Earthworms and sewage sludge: circular economy in integrated water management

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This presentation provides an overview of the potential of earthworms and vermicomposting to promote circular economy and sustainable agriculture through the development of an integrated cycle that allows in situ conversion of the sewage sludge generated in wastewater treatment plants into a safe and high-value soil amendment and /or plant growth medium.

The disposal of sewage biosolids can cause major logistical difficulties that result in serious environmental problems, particularly in terms of anthropogenically-derived contamination of soils with heavy metals and organic pollutants, including new emerging contaminants. Land disposal and composting of biosolids can be costly and have had relatively limited success, particularly in minimizing soil pollution. During the last twenty years, various methods of processing organic wastes (mainly animal manures) have been developed using earthworms, ranging from simple windrow systems to fully automated systems needing little input of labour. Such systems have consistently produced vermicomposts that serve as excellent horticultural plant growth media and often outperform current commercially available materials. Vermicompost, which is rich in nutrients, can also be used as a valuable cropland amendment, to improve soil structure, aeration and drainage.

Technologies developed by the Animal Ecology Group (GEA) at the University of Vigo utilize medium-scale continuous flow vermicomposting reactors to rapidly convert different types of organic waste into nutrient-rich, peat-like materials, which are excellent soil additives and are also valuable as commercial plant growth media. We have promising preliminary data suggesting that biosolids can be efficiently processed in such reactors to produce plant growth media and that human pathogens and other contaminants are eliminated in the process.

Our group has long experience in vermicomposting and in studying the interactions between earthworms and microorganisms during the conversion of organic waste products into safe biofertilizers. Our research focuses on exploring the efficacy of a pilot-scale vermicomposting-based process that will improve in situ valorisation of sewage sludge by removing human pathogens and pollutants from the waste during its conversion into a safe and high-value plant growth medium.

Pilot-scale vermicomposting trials are being conducted in a continuous "industrial-sized" vermicomposting flow reactor prototype (length, 6.25 m x width 1.7 m x height 1.6 m), of capacity 3.37 m3, designed and built "in house". Our group has wide experience in vermicomposting research and technical know-how in scaling up laboratory projects to pilot production. The vermicomposting reactors are currently operating in fully optimized mode, with very dense earthworm populations (up to 18,000 ind. m^{-2}).

In a recent prospective study we have found that 1) most of the bacterial (96%) and fungal (91%) taxa were eliminated during vermicomposting of sewage sludge, mainly through gut associated processes (GAPs), and 2) that these modified microbial communities in the earthworm casts (faeces) later undergo a series of processes leading to more diverse microbiota than those present in the original sewage sludge (Fig. 1, Domínguez et al., 2021).

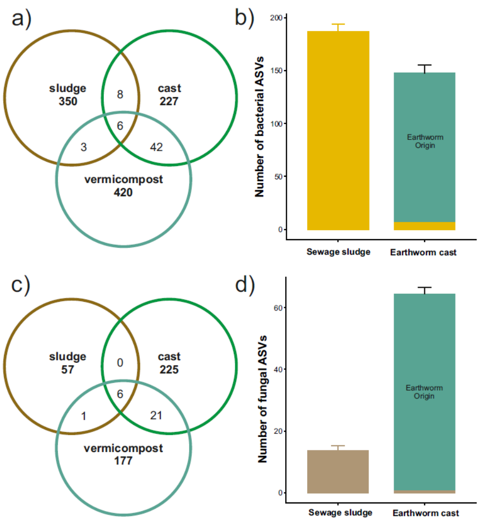

Figure 1. Changes in richness and diversity of bacteria and fungi during vermicomposting of sewage sludge. Venn diagrams showing the absolute number of (a) bacterial and (c) fungal ASVs found in sewage sludge, fresh

earthworms casts and vermicompost (3 months old). Effect of gut-associated processes (GAPs) on the richness and diversity of (b) bacteria and (d) fungi. Domínguez et al. (2021) Scientific Reports, 11:15556.

We have also observed high, variable levels of enzymatic activity during vermicomposting, the rate of which largely depends on the substrate used and on the earthworm activity (Sanchez and Domínguez, 2017; Domínguez et al., 2019).

Based on these findings, we hypothesize that a drastic change in the structure and function of the microbial communities occurs during vermicomposting of sewage sludge, and that these changes are concomitant with significant increases in extracellular detoxifying enzymatic activity, which together trigger and accelerate the enzymatic degradation of human pathogens. Such drastic changes in the microbiome of the vermicompost will improve the functioning of the soil-plant system, enhancing plant growth and the health of soil agroecosystems (Fig. 2).

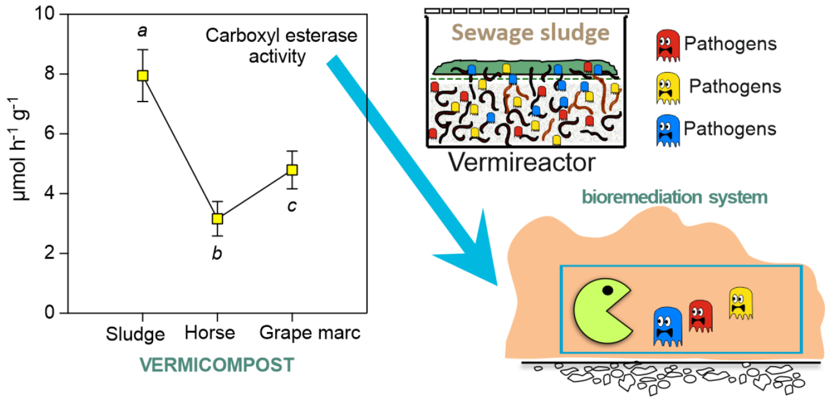

Figure 2. The interactions between earthworms and microorganisms during vermicomposting constitute a promising bioremediation system for eliminating microbial pathogens from sewage sludge and thus minimising the associated health and environmental pollution problems.

The results of this research will be instrumental for the assessment of vermicomposting as a recycling strategy for sewage sludge in WWTPs. The validation and improvement of an effective new earthworm technology, which provides not only for efficient and environmental-friendly treatment of sewage sludge, but also involves conversion of the waste product into environmentally acceptable soil amendments or high-value plant growth media, would constitute a major contribution to the environmental improvement and the sustainability of urban, rural and agricultural ecosystems. Such studies also address other important aspects of the biotreatment of organic residues and also of soil ecology, agroecology and microbial ecology.

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