Electrocoagulation of real bilge wastewater: effect of electrode type (Al, Fe), spacing and voltage

M. Constantinou[1,2], A.A. Mazioti[3], C. Varavvas[2], G. Vyrides[3], G. Constantinides[1]

[1]Department of Mechanical Engineering and Materials Science and Engineering, Cyprus University of Technology, Lemesos, 3036, Cyprus
[2]Ecofuel (Cyprus) Ltd, Lemesos, 3071, Cyprus
[3]Department of Chemical Engineering, Cyprus University of Technology, Lemesos, 3036, Cyprus
Keywords: Electrocoagulation, real bilge wastewater, quality enhancement.
Presenting author email: m.k.constantinou@cut.ac.cy

Bilge water is the main pollutant of shipboard; a saline, oily and greasy wastewater with chemical oxygen demand (COD) values higher than 3-15 g/L [1]. Bilge water can also be described as a suspension of colloidal matter, composed of water and solids, including suspended solids and dissolved solids [2]. Conventionally, bilges are usually treated with chemical or physicochemical processes such as flotation, separation by centrifuge, and/or filtration [1]. Nevertheless, the existing conventional methods for the treatment of bilge are expensive or taking long retention time to achieve the targeted quality levels, since a major part of the oil in bilge water is emulsified in very small colloidal form [3].

Ecofuel (Cyprus) Ltd, is the sole company in Cyprus that receives and treats this type of wastewater using a three-treatment steps process consisting of: i) Dissolved Air Flotation (DAF), ii) aerobic 200 m^3 Moving Bed Biofilm Reactor (MBBR) and iii) ozonation. The purpose of DAF is to remove the floatable matter and easily settleable suspended solids from bilge, while MBBR aims to remove the biodegradable organic matter. The resulting liquid effluent is a treated wastewater which does not contain inorganic suspended solids, organic suspended solids and organic dissolved solids. It is finally treated with ozone to eliminate pathogens and oxidize remaining organic and inorganic compounds in order to meet effluent standards for disposal to sea waterbodies. The extent of COD removal during aerobic microbial treatment, however, is only 30-50% and considerable amount of energy is consumed during the ozonation step, significantly increasing the total treatment cost.

This work relates to the use of an electrocoagulation (EC) technique as a tool to enhance the quality and process of treated real bilge wastewater. EC was successfully used to treat real bilge oily effluent and remove the small colloidal particles because of coagulation, flocculation, and gravity sedimentation of suspended solids. EC requires an electrode configuration, cell configuration, and a power source, as schematically shown in Fig. 1. When electricity is passed through the system, strong oxidizing species are formed in the medium, which interact with the contaminants and degrade them. The oxidation efficiency depends on the current density and effluent characteristics; an increased current density leads to higher energy consumption and costs. This study was focused to compare the effectiveness of Aluminium (Al) and Iron (Fe) as electrodes so to reduce the pollutants within the bilge liquid effluent during EC) changing their distance and applied voltage, respectively.

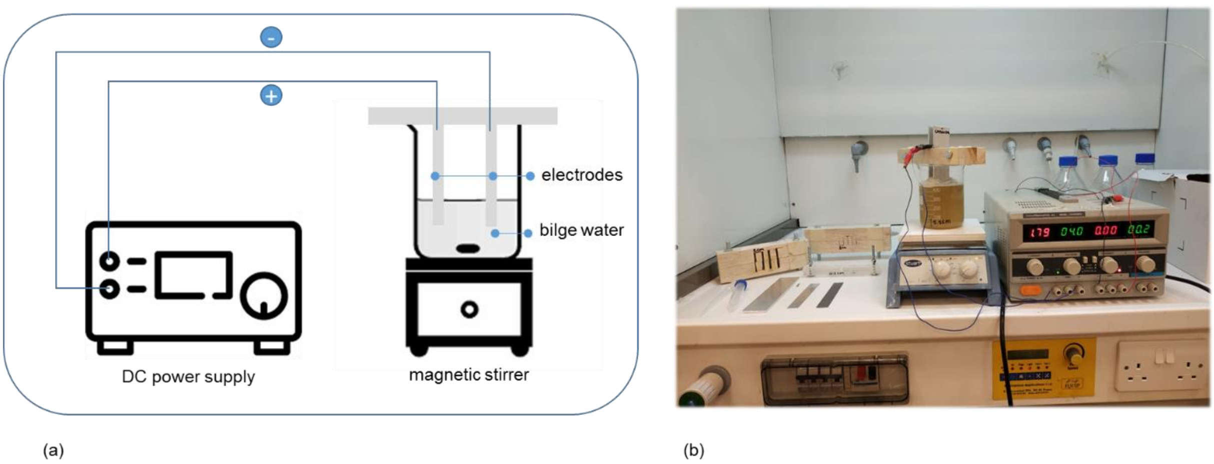

Figure 1. Schematic of the developed electrocoagulation system.

The bilge oil effluent that was used as electrolyte in this study, was collected from Ecofuel (Cyprus) Ltd pre-treated using the DAF operation unit, and for other experiments pre-treated with the MBBR reactor. For EC, a direct current electricity ranging in the 2-5.5 V domain was used in the presence of either aluminium (Al) or iron (Fe) electrodes in a batch reactor with a volume of 450 ml. The batch reactor with no inflow or outflow was continually stirred, for the colloids within the liquid to remain suspended during the EC process. COD, pH, conductivity, and turbidity measurements of bilge oil effluent were collected at various time points of the EC treatment. The results show that EC was responsible for the reduction of COD (~60%) and turbidity of bilge, where turbidity provides a qualitative measure of the removal of colloidal solids. During batch EC we observed what is called overflow and underflow; overflow occurs throughout the whole EC process, while underflow happens after the end of the process. Overflow is the liquid that is going out of the treatment unit in the form of foam and underflow is the concentrated solids which are precipitated at the bottom of the reactor through gravity sedimentation. The anode reaction was responsible for producing aqua metallic ions which are very reactive for coagulation and flocculation of suspended colloidal solids. The solids that settled at the bottom of the reactor were characterized using X-ray Diffraction (XRD) and used for understanding the efficiency and operating mechanisms of the EC unit. It is important to note that overflow foam was helpful in removing the lighter solids from liquid effluent and was generated due to hydrogen production (cathodic reductions) which contributes significantly to the removal of pollutants from bilge wastewater. The exact froth floatation characteristics were also studied in detail.

One of the innovative parts of this study relates to the use of EC in treating real bilge wastewater (which is a mixture of bilge and seawater – thus a naturally conductive solution), in contrast to previous studies that used synthetic wastewaters [4, 5]. A detailed explanation of the experimental procedure is provided in order to establish a reproducible methodology and conclusive decisions for scale-up. The overall objective of this work is to move from batch mode experimental learning to large scale reactor and the sequential combination of Electrochemical and Bio-Electrochemical system.

References

[1] McLaughlin, C., Falatko, D., Danesi, R., & Albert, R. (2014). Characterizing shipboard bilgewater effluent before and after treatment. *Environmental Science and Pollution Research*, *21*(8), 5637-5652.

[2] Körbahti, B. K., & Artut, K. (2010). Electrochemical oil/water demulsification and purification of bilge water using Pt/Ir electrodes. Desalination, 258(1-3), 219-228.

[3] Caplan, J. A., Newton, C., & Kelemen, D. (2000). Technical report: novel oil/water separator for treatment of oily bilgewater. *Marine technology and SNAME news*, *37*(2), 111.

[4] Asselin, M., Drogui, P., Brar, S.K., Benmoussa, H. and Blais, J.F., 2008. Organics removal in oily bilgewater by electrocoagulation process. Journal of hazardous materials, 151(2-3), pp.446-455.

[5] Dermentzis, K.I., 2016. Removal of Sulfide and COD from a Crude Oil Wastewater Model by Aluminum and Iron Electrocoagulation. Journal of Engineering Science and Technology Review, 9(1), pp.13-16.

Acknowledgements

The project POST-DOC/0718/0213 is co-funded by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation.