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Perlite Rocks as a Beneficial Material in Heavy Oil Bioremediation

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Abstract - Perlite rocks could be used as either adsorbent or support materials in relation to the cell immobilization of microorganisms in removing heavy oil spilled from *Nakhodka* Russian oil tanker for bioremediation process. Their application on cleaning up oil spills was a profound effective and efficient method due to the multi-cellular nature and high surface area. In addition, their use has a significant effect in accelerating the removal rate of heavy oil due to the attached-growth of microorganisms onto their surfaces.

I. Introduction

Perlite is a unique aluminosilicate volcanic mineral holding and retaining substantial amounts of water, which can be released as needed. Expanded perlite is being used in many applications, particularly in the construction, horticulture and other various industrial fields. It is recommended as an efficient purifying agent and as a carrier for pesticides, feed concentrates, herbicides and other similar applications. It is also used as a solid support in solid-state fermentations [1, 2]. In addition to its application as adsorbent or carrier, an expanded perlite can be used to control and clean up liquid spills, for instance, oil spills which often occurred. A few studies have been conducted on the application of expanded perlite in removing oil spills on either in situ experiment or laboratory-scale one [3, 4, 5, 6]. Other works have also shown that expanded perlite could be employed for the sorption of heavy metal such as chromium, cadmium, and copper (II) [7, 8, 9]. In addition to the aforementioned studies, other studies have shown that expanded perlite were mostly used for both the filter and biofilter bed media to remove toxic compounds (organic and inorganic compounds), odors, and volatile organic compounds from contaminated air and wastewater [10, 11, 12, 13, 14, 15, 16, 17, 18]. However, little is known and even it is very scarce about studies concerning the use of perlite rock for both the adsorbent and biofilm growth-support material in removing petroleum hydrocarbons simultaneously in the bulk of the fluid. For these purposes, we have therefore investigated the potentials of expanded perlite as optimal as possible for their application to clean up oil spills. These results would be applicable for the bioremediation of oil-polluted sites, chiefly marine and coastal ones. Since geographically Japan is a volcanic country, we thereafter seek all possibilities to exploit the indigenous resources/materials to implement in removing the oil spills. The present research focused on optimizing the use of expanded perlite for the removal of *Nakhodka* oil spill in conjunction with the immobilization of cells on its inert support surfaces. The attached and suspended growth of microorganisms was also evaluated.

II. Materials and Methods

The laboratory experiment was designed in batch culture by shaking on rotary shaker (125 rpm). A series of 500-ml Erlenmeyer flasks were used for this experiment. Each contained 200 ml of natural seawater medium (NSW), that is, 160 ml of natural seawater without filtration was mixed with 40 ml of an autoclaved solution containing nitrogen, phosphorous, and iron nutrients (1.0 g of NH_4NO_3, 0.02 g of $FeC_6H_5O_7.nH_2O$, 0.02 g of K_2HPO_4 in 40 ml of distilled water). The pH of medium was adjusted to pH 7.8. The heavy oil collected from the heavy oil contaminated coastal area at Atake Seashore (Ishikawa Prefecture) in Japan was added to NSW at a final concentration of 10 g/l as the sole carbon and energy source. Microorganisms inhabiting the natural seawater and heavy oil were used as inoculum. Cultures were then inoculated with 1000 mg/l of expanded perlite and incubated at the room temperature for 30 days. Expanded perlite-uninoculated flask and microorganisms-uninoculated flask were also incubated as control. Thereafter, microbial growth was monitored by plating microorganisms on nutrient agar and as biomass concentration, and a depletion of heavy oil was detected by using the FTIR at wavenumber 2700-3200 cm^{-1}. The contents of carbon, nitrogen and sulphur were determined by means of a NCS analyzer. Observation of the microbial morphology was conducted by using an optical and epi-fluorescence microscope with DAPI staining, and biofilm formation was observed by using the scanning and transmission electron microscope. Ultimately, the sorption potential of expanded perlite for the removal of heavy oil was detected by using the FTIR and NCS instruments.

III. Results and Discussion

The results exhibited that the removal of heavy oil using a combination of expanded perlite and microorganisms was exceptional rapid compared with those of controls (microorganisms or expanded perlite only). It also seems that the adsorption capacity of expanded perlite for the removal of the heavy oil was substantial in the presence of microorganisms, indicating that microorganisms promoted the degradation process. This was in response to the attached-growth of microorganisms which occurred onto inert support surface of expanded perlite as a result of cell immobilization. Our result also corroborated the previous work reported by [19], demonstrating that it was possible to develop biofilters based on the action of fungi with high elimination capacities for alpha-pinene (one kind of hydrophobic compounds). Also, it was reported that biofilters based on the action of fungi are cost-effective for the treatment of waste gases containing aromatic compounds, alkenes and other hydrophobic compounds [16]. Furthermore, the adsorption increases with increasing the variables such as contact time, initial heavy oil concentration, temperature, and pH [20]. These were also consistent with the result reported by [8], stating that the sorption capacity of expanded perlite increases with increasing the pH of the suspensions. In addition to sorption capacity, the surface complexation plays an important role in the sorption of heavy oil on expanded perlite. Based upon the adsorption process of heavy oil by expanded perlite, the results also demonstrated that as this perlite was added to a water-oil mixture, the light perlite particles migrated on the surface spreading over it very instantly (in fractions of a second). It ultimately seemed that perlite particles saturated with it. Some of them were still on the surface, whereas others submerged.

IV. Summary and Conclusions

It can be concluded that perlite rocks are a valuable material as adsorbent for the removal of heavy oil in which they are capable of enhancing its degradation rate as a result of adsorption of cells on their inert surfaces (cell immobilization). These results are influential in implementing for the bioremediation of heavy oil contaminated environments, primarily marine and coastal sites in relation to the oil spills.

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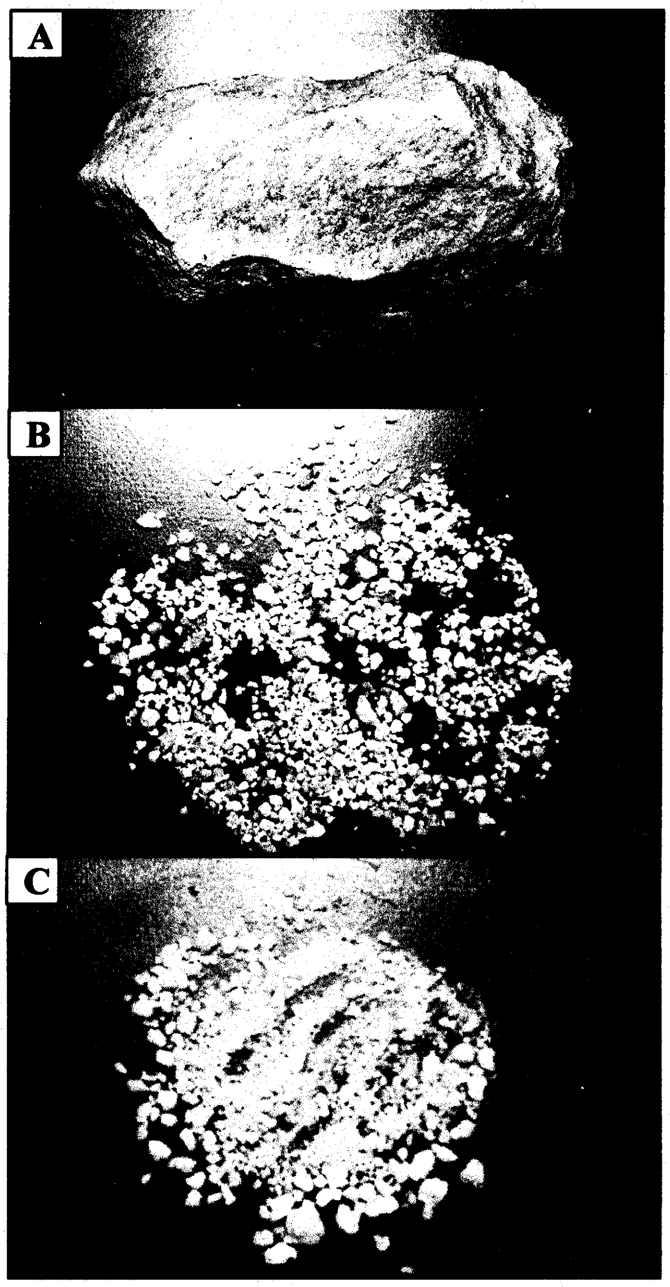

Fig. 1. Photograph of three stages of perlite production illustrating the great increase in surface areas after the furnace process. A, crude perlite; B, crushed crude perlite; C, expanded perlite

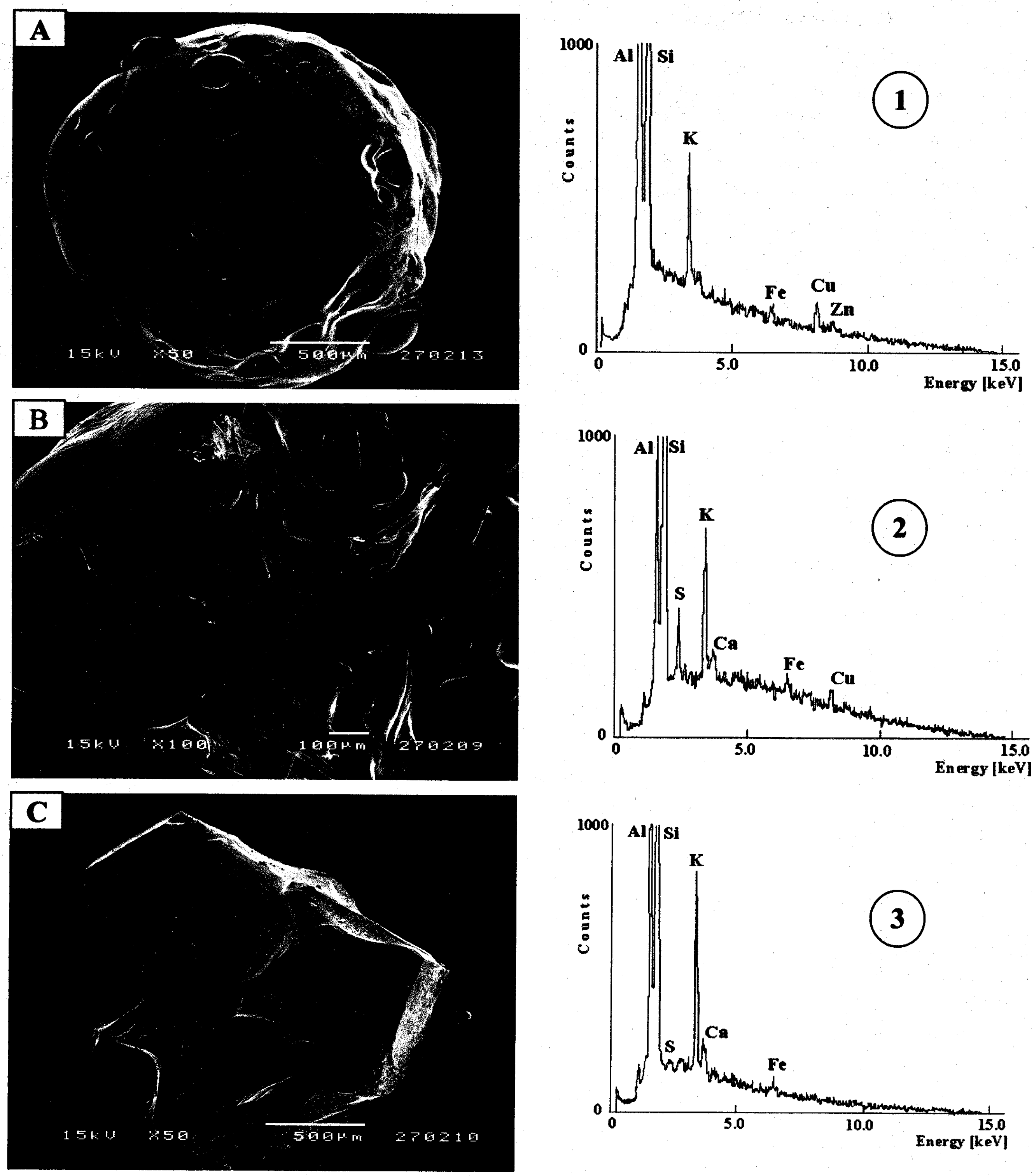

Fig. 2. SEM images and EDX spectra of perlite rock used in this experiment. A, the expanded perlite used as starting material shows the high concentrations of Al, Si, K with traces of Fe, Cu and Zn (1). B, the heavy oil-adsorbing expanded perlite shows the high concentrations of Al, Si, S, K with traces of Fe, Cu and Ca (2). C, the crushed perlite used as starting material shows the high concentrations of Al, Si, K with traces of Fe, S and Ca (3).

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