
National Technical University of Athens
CARTIF
Municipality of Ancient Olympia
PAVE THE WAySTE
NAXOS2018
13-16 June 2018
6th International Conference on Sustainable Solid Waste Management
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Demonstrating resource efficiency through innovative,
integrated waste recycling schemes for remote areas
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Investigation of the humic acids evolution during bioremediation of heavy residual fuel oil

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Keywords: heavy residual fuel oil, bioremediation, humic acids, humification.
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The advance of technology and industry in the last hundred years, population growth and the development of big cities have led to the production of waste materials in quantities which exceed self-purification capacity of nature. The accumulation of waste materials of various origin causes increased pollution of the environment. Petroleum and its derivatives such as heavy residual fuel oils are one of the major and most dangerous pollutants of soil. Bioremediation is a method of reducing petroleum pollution which has been widely used in the last years. Bioremediation is a process which is based on the natural capacity of microorganisms to degrade or transform toxic substances from the environment into harmless products (Gomez and Sartaj, 2014.). Bioremediation technologies are in harmony with the principles of sustainable development since waste materials are not generated (Avdalović et al. 2016, Jednak et al. 2017).

The aim of this paper is to study the use of different microorganisms as "biological agents" for *ex situ* bioremediation of a petroleum contaminant (heavy residual fuel oil), along with simultaneous monitoring of the humification process, because there are indications that during biodegaradation of polycyclic aromatic hydrocarbons (PAH), substances similar to humic substances are creating (Henner et al. 1997, Ressler et al. 1999).

The content of total petroleum hydrocarbon (TPH) in the sample was extracted as per method ISO 16703 (ISO 16703, 2004) and determined gravimetrically in accordance with DIN (DIN EN 14345, 2004). The results were calculated according to dry matter. For the analysis of humic acid, 40 g of each air-dried soil sample was mixed with 200 ml of $NaOH/Na_4P_2O_7$ solution (ISO 5073, 1999). The mixture was heated in a boiling water bath for 2 h, with frequently shaking to ensure precipitation of insoluble material. Then, the flask was removed from the water bath, cooled to room temperature, and supernatant was separated from residue by centrifugation at 3000 rpm (residue was discarded). Humic acids were precipitated from supernatant by acidifying with 6 M HCl to pH 1. After that, the suspension was centrifuged. The supernatant was decanted and discarded. The HA was purified according to the method of the International Humic Substance Society (IHSS). The effects of humification on the structure of humic acids were evaluated by Fourier Transform Infrared Spectroscopy (FT-IR), potentiometric titrations, the ratio of absorbances at 465 and 665 nm (E4/E6 ratio), the C/H ratio and gel chromatography.

In the pilot experiment, which lasted for 170 days, bioremediation of a petroleum pollutant was carried out in the layer of artificial soil substrate, with river sand as mother substrate. One container was a control biopile and it contained a mixture of sawdust, sand and the pollutant. The second container was an inoculated biopile and it was prepared in the same way as the control biopile but, in addition to sawdust, sand and the pollutant, it also contained biostimulants, the sources of nitrogen and phosphorus, and biomass. The initial concentration of petroleum hydrocarbons in the pilot experiment was 23,05 mg/kg dry weight. At the end of the experiment, the total hydrocarbons were reduced to 8,15 mg/kg dry weight in the inoculated biopile, while the concentration was 21,35 mg/kg dry weight in the control biopile. It was observed that the content of humic acids increased from 0,32% to 0,42% in the inoculated biopile during the bioremediation process, while the increase in the content of humic acids in the control biopile was insignificant. Additional analyses of humic acids from the inoculated biopile showed that they were transformed during the bioremediation process and that they had a higher degree of aromaticity as well as greater redox and buffering capacity at the end of the experiment. In addition to this, gel chromatography was performed on the samples of humic acids isolated from the inoculated biopile during the bioremediaton process. The results showed that on day 0 the share of fraction of great molecular mass (greater than 100 kDa) was 72,67%, while the share of the above mentioned fraction was 76,17%, 170 days after the beginning of the process, which was probably due to the fact that undegraded organic compounds were transformed and included in complex polymer structures which are analogues of humic substances.

References

Avdalović J., Đurić A., Miletić S., Ilić M., Milić J., Vrvić M.M. (2016) Treatment of a mud pit by bioremediation. Waste Manage Res 34:734–739.

DIN EN 14345 (2004) Characterization of Waste. Determination of hydrocarbon content by gravimetry. DIN, Berlin.

Gomez F., Sartaj M. (2014) Optimization of field scale biopiles for bioremediation of petroleum hydrocarbon contaminated soil at low temperature conditions by response surface methodology (RSM). Int. Biodeter. Biodegr. 89:103-109.

Henner P., Schiavon M., Morel J.L., Lichtfouse E. (1997) Polycyclic aromatic hydrocarbon (PAH) occurrence and remediation methods. Analusis 25:9-10.

International Humic Substance Society (IHSS) Available at URL: http://humic-substances.org/ (2013).

ISO 5073 (1999) Brown coals and lignites — Determination of humic acids. Geneva.

ISO 16703 (2004) Soil quality – Determination of content of hydrocarbon in the range C10 to C40 by gas chromatography. Geneva.

Jednak T., Avdalović J., Miletić S., Slavković-Beškoski L., Stanković D., Milić J., Ilić M., Beškoski V., Gojgić-Cvijović G., Vrvić M.M. (2017) Transformation and synthesis of humic substances during bioremediation of petroleum hydrocarbons. Int Biodeterior Biodegrad 122: 47-52.

Ressler B.P., Kneifel H., Winter J. (1999) Bioavailability of polycyclic aromatic hydrocarbons and formation of humic acid-like residues during bacterial PAH degradation. Appl. Microbiol. Biot. 53:85-91.

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Investigation of the humic acids evolution during bioremediation of heavy residual fuel oil

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Aim

The aim of this paper is to study the use of different microorganisms as "biological agents" for *ex situ* bioremediation of a petroleum contaminant (heavy residual fuel oil), along with simultaneous monitoring of the humification process, because there are indications that during biodegradation of polycyclic aromatic hydrocarbons (PAH), substances similar to humic substances are creating.

Introduction

The advance of technology and industry in the last hundred years, population growth and the development of big cities have led to the production of waste materials in quantities which exceed self-purification capacity of nature. The accumulation of waste materials of various origin causes increased pollution of the environment. Petroleum and its derivatives such as heavy residual fuel oils are one of the major and most dangerous pollutants of soil. Bioremediation is a method of reducing petroleum pollution which has been widely used in the last years. Bioremediation is a process which is based on the natural capacity of microorganisms to degrade or transform toxic substances from the environment into harmless products. Bioremediation technologies are in harmony with the principles of sustainable development since waste materials are not generated.

Material and Methods

The content of total petroleum hydrocarbon (TPH) in the sample was extracted as per method ISO 16703 (ISO 16703, 2004) and determined gravimetrically in accordance with DIN (DIN EN 14345, 2004). The results were calculated according to dry matter. For the analysis of humic acid, 40 g of each air-dried soil sample was mixed with 200 ml of $NaOH/Na_4P_2O_7$ solution (ISO 5073, 1999). The mixture was heated in a boiling water bath for 2 h, with frequently shaking to ensure precipitation of insoluble material. Then, the flask was removed from the water bath, cooled to room temperature, and supernatant was separated from residue by centrifugation at 3000 rpm (residue was discarded). Humic acids were precipitated from supernatant by acidifying with 6 M HCl to pH 1. After that, the suspension was centrifuged. The supernatant was decanted and discarded. The HA was purified according to the method of the International Humic Substance Society (IHSS). The effects of humification on the structure of humic acids were evaluated by Fourier Transform Infrared Spectroscop (FT-IR), potentiometric titrations, the ratio of absorbances at 465 and 665 nm (E4/E6 ratio), the C/H ratio and gel chromatography.

Results & Discussion

In the pilot experiment, which lasted for 170 days, bioremediation of a petroleum pollutant was carried out in the layer of artificial soil substrate, with river sand as mother substrate. One container was a control biopile and it contained a mixture of sawdust, sand and the pollutant. The second container was an inoculated biopile and it was prepared in the same way as the control biopile but, in addition to sawdust, sand and the pollutant, it also contained biostimulants, the sources of nitrogen and phosphorus, and biomass. The initial concentration of petroleum hydrocarbons in the pilot experiment was 23,05 mg/kg dry weight. At the end of the experiment, the total hydrocarbons were reduced to 8,15 mg/kg dry weight in the inoculated biopile, while the concentration was 21,35 mg/kg dry weight in the control biopile.

It was observed that the content of humic acids increased from 0,32% to 0,42% in the inoculated biopile during the bioremediation process, while the increase in the content of humic acids in the control biopile was insignificant.

Additional analyses of humic acids from the inoculated biopile showed that they were transformed during the bioremediation process and that they had a higher degree of aromaticity as well as greater redox and buffering capacity at the end of the experiment.

In addition to this, gel chromatography was performed on the samples of humic acids isolated from the inoculated biopile during the bioremediaton process. The results showed that on day 0 the share of fraction of great molecular mass (greater than 100 kDa) was 72,67%, while the share of the above mentioned fraction was 76,17%, 170 days after the beginning of the process, which was probably due to the fact that undegraded organic compounds were transformed and included in complex polymer structures which are analogues of humic substances.

Conclusions

We concluded that in parallel with biodegradation of petroleum contamination there is an increase in the content of humic substances and the structure of this substances undergoes changes as well.

This research was partially financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia as a part of the Projects III 43004.