



A circular approach for landfill leachate treatment: Chemical precipitation with biomass ash followed by bioremediation through microalgae

Catarina Viegas^{a,*}, Catarina Nobre^b, André Mota^c, Cândida Vilarinho^{c,d}, Luísa Gouveia^{e,f}, Margarida Gonçalves^a

^a MEtRICs, Mechanical Engineering and Resource Sustainability Center, Department of Science and Technology of Biomass, FCT-NOVA, Campus de Caparica, 2829-516 Caparica, Portugal

^b CoLAB BIOREF - Collaborative Laboratory for Biorefineries, Rua Amieira Apartado 1089, 4466-901 S. Mamede Infesta, Portugal

^c CVR, Center for Waste Valorization, Campus de Azurém, 4800-058 Guimarães, Portugal

^d MEtRICs, Mechanical Engineering and Resource Sustainability Center, Mechanical Engineering Department, School of Engineering, Minho University, Campus de Azúrem, 4800-058 Guimarães, Portugal

^e LNEG - Laboratório Nacional de Energia e Geologia, I.P./Bioenergy and Biorefineries Unit, Estrada do Paço do Lumiar 22, 1649-038 Lisbon, Portugal

^f GreenCoLab - Green Ocean Technologies and Products Collaborative Laboratory, Centro de Ciências do Mar do Algarve, Universidade do Algarve, Portugal

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ABSTRACT

The aim of this work was to study an integrated approach for landfill leachate remediation comprising chemical precipitation with biomass bottom ash as a pre-treatment to reduce color and turbidity followed by bioremediation through microalgae treatment for effluent disposal. Optimal pre-treatment conditions were determined through batch experiments and were found to be 160 g L⁻¹ ash dose, 96 h of contact time, overhead agitation at 15 rpm and ash particle size below 500 μm. These conditions led to removal efficiencies of 74.3% for chemical oxygen demand and 98.5% for color. Large quantities of sludge containing excess biomass ash and precipitated compounds were formed during the pre-treatment. To minimize solid disposal, this sludge was tested as a raw material for cementitious and aggregate substitute in mortar formulations. Following the pre-treatment, the leachate was inoculated with six different microalgae species to evaluate their ability to grow in such a recalcitrant effluent and remediate it. After a period of 27 days biomass concentration from 0.4 to 1.2 g L⁻¹ were achieved for the tested microalgae. Removal efficiencies were in the range of 18–62% for COD, 63–71% for N, and 15–100% for P. At the end of the treatment, algal biomass was characterized regarding protein, lipid, fatty acids, carbohydrate, and ash contents. This approach allows a low-cost remediation of these recalcitrant effluents when compared with the present options that include inverse osmosis, and the valorization of ash-rich precipitates and microalgae biomass improves the sustainability of the overall process.

1. Introduction

One of the most significant aspects in landfill management is the production of a highly complex leachate, that represents a very serious pollution problem affecting soils, water bodies and human health. Landfill leachate is an aqueous solution of organic and inorganic components produced by infiltration of rain water into the layers of waste deposits exposed to environmental conditions and subject to processes of aerobic and anaerobic decomposition by the local microbiome [1]. The composition of leachate is highly variable depending mostly on the type of waste in the landfill, landfill age, climate conditions and geochemical characteristics of the landfill site [2]. These complex

effluents are characterized by a dark color, bad odor and significant values of chemical oxygen demand (COD), ammonia-nitrogen and heavy metals [3]. Among the different leachate categories, the treatment of stabilized leachate is very difficult to achieve, largely due to the presence of refractory substances, such as humic and fulvic acids, which are not easily degraded [4,5]. To eliminate these refractory organic materials found in stabilized landfill leachate, it is necessary to use complementary remediation techniques, such as membrane technologies, ion exchange, adsorption by activated carbon, flocculation-coagulation, chemical oxidation or advanced oxidation processes [4,6]. The combination of different treatment processes has been proposed by several authors in order to achieve high treatment efficiencies and maximize the

* Corresponding author.

E-mail address: cv.sousa@campus.fct.unl.pt (C. Viegas).

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