A Molecular Approach to Lindane Biodegradation

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Background/Objectives. Lindane (Gamma HCH) was produced and used as a broad-spectrum insecticide and treatment against ectoparasites between 1945 and 2000. Production was inefficient because each ton of lindane resulted in the production of 8 to 12 tons of waste isomers. These waste isomers were dumped at production facilities and often led to huge landfills. More than 4.8 million tons of HCH-waste were and vastly still are present worldwide. Lindane and the other HCH isomers barely degrade in the environment, bio-accumulate through the food chain, and present a risk to human health and the environment. They were banned in the EU in 2000 and placed under the Stockholm Convention on POPs in 2009. The MIBIREM project, awarded within the Horizon Europe frame 2021-2027, aims at identifying and studying microbial population and species that can degrade effectively lindane and its isomers as well as testing their efficiency in laboratory and pilot scale trials. The final goal is the exploitation of microbiomes to implement a sustainable and cost-effective approach for widespread diffused contamination, particularly petroleum hydrocarbons, pesticide HCH and cyanides. To do so, a toolbox will be developed to identify, analyze, cultivate and upscale the microbiomes for bioremediation applications, while ensuring safety and policy alignment.

Approach/Activities. As a background of the MIBIREM project, a model site in Italy, Colleferro industrial area and Valle del Sacco, has been studied and characterized. Microorganisms have been isolated, cultured and studied for their ability to grow on and degrade HCH (α-, β-, and γ-HCH) through their enzymatic activities. Both single strains and mixed culture are being tested for aerobic in situ and ex situ remediation treatments. Microbial community analysis will be performed by a metagenomic approach, to identify the bacterial and fungal communities and to predict their functional abilities. Additionally, specific strains and microbiomes of interest will undergo a high environmental selective pressure process to improve their abilities and efficiency to degrade the contaminants of interest. Throughout the treatment trials, metagenomics will be performed to follow the evolution of the microbial communities while the degradation process advances. Ultimately, ex situ on-site field testing will be conducted using the proprietary pilot testing plant RoboNova.

Results/Lessons learned. At the selected model site in Italy, lindane was produced from the mid 1940s to late 1970s and two disposal waste areas in disuse reported high concentrations of HCH isomers (α, β, γ). In 2005 high concentrations of the beta isomer were detected in cow milk and dairy products from farms nearby. The state of environmental crisis was declared by the Italian government for the area and epidemiological surveillance was implemented. The two disposal areas were studied and characterized; containment plans were put in place to permanently separate the contaminated soil. However, the sediments of the river, as well as agricultural soil, have absorbed the contaminant, releasing it during flooding events. Soil and groundwater samples have been taken, characterized and used as baseline to create microbial enrichment cultures. Three fungal and five bacterial strains have been isolated from these cultures grown on basic medium spiked with HCH as sole carbon source. One microbial community has also been established and is being tested for its abilities to degrade HCH on soil. Next steps in the MIBIREM project will allow to (i) determine biodegradation rates of lindane; (ii) identify the most effective treatment protocol, examined in the degradation tests experiments; (iii) characterize the degradation pathway of lindane based on the mass spectrometry analysis of the degradation products; (iv) develop the MIBIREM toolbox for microbiomes for lindane biodegradation and their sound application.