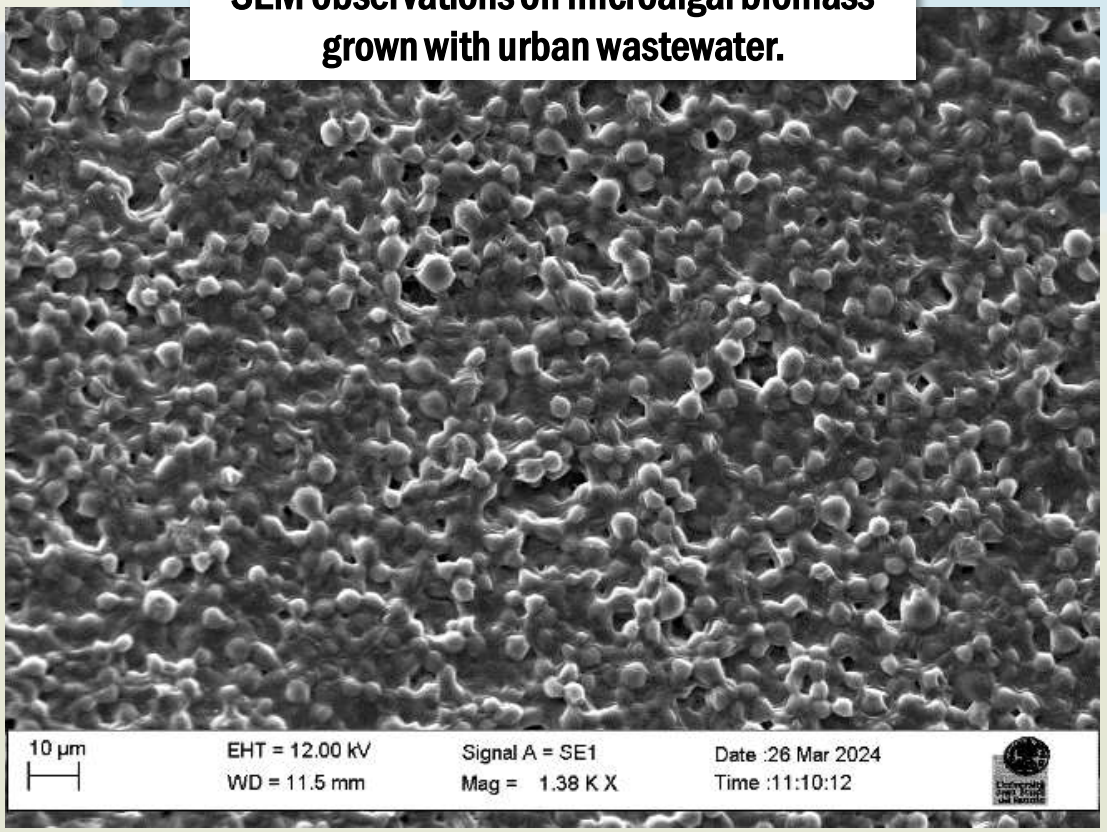
1) ACTIVITY #1: CULTIVATION TESTS AND RESULTS: SEM analyses

SEM analysis showed no morphological differences between biomass grown in W vs the standard

The biomass is homogeneous and clean, with no presence of competing micro-organisms (molds)



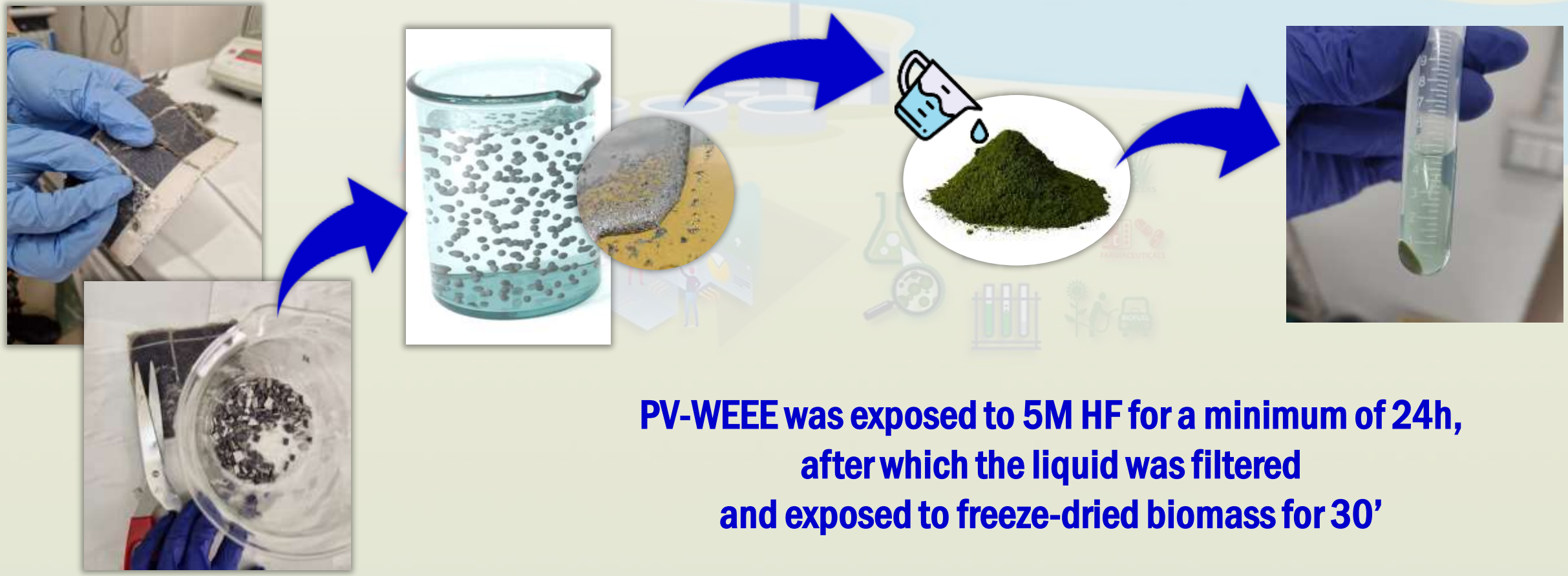
SEM observations on microalgal biomass grown with urban wastewater.



2) ACTIVITY #2: Silicon recovery Application

Is it possible to use the cultivated biomass as a substrate for the recovery of elements from critical waste?

PRELIMINARY TEST: acid leaching on coarse pieces of dismantled photovoltaic panels (PV-WEEE) and qualitative assessment of elements retention on dry biomass



PV-WEEE was exposed to 5M HF for a minimum of 24h, after which the liquid was filtered and exposed to freeze-dried biomass for 30'

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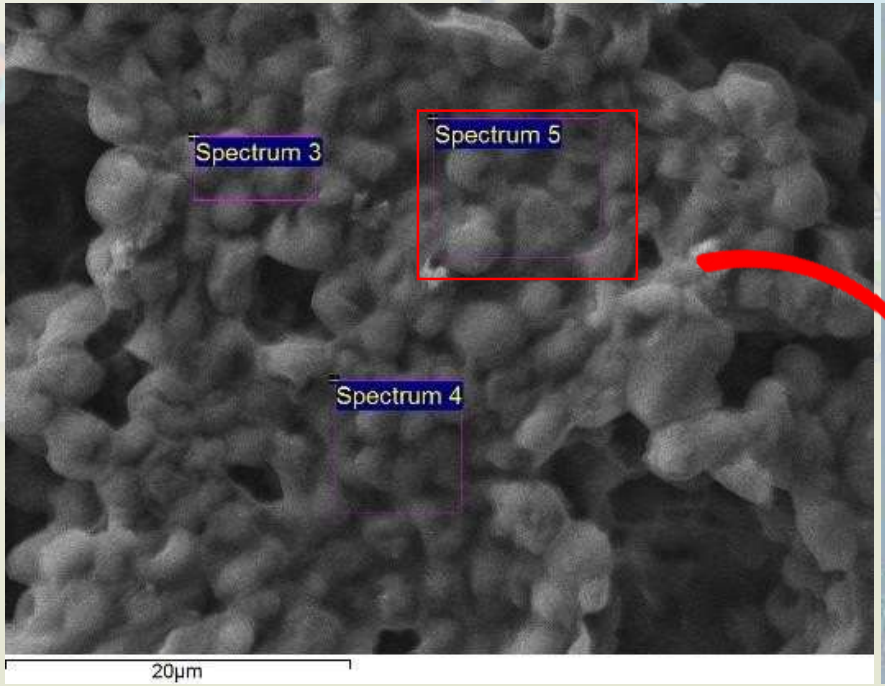

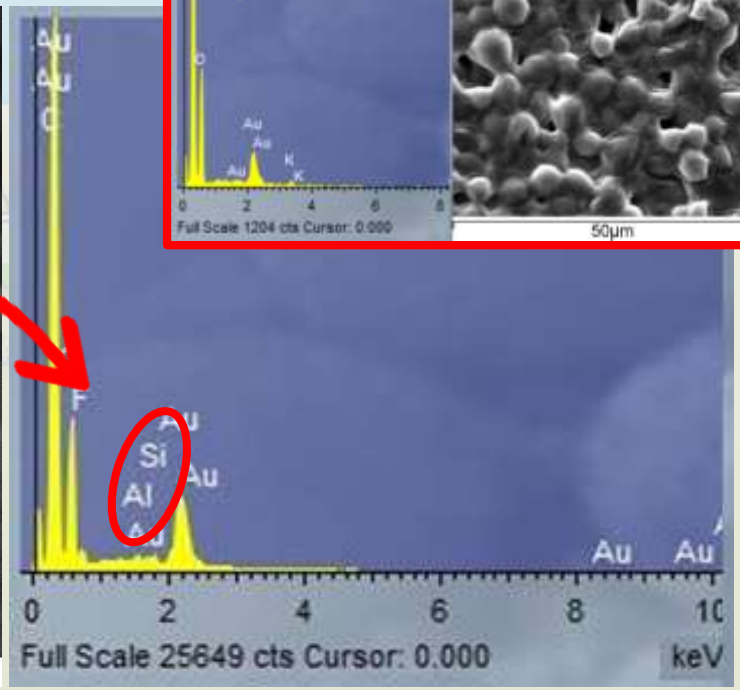

Biomass was rinsed with distilled water and then analysed with SEM methodology, revealing the presence of Silicon and Aluminium (two main components of PV-WEEE) on the biomass surface

The contribution falls within the framework of the projects GLASS and PHYRE (PHYcoREcycling), funded respectively by the University of Campania Luigi Vanvitelli and the Italian Ministry of Ecological Transition (MITE). Thanks are due to companies Geos Environment and TCycle Industries for providing support and the waste materials included in the research.

THANK YOU FOR THE ATTENTION