Bioremediation of oil-contaminated beach using slow-release fertilizer in Indonesia

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1. Introduction

Oil transportation through Malacca and Sunda straits makes high risk of oil contamination in offshore area of Indonesia due to oil spills from tankers. Amendment of nutrients (biostimulation) for oil-contaminated beach is one of remedial options and studied for several years [1)2)3)], but in open marine environments it is often impractical as water-soluble nutrients can be rapidly diluted and leached out. Previous studies suggest that slow-release fertilizers (SRFs) can be considered to keep nutrient enrichment in contaminated marine beach [2)3).] Bioremedial application using SRFs seems to be suitable for low-energy beaches or coral zones, because oil-contaminated sand and SRFs not to be easily washed out by wave actions in these areas. Optimization of SRFs application is indispensable for biostimulation to avoid secondary nutrients pollution in low energy shorelines. Hence, we attempted to optimize the dosage and application method of SRF, Osmocote® 14-14-14 using pilot-scale beach–simulator in a coral beach in Indonesia.

2. Materials and methods

A field bioremediation study was conducted at a coral beach of Pari island in Indonesia using a "beach-simulating system", consisting of beach sand columns (Fig. 1). The body of the sand columns was composed of 5 detachable poly vinyl chloride (PVC) column segments of 20 cm height and 10 cm in diameter, which were filled up using 0.25-4.00 mm in size beach sand of Pari Island. The columns were subjected to 6 different cases with seven replications (Fig. 1). Same columns of each case were installed in same concrete well constructed in intertidal zone. Among these columns, 1 column was used for pore water sampling from different segments and others were for sand sampling.

We started the experiment at the time of Arabian light crude oil supplied (200g) on the top of sand columns and collected pore water samples and columns for sand sampling at days 0, 10, 27, 60, 91 and 116.

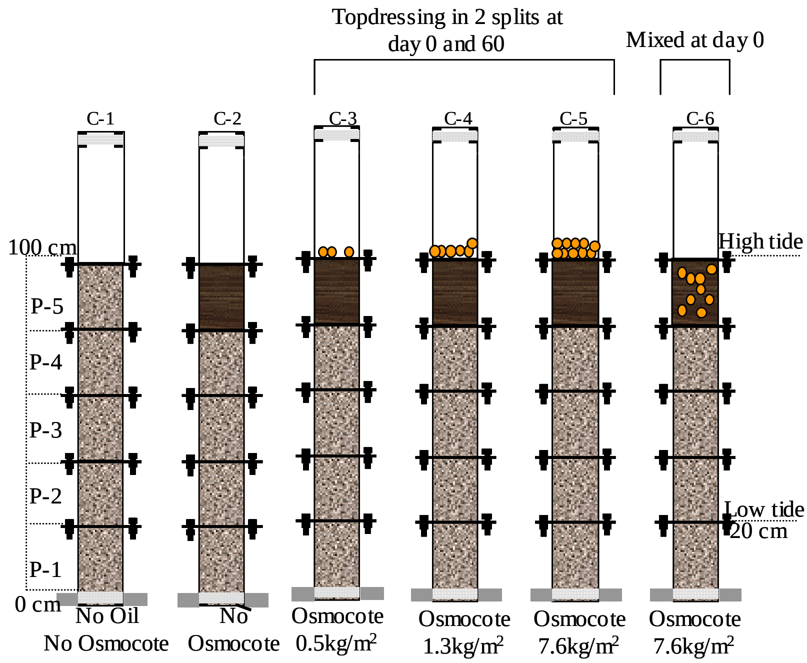

Fig. 1. Sand columns imposed with treatments

3. Results and discussions

3.1 Total bacterial cells in pore water

Fig.2 shows that total bacterial cells in sand columns increased with high fertilizer doses (C-4, C-5 and C-6) comparing with low and no fertilizer addition treatments (C-1, C-2 and C-3). The results revealed that the presence of Osmocote® accelerated bacterial growth in oil contaminated sand column. However, growth rate of bacterial cells rapidly decreased after day 10, indicating that bacterial growth seemed to be limited by environmental factors except nutrients supply.

Key words: Marine beach, crude oil, bioremediation, slow release fertilizer

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3.2. Degradation of total petroleum hydrocarbon

Total residual petroleum hydrocarbon (TRPH) content in the sand column decreased in all oil-contaminated sand columns (Fig.3). On day 116, it was found that 28% oil was degraded naturally without biostimulation (C-2). On the other hand, degradation rates in C-3, C-4, C-5, and C-6 were 37%, 42%, 48%, and 52%, respectively. The result shows that oil degradation rate with 1.3-kg/m^2 and 7.6-kg/m^2 Osmocote® were about 1.5 and 1.8- fold, respectively higher than without Osmocote®. Gas chromatograph clearly shows that Osmocote® applied in mixed method (C-6) performed better than topdressing method (C-5) with same fertilizer dosage as shown in Fig 4.

3.3. Pore water quality

Oxidation-reduction potential (ORP) value of pore water decreased very rapidly in fertilized sand columns on the day 10 and it continued to the end of this experiment (Fig. 5). On the day 27, ORP value at P-4 segment decreased to less than -300 mV with high Osmocote® dosage (C-5 and C-6) and other sand oil-contaminated columns became same low values on the day 60. Less than –300 mV ORP value shows sulfate reduction condition, indicating redox condition in oil-contaminated columns seemed to be changed from aerobic to anaerobic in several days and oxygen might be limiting factor of aerobic microbial growth.

Pore water nitrogen concentrations were found so high enough in C-5 and C-6 with 7.5-kg/m^2 Osmocote® during experiment (Fig. 5), which may cause secondary pollution of nitrogen in marine environment. However, total-N in pore water of C-4 were relatively low between 4 and 24 mg/L, indicating that 1.3 kg/m^2 Osmocote® was sufficient for biostimulation.

4. Conclusions

From this research work, we can conclude that mixing of 1.3 kg/m^2 Osmocote® into the contaminated beach sand might be the best option for biostimulation without having secondary nitrogen pollution risk in marine environment of this area.

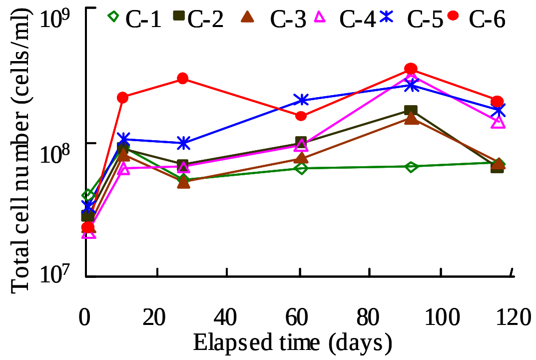

Fig. 2. Total bacterial cells in P-4 segment

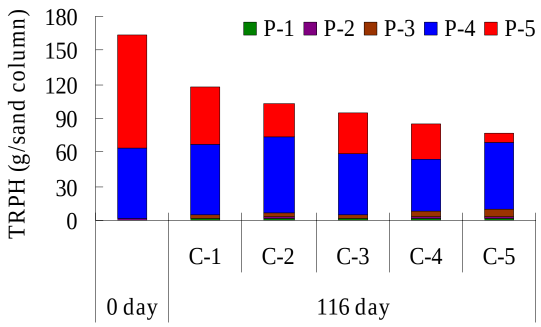

Fig. 3. Residual petroleum hydrocarbon in sand columns

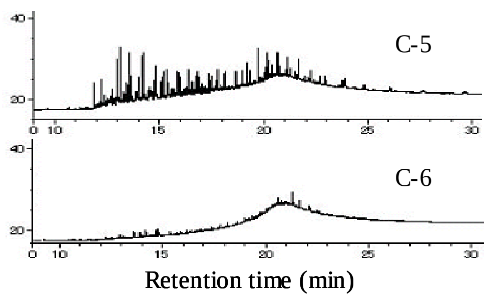

Fig. 4. Gas chromatograph of oil at P-5 segment

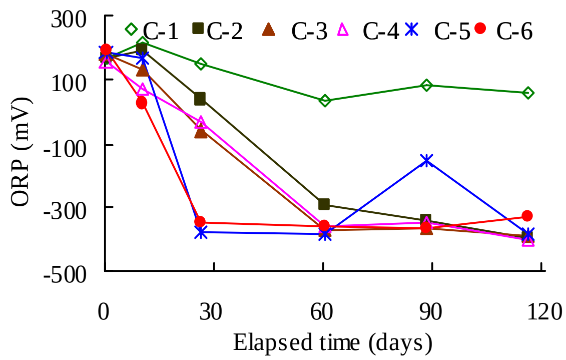

Fig. 5. ORP value in pore water at P-4 segment

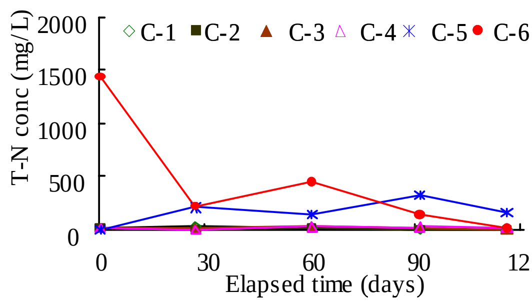

Fig. 6. Total available-N in pore water at P-5 segment

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