A Sustainable Approach For Chlorinated Compounds Contaminated Groundwater Remediation: Raw Polyhydroxyalkanoates (PHA) from Organic Waste as Electron Donor for Biological Reductive Dechlorination Coupled with Adsorption on Biochar

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Background/Objectives. In anaerobic conditions, an organic fermentable substrate can be oxidized, providing the eligible electron donor (H_2) for the biological reductive dechlorination (BRD) of highly chlorinated compounds. Recent field application studies in Italy have shown the effectiveness of combining the immobilization of chlorinated solvents and the biostimulation. In compliance with sustainability and circular economy principles, the current research interest is focused on alternative materials such as long-lasting electron donors and possible growth support for biofilm as adsorbents. Previous studies showed the potentialities of bio-based materials for bioremediation purposes, including polyhydroxybutyrate (PHB), a biodegradable microbial polyester tested as a fermentable source of slow-release electron donor. On the other hand, a low-cost biobased material, biochar (BC), also used as a sorbent, has recently been proposed to accelerate reductive microbial dehalogenation. Here we proposed a coupled adsorption and biodegradation (CAB) process for trichloroethylene (TCE) removal in a mini-pilot-scale reactor filled with a raw PHA produced from mixed microbial cultures (MMC) and fermented organic waste (as feedstock) and pinewood BC, with the goal of evaluating the performance and the effectiveness of the BC in sustaining the biofilm, mostly enriched by *Dehalococcoides mccartyi* (*Dhc*).

Approach/Activities. The reactor was carried out in a column of 150x10 cm, in which the dechlorinating biofilm was supported by pinewood biochar (4% wt) mixed with sand for the entire length of the reactor. Moreover, in the first half of the column, from the bottom, called the "fermentation zone", a dry raw PHA-rich biomass (35 %wt of PHA) in powder form was added. The reactor was equipped with 13 gates for lateral sampling. The startup was carried out with an active TCE-to-ethylene consortium. After the tracer test, the flow rate was maintained at 2.9 ± 0.6 L/d on average, with 35 hours as hydraulic retention time (HRT). The feed solution consisted of contaminated tap water, resulting in a final TCE concentration of 100 µM. The monitoring of volatile fatty acids (VFA) and chlorinated compounds was carried out through regular sampling of the side doors of the column. Samples were stored for microbiological analysis.

Results/Lessons Learned. During the first two months of operation, the reactor has treated 180 Liters of contaminated water (10.5 ± 1.7 mg L^{-1} was the average of TCE IN) removing 2.6 g of TCE. The PHA compartment yielded a very high concentration of total VFA at the beginning of the experiment (1.3 g/L of VFA during the first week, at the outlet), decreasing progressively until a constant concentration of 6 mg/L from day 118 to 160. After 160 days of operation, a complete conversion of TCE to cis-dichloroethylene and the following daughter product vinyl chloride was observed in the fermentative zone, while the final product, ethylene, was detected only in outlet. A slow and constant release of acetate from the PHA compartment and the high flow rate used are interesting conditions for field applications. This configuration also allowed the treatment of high contaminant load at high solution feed rate (30.6 mg TCE day^{-1}; 1.5 m day^{-1}). The promising results open doors to the circular economy concept where a byproduct of

biomass thermal treatment and a biopolymer could support specific dechlorinating biofilm for bioremediation application.