FIELD DEPLOYMENT OF OILY SLUDGE BIOREMEDIATION IN ROMANIA

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Oil extraction and processing operations in Romania have resulted in the production of large volumes of oily sludge, which constitute a severe pollution problem for this industry. The oily sludge contains crude oil (10-60%), water (30-90%) and petroleum solid particles (5-40%) in various proportions depending on its origin. These oily sludges are emulsions of either oil-in-water or water-in-oil type, with relative stability determined by the presence of mineral particles along with the oil and reservoir water. Previous investigations of our research group have selected several bacterial consortia with high efficiency for hydrocarbon degradation. This paper presents the results of the studies regarding the degradation of sludge hydrocarbons by selected bacterial consortia. The bioremediation studies were conducted at Potlogi Oil Field, Dambovita County (Southern Romania). The experiments were carried out in field plots with and without addition of a special selected bacterial inoculum. Before addition of the inoculum, the sludge-contaminated soil was mixed with coarse sand and chopped hay in all experimental parcels except controls. These bulking agents increase the permeability and porosity of oily sludge, improving bacterial accessibility to hydrocarbons. A nutrient solution was added to all parcels to stimulate naturally occurring microbiota. Hydrocarbon concentrations in soil samples as well as the status of soil microbial communities were evaluated routinely. At the end of the 2-year experimental period, good residual hydrocarbon degradation efficiencies (exceeding 90 %) were observed, being associated with rich microbial populations in the soils of all parcels. The best results were found in those plots to which the bacterial inoculum was added.

Extensive oil extraction and processing worldwide have resulted in massive accumulation of oily sludge, with severe environmental impact. The oily sludges are usually stable emulsions of either water-in-oil or oil-in-water type. Consequently, the success of any sludge remediation process relies on the ability to firstly brake up the sludge emulsion, substantially reducing its volume and facilitating hydrocarbon availability to degrading agents (El Nawawi et al., 1992). Biosurfactants are well known for their ability to brake up stable emulsions till the complete separation of the two phases. Usually, bioremediation consists in either biostimulation or bioaugumentation (Hazen, 1997). In many cases, it is rather difficult to assess the advantages of bioaugumentation over biostimulation of indigenous microbiota. The present paper presents a field experiment investigating the potential of bioremediation for the cleaning up of sludges that are blocking oil reservoirs from Potlogi oil field, Dambovita County, in Southern Romania. These sludges constitute a permanent threat to the neighboring environment. The experiment was carried out over a 2-year period, starting in 1996, on parcels of 2/1 m with 25-35 cm in high. Each parcel was filled with oily sludge from Potlogi oil reservoirs (with 24.66 % residual hydrocarbon content) and other materials as follow:

V_1 = Oily sludge (5 %) + sand (87 %) + chopped hay (8 %)

V_2 = Oily sludge (10 %) + sand (82 %) + chopped hay (8 %)
V_3 = Oily sludge (15 %) + sand (77 %) + chopped hay (8 %)
V_4, V_5 and V_6 = same as V_1, V_2 and V_3 + bacterial inoculum (10 %)

To all the parcels, 50 L of mineral solution (Koronelli et al., 1984) was added. The inoculum was represented by 6 bacterial consortia, previously isolated from Potlogi oily sludge (Lazar et al., 1999). The parcels were watered every 2-3 days and aerated every 15 days. For the parcels with addition of inoculum, periodic supplementations with 10 L of inoculum and 50 L of mineral solution were performed every 30 days. These treatments were interrupted during the cold period. Periodic analyses of residual hydrocarbon degradation percentages (Soxhlet benzene extraction) and microbial community characteristics have been performed every 6 months.

The selected bacterial consortia with high efficiency in sludge degradation, mainly composed by the genera: *Bacillus, Pseudomonas, Mycobacterium, Corynebacterium* and *Micrococcus,* were firstly tested in the lab. The results (table 1) confirm their efficiency in paraffinic and semi-paraffinic oil degradation and good production of biosurfactants and biosolvents (nigrozine test).

Table 1. Characteristics of the bacterial consortia used as inoculum in the bioremediation experiment of oily sludge from Potlogi oil field

Bacterial consortium	Metabolites production		Degradation % of :		
	biosurfactants (% kerosene emulsionation)	biosolvents *	paraffinic oil	semi-paraffinic oil	asphaltic petroleum
CB_{22}	90	++	60.2	70.5	58.1
CB_{24}	95	+++	69.5	68.9	62.3
CB_{25}	90	++	60.2	65.3	53.5
CB_{38}	85	+++	74.3	62.5	61.3
CB_{45}	95	+++	70.5	68.3	65.4
CB_{47}	80	++	64.2	65.8	60.1

* The intensity scale considered was arbitrary chosen between: - to +++

The results from the periodic analyses of sludge samples from Potlogi field experiment, presented in fig.1 (residual hydrocarbon degradation percentages) and table 2 (microbiological characterization), indicate an over 90 % reduction of residual hydrocarbons in all the parcels, after 2 years. As expected, the highest degradation percentages were obtained in the parcels with inoculum addition, but not significantly higher to justify the inoculum use. This can be due to the good activity of the indigenous microbiota that was stimulated during this application by nutrient addition and aeration. The sand and chopped hay, in all used proportions, facilitated sludge degradation, which is in accordance with the study of El Nawawi et al., 1992. The degradation percentages increased gradually over the 2 year-period, with slightly higher rates in the first and the last 6 months. The microbiological study revealed a rich microbial community, justified by the high number of studied bacteria, reported over all this study. The insignificant difference in the number of bacteria from inoculated and uninoculated parcels confirm the good results obtained in residual hydrocarbon degradation in each case and might be due to the natural good colonization of the sludge. After the end of this experiment, bean and corn were cultivated on the parcels. The crop development was optimal, demonstrating the success of our field experiment.

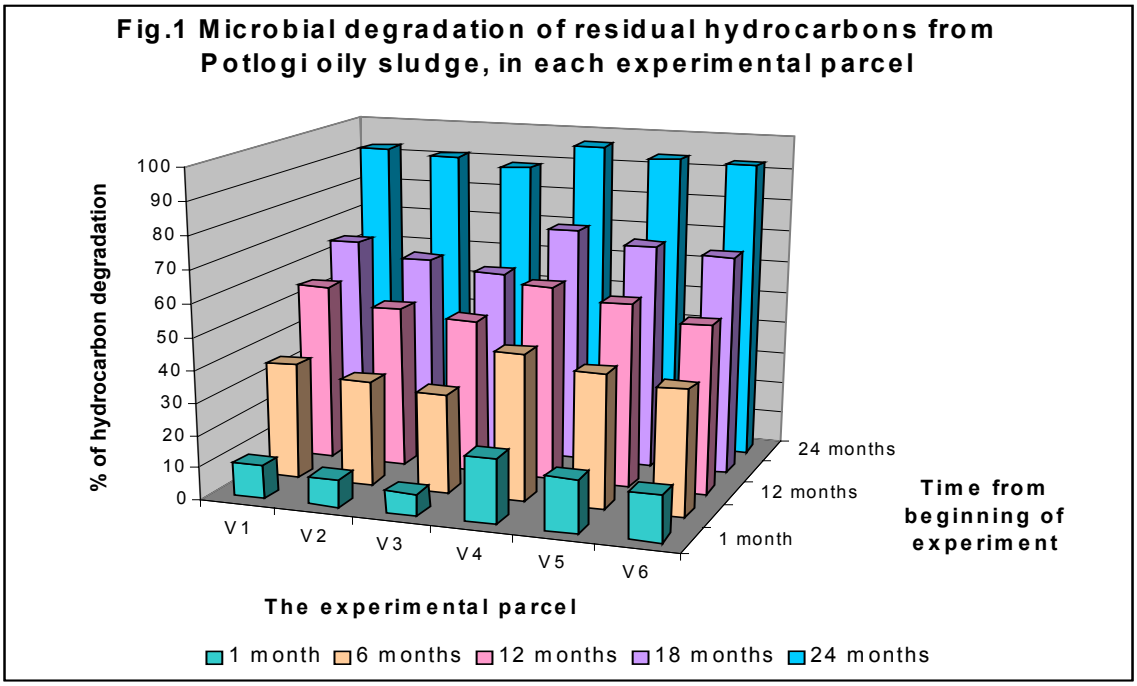

Table 2. The presence of microorganisms in Potlogi oily sludge, from experimental parcels at different time periods

The exp. parcel	No. of microorganisms / g sludge sample, at several time periods for:				
	Heterotrophic aerobic, facultative anaerobic bacteria				
	May 1996	Nov. 1996	May 1997	Nov. 1997	May 1998
V_1	4.0×10^6	2.5×10^5	7.5×10^7	1.5×10^5	5.0×10^7
V_2	3.0×10^7	1.5×10^5	4.5×10^7	2.0×10^5	7.5×10^7
V_3	7.5×10^7	2.0×10^6	7.0×10^7	1.5×10^6	6.5×10^8
V_4	7.5×10^7	4.5×10^6	1.2×10^7	2.8×10^6	1.4×10^8
V_5	2.5×10^8	3.5×10^6	6.5×10^9	5.5×10^6	2.5×10^9
V_6	9.5×10^8	3.5×10^6	1.4×10^9	4.5×10^6	7.0×10^9
	Hydrocarbon-oxidizing bacteria				
V_1	1.2×10^2	2.5×10	3.5×10^3	7.5×10	7.5×10^2
V_2	3.5×10^3	1.1×10^2	3.5×10^4	2.5×10^2	3.0×10^4
V_3	1.1×10^3	9.5×10^2	7.0×10^4	3.5×10^3	4.5×10^4
V_4	1.4×10^3	2.0×10^2	6.5×10^4	1.5×10^2	9.5×10^4
V_5	3.0×10^6	1.4×10^2	1.5×10^4	2.0×10^3	9.5×10^4
V_6	1.1×10^4	1.5×10^3	2.5×10^4	2.8×10^3	7.0×10^5

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