Electrokinetic based technologies in cold climate conditions - remediation of contaminated polar soil

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Introduction

It is well known that large amounts of organic pollutants are being released daily to the environment. However, some environments are more sensitive than others and deserve special attention. The Arctic environment is very fragile to anthropogenic disturbances and the impact of the pollution in the fauna and flora can be irreversible (AMAP, 2009). Pollution of the Arctic environment from Greenlandic towns and settlements has been increasing over the years for several reasons. The pollutants can be transported to the Arctic from emission sources located far outside the region, or emitted within the Arctic from activities including shipping, power production, and other industrial activities. Some researchers pointed out that residents in Arctic regions are exposed to high concentrations of persistent pollutants (Johansen and Rydahl, 2007) and bioaccumulation in the food chain has also been reported (Dietz et al., 2000; Andersen et al., 2015).

The potential of biological approaches for reducing the concentration of contaminants and the remediation time can face some limitations (e.g. Couto et al., 2015). The development of efficient technologies to remediate pollutants that pose risk to human health and the environment are of great importance due to the future consequences. In the present work the electrokinetic remediation (EKR) was tested in a contaminated soil with oil. The EKR involves the controlled application of a low level direct current through the soil between inert electrodes. The electric field initiates electrolysis reactions at the electrodes, producing H^+ ions at the anode and OH^- ions at the cathode. The present work discusses the effects of EKR in cold regions that could work as an effective removal of pollutants with minimum maintenance and disturbance for the environment. For this purpose, different strategies of applying the electric current in two different temperatures were tested to oil spill remediation from soil.

Experimental

Description of the site

The soil samples were collected in Sisimiut (66º56’ N, 53º40’ W), a city at the west coast of Greenland, approximately 75 km north of the Arctic Polar Circle. This city is the second largest town in Greenland with about 5524 inhabitants (Greenland in Figures, 2014). The activities and the life style in Sisimiut have a high oil demand (e.g. transportation and heating). There are many industrial activities located in Sisimiut, being known by the fishing industry, which also increase the oil demand. The warmest months are July and August with average daily low and high temperatures of 6ºC and 16ºC for the warmest day, respectively. The shortest day only has one and a half hours of daylight, where the longest day has daylight in 24 hours (Weatherspark, 2017).

Sampling

The soil samples were taken in Sisimiut dump site where the waste is stored to be further burned at the local waste incineration plant. The area is full of used barrels where oil spills can be seen due to leaking (~~see~~ Figure 1). The soil in study was sampled from one of the identified spills in August 2017. The oil-contamination could have happened when the oil was being transported or stored. During the sampling, a strong odor of oil products and free phase oil in the surface was observed. The soil was dug up from 0 to 30 cm depth by using a shovel, and transported to DTU, Denmark, in polyethylene buckets. In laboratory, the soil was carefully homogenized by turning it continuously and stones, bricks, clinker, fibrous roots among others were picked out.

Figure 1. Identification of the area of soil sampling

Electrokinetic remediation experiments

The EKR experiments were designed having in mind the lowest disturbance of the soil in the natural cold environment (see Table 1). The polarity of the electrodes was changed every 24 h (exp. 2) and the current switched on and off every 6 hours (exp. 3). The experiments were carried out at room temperature (22 ºC) and cold temperature, where for the last the experiments were kept in the fridge 6 ºC. 250 g of soil was used in each box (L=9 cm; h=5 cm; internal Ø= 8). The soil was weight once a day and water was added in order to keep the same water content during the experiments. Mixed metal oxide (MMO) coated titanium bars (Ø=3mm) were used as inert electrodes. A power supply (Agilent E3612A) was used to maintain the current between electrodes. At the end of the EKR experiments the box was divided in two (anode and cathode) and oil content, elements and metals, pH, conductivity and organic content were measured. Laser and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX) analysis was also carried out.

Table 1. EK experimental conditions

EKR exp. #	Current	Temperature (ºC)	Current density (mA cm^{-2})	Time (days)
1	Continuous	22	0.02	14
2	Periodic polarity reversal	22	0.02	14
3	On/Off	22	0.02	14
4	Control	22	0	14
5	Continuous	6	0.02	14
6	Control	6	0	14

Results and discussion

The preliminary results showed that EKR decreased the level of oil contamination in the tested conditions (see Figure 2). In terms of the overall concentration of metals and nutrients no mobilization through soil was verified. Fe was the most abundant metal (12702 mg kg^{-1}) found in the sample. This aspect is important because Fe is known to play an important role in the degradation of organic compounds by Fenton reaction. The periodic reversal of polarity showed the advantage of not interfering with the soil pH. Some differences were found between cold and room temperature with higher oil remediation in cold environment.

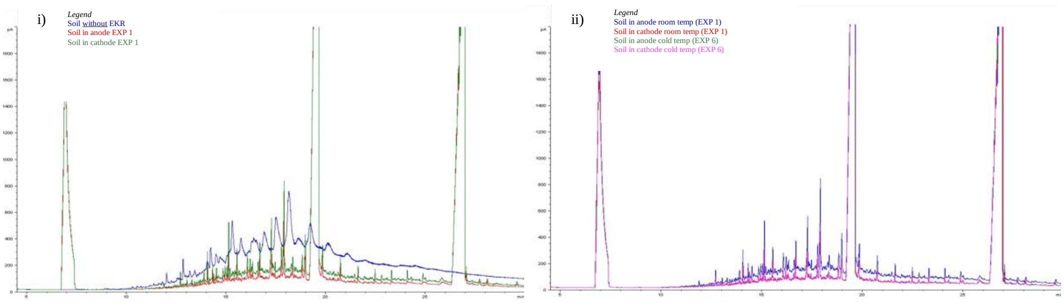

Figure 2. Chromatograms of soil from gas Chromatography using a Flame Ionization Detector (GC-FID) (i) after EKR *vs.* soil without EKR; (ii) after EKR in cold and room temperature.

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