

SOLID WASTE VALORISATION FOR WASTEWATER TREATMENT PROCESSES

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ABSTRACT

The present work was part of a research project, which pursued the treatment and reuse of urban and industrial wastewaters as well as solid waste. Its main goal was the development of modular systems for wastewater treatment based on constructed wetlands (CWs). The project involves the concept of circular economy and the rationale of “using waste to treat waste”, exploring the possibility of the treatment systems being composed of solid waste and by-products from significant industrial sectors. The work thereof presented describes the physical and chemical characterization of five waste solids, which were used as lab-scale CWs’ fillers. Optical microscopy observations, μ FRX and FTIR-ATR analyses were conducted to characterize the solid wastes before and after use in the CWs treating urban type wastewater. Results indicated that, among the five solid wastes studied, limestone fragments from construction showed favorable conditions to biofilm growth, and coal slags from power plants and cork granulates showed the highest indication of adsorption of organic compounds.

Keywords: Circular Economy; Constructed Wetlands; Solid Waste Valorization; Sustainable Development

INTRODUCTION

Biological-based technologies for waste treatment and recovery are essential to promote the basis for sustainable development and to potentiate the circular economy. Constructed wetlands (CWs) are an example of ecologically efficient wastewater treatment technology and can be an application of the concept of using waste to treat waste. The water purification processes by CWs are based on the assimilation of pollutants by macrophytes and the microbiological community, which contribute mainly to the assimilation of organic compounds, as the water under treatment flows through a porous filler material, which serves as a support for the growth of plants and the development of the microbial community.

Filling materials, themselves, can contribute to the removal of pollutants from water by physical and chemical processes, such as filtration, adsorption, and precipitation. The use of solid waste as fillers can improve the sustainability of CWs and represent a way to reduce the deposition of such materials in landfills. The proper choice of the filler material is important to obtain a good performance and to ensure the sustainability of the CWs for three reasons: the material must allow the proper disposal of the water to be treated throughout the lifetime of the installation; the material must be suitable for the growth of macrophytic plants and for the development of microorganisms involved in wastewater purification processes; the material can itself contribute actively to the removal of pollutants through physicochemical processes [1,2].

The filling material may represent one of CWs main investment costs, so its price can be a barrier to CWs implementation, particularly in the construction of larger treatment systems, which have been one of the major obstacles to the development and use of this potentially greener technology. The

most accessible materials are usually found among by-products and waste from various industries and among natural materials. In addition to their use of CWs, there are different possibilities to increase the usefulness of the materials after their use, such as to regenerate and to reuse them [1,2].

MATERIAL AND METHODS

In the developed project, ten solid wastes generated in the Middle Tejo region were initially evaluated in order to assess their capacity as CWs filling material: crushed eggshells; dealcoholized grape pomaces; olive seeds; wood pellets; pine bark fragments, fragmented residues from Moleanos limestone; clay brick fragments; coal slags; cork granulates; and snail shells. Leaching and adsorption tests were performed for all the materials, and the materials that showed better properties for use as CWs filler were used to determine adsorption isotherms. Limestone fragments, brick fragments, coal slags, snail shells and cork granulate presented potential to be used as CWs filler material. On the other hand, the other materials tested did not demonstrate sufficient potential and were not further used [2].

In laboratory scale assays, the use of mixtures of the five materials previously selected as CWs filler was evaluated. In this way, it was intended to combine their different adsorption capacities for different pollutants and to minimize the possible disadvantages of some of them as fillers. Thus, five sets of laboratory-scale CWs were established. These were placed inside a laboratory, in a well ventilated and illuminated place, and consisted of vessels in opaque plastic. A reference CW was also built, filled only with fragments of limestone, which in previous works proved to be a good substrate [3]. The remaining four sets were filled with three layers: a lower layer and a top layer of limestone fragments and an inner layer of each of the other residues evaluated. Several tests were carried out in batch or continuous mode, using an urban type wastewater or an industrial effluent.

In order to characterize the materials used, Micro x-ray fluorescence (μ FRX) and Attenuated Total Reflection Fourier Transform Infrared Spectroscopy (FTIR-ATR), as well as petrographic and stereoscopic microscopic observations, were performed before and after the use of the materials in the CWs.

RESULTS AND DISCUSSION

Microscopic observations did not show significant changes after four and eleven months of use for most materials (Figure 1), except limestone, which exhibits an evident formation of biofilms, which were not observed after four months of use.



Figure 1 – Material observations under stereoscopic microscopy, after 11 months of use in CWs, with 20x magnification (left to right): coal slag; snail shells; cork granulates; brick fragments; limestone fragments.

The μ FRX spectra revealed no significant changes after four and eleven months of use, as no additional peaks were detected in relation to the material prior to use in the CW: there were only some changes in the intensity of the peaks observed.

In the FTIR spectra (Figure 2), both cork granulate and coal slag showed water adsorption (O-H), revealed by the very intense band at about 3300 cm^{-1} , after four months of use. After eleven months of use, there was a significant reduction of this band for cork granulate and a very strong reduction in the case of coal slag. The band attributed to the carbonyl group (C=O) that appears at 1600 cm^{-1} after four months of coal slag use almost disappears after eleven months, replaced by a band at 1400 cm^{-1} attributed to aliphatic groups (C-H). For lower wave numbers, the presence of aliphatic groups and C-O groups is observed in addition to the species originally present. For cork granulates, the spectra are somewhat more complex due to the nature of the material, but after four months of use no significant changes occur except in the $500\text{--}750\text{ cm}^{-1}$ zone, where there seems to be an

increase in the presence of aliphatic groups. After eleven months of use, a generalized reduction of the bands attributed to the aliphatic groups is observed, as well as to the groups C=O, C-O and C-O-H, and to the increase of the band intensity attributed to alkene groups (C=C) [4,5]. These results suggest the formation of different organic compounds, both on the surface of coal slag and cork granulates, that develop into different species over time. The remaining materials did not show significant changes after four and eleven months of use.

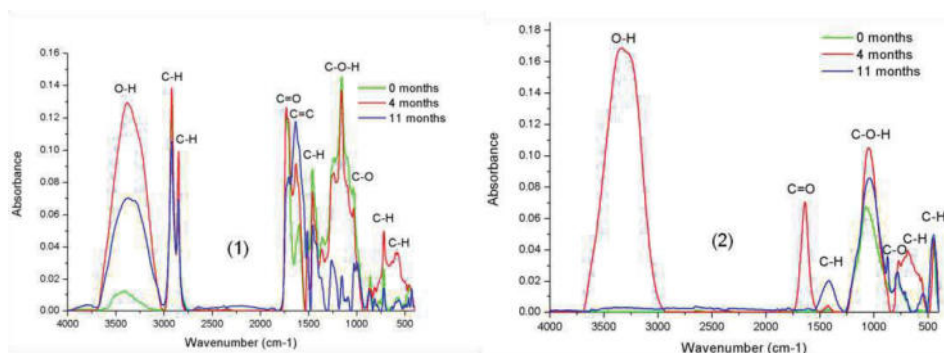


Figure 2 – FTIR-ATR spectrum of cork granulates (1) and coal slag (2), before and after 4 and 11 months of use in the CWs.

CONCLUSIONS

The observed growth of biofilms in the surface of the limestone fragments can be favorable to the contribution of microbiologic biota to wastewater treatment.

The apparent adsorption of organic compounds in the surface of coal slag and cork granulates indicates that these materials can be selected to remove organic pollutants from wastewater.

The obtained results have demonstrated the feasibility of using these alternative materials as fillers for CWs, providing a promising means of recovering waste that would otherwise be simply disposed off, thereby contributing to sustainability and circular economy.

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