Recovery of technology-critical elements from secondary sources through living marine macroalgae

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The shortage of critical raw materials (CRM) for key-emerging technologies (e.g. clean energy) and daily high-tech products (e.g. smartphones), and the negative environmental impact of mining, led EU to encourage joint efforts to find supply alternatives. Obtaining CRM from secondary sources, such as end-of-life products and wastewaters (urban mining) represents a huge opportunity (50 M tons/year of e-waste are generated, worth € 55 billion), yet poorly explored due to technologies constraints.

In this pioneering research, we highlighted the potential of different living macroalgae, such as the cosmopolitan *Ulva* sp. or *Gracilaria* sp. to capture, concentrate, and recover Technology-Critical Elements (TCE), particularly rare earths, from water. With bioconcentration factors up to 3500, the contents of TCE in macroalgae directly cultivated, for 3 days, in aqueous media containing the elements, reach values like those found in common apatite ores (primary TCE source). Findings emphasize macroalgae-enriched biomass as an alternative source of TCE for the technological industry. The knowledge has been proven in mono- and multi-contamination scenarios, at different water ionic strengths, in absence or co-existence with common potentially toxic elements (e.g. Hg, Pb, Ni). Besides contributing to a mining-free circular economy, and to a true independence from China exports, this macroalgae-based technology will also help to reduce carbon footprint (cultivation of 1 ton of macroalgae consumes approximately 1.5 tons of CO_2).

This work has been a successful case of collaboration between the academia (University of Aveiro) and business (company N9VE – Nature, Ocean and Value, Lda), leading to the provisional patent application nº20191000043519 of 08/28/2019 – "Processes and systems for recovery of rare earth elements and/or lithium by marine macroalgae", and more recently to the Co-development TR&D project N9ve-REE (1/6/2020-30/03/2023), approved with a total funding of € 1.1 M.

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FIGURE 1
Schematic representation of a circular economy of Technological-Critical Elements (TCE), based on their recovery from end-of-life products and wastewaters (urban mining) through living marine macroalgae, allowing their reuse by the manufacturing industry.