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Advanced processes for remediation of contaminated sediments

ABSTRACT

Angela Fraiese

Il Tutor
Prof. Vincenzo Belgiorno
Il Co-Tutor
Prof. Vincenzo Naddeo

Il Coordinatore
Prof. Fernando Fraternali

Abstract

Sediments play a fundamental role in the aquatic environment, especially for their interaction with the aquatic life. However, in the last decades, due to the increasing anthropic activities, a large amount of contaminants were released into the environment, as well as in the water bodies. The sediments, due to their characteristics, tend to adsorb the polluting compounds becoming a potential sink of contaminants.

Among the several hazardous compounds, polycyclic aromatic hydrocarbon (PAHs) and heavy metals represent the contaminants most frequently detected onto sediments. These compounds are classified as “known” or “probable” human carcinogen by U.S. Environmental Protection Agency (US EPA) and the International Agency for Research on Cancer (IARC).

The presence of hazardous compounds in the sediments constitutes a concern, not only for the possible negative effects on the environment and human health, but also for the technical-economical aspects related to their management. Indeed, contaminated sediments need a proper management and their free disposal in the aquatic system is not allowed. It was estimated that in Europe about 200 million cubic meters of sediments are dredged every year. These dredging activities are necessary not only for remediation purposes, but also to maintain adequate depth of navigation in the water bodies. Once removed, the traditional management options for the sediments include landfill and confined aquatic disposal, which are among the most used solutions. Nevertheless, these options are not sustainable under both an economic and an environmental point of view. The sediment reuse could be an effective alternative, but their adequate treatment is fundamental in order to avoid the possible release of hazardous compounds into the environment and the resulting adverse effects.

In scientific literature different remediation technologies were proposed for treatment of contaminated soil. Few attempts have been also provide to adapt some of these techniques to polluted sediments. However, due to the specific characteristics of the sediments, including the prevalent fine grain size fraction, the technologies used for soil remediation are not always suitable for sediment treatment.

Advanced Oxidation Processes (AOPs), which are widely used for the wastewater treatment, were also applied for the treatment of other environmental matrices thanks to their technology flexibility.

Among AOPs, ultrasound (US) has raised growing interest in the scientific community, as an environmental friendly technology holding several advantages over conventional treatment solutions.

In the field of wastewater treatment, US has been studied in order to promote either the partial degradation of organic compounds before biological process or the mineralization of the same kind of contaminants. Few research experiences also focused on US application to solid matrices, with the main aim of desorbing inorganic compounds.

In polluted sediments, both organic and inorganic contaminants are simultaneously present and this aspect represents a major challenge in the choice of a remediation technology that could be effective for each kind of polluting compound. In this regard, the application of US can promote both the contaminant desorption from the solid particles and the degradation of the dissolved organic compounds.

Therefore, aim of this work was in the study of the advanced technology effectiveness for the remediation of contaminated sediments. For this purpose, the experimental activity was divided in two main parts:

- the first one focused on the study of US treatment effectiveness in promoting the reduction of both organic and inorganic contamination in a single stage;

- the second part, performed on the basis of the results of the previous phase, was devoted to the assessment of the US effectiveness as treatment prior to another main remediation technique. In particular, US was implemented as pretreatment for electrokinetic (EK) processes.

The first step was conducted at the laboratory of the Sanitary Environmental Engineering Division (SEED) of Salerno University. During this step both sonication frequency and treatment time were varied to investigate their effect on the removal yields of organic (B[α]A and B[α]P) as well as inorganic (Cd, Pb and Zn) contaminants.

Experimental results demonstrated that the application of ultrasonic waves led to an overall reduction of the contaminant concentration. The best performances were achieved for the organic compounds, with high removal efficiencies reached after few minutes of treatment. Heavy metals showed removal yields almost constant in all experiments, despite the sonication frequency as well as the treatment time. The desorption of inorganic compounds was variable for each compound and the best results were obtained for Cd and Zn compared to Pb.

In order to improve the heavy metal desorption by US, two different processing solutions, namely citric acid and ethylenediaminetetraacetic acid (EDTA), were tested as sonication medium. Both solutions determined an improvement in the desorption yields. However, the best performances were achieved with the citric acid, at a sonication frequency of 130 kHz. As previously noted, the variation of the treatment time was observed to be not significant, thus a long US treatment is not justified. In this regard, the process optimisation was pursued by reducing the treatment time. To this end, further tests were performed using a citric acid solution at 130 kHz and 2,5 min of sonication.

An slight decrease in desorption percentage, was observed for each metal. Nevertheless, the desorption yields were satisfactory, with percentages always more than 75%.

The second part of the work was performed at the laboratory of the Bioengineering and Sustainable Processes (BIOSUV) group at the University of Vigo (Spain). In order to evaluate the effectiveness of US as pre-treatment, this technology was applied before the electrokinetic process (EK). To this end, the combined process (US+EK) was compared with the remediation performances provided by the EK alone. Referring to the Cd and Zn, the results demonstrated a comparable desorption efficiency, close to the complete removal, for both EK process alone and US+EK. For Pb, instead, the use of US pre-treatment was able to improve the its desorption promoted a synergetic effect.

The results obtained from the experimental activity proved that US technology could be a promising alternative for the reduction of both organic compounds and heavy metals from contaminated sediments.

The studied process was observed to be very versatile, providing interesting performances as either stand-alone treatment or in combination with other remediation technologies.