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Extensive Evaluation of Aerated Accumulation Technique for Soil Treatment

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Abstract

A pilot study of hydrocarbon biodegradation in soil using the aerated accumulation technique (AA), performed in the oil field Loma La Lata of Repsol-YPF SA in the province of Neuquén (Ercoli and others, IAPG, 2000) yielded satisfactory results. We considered the possibility of applying this biological technique on the treatment of big amounts of contaminated soil. The experimentation showed the possibility of reaching cleaning goals in comparative shorter periods of time, of about three months, starting from soils moderately contaminated with light hydrocarbons. Some important advantages in comparison with other biological techniques such as land-farming or biorestoration were additionally observed. The moisture of the soil was maintained during the treatment with no need of extra addition of water - cost to be considered in superficial treatments- and produced an important spontaneous increment of the temperature of the soil. These two characteristics of the process are particularly attractive for arid soils and cold regions, since these two factors, scarce humidity and low temperature, delay the global kinetic of biodegradation.

On the base of the pilot experiment results, the application of the technique in larger scale on diverse kind of contaminated soils in oil field of Neuquén province was decided. Volumes of 20000 m^3 of lightly contaminated soil, 8000 m^3 of moderated contaminated soil and 22000 m^3 of highly contaminated soil, were treated. In all of the cases, an efficient reduction of the contaminants up to predetermined values was observed. The evaluation of these parameters let us conclude that an important number of cases of contaminated soils with hydrocarbons can be resolved in an efficient and economic form using this technique.

Introduction

Bioremediation is considered in many cases an effective and cheap mean of erradicating hazardous wastes compounds from the soil. A number of biological techniques have been applied successfully to the treatment of oily contaminated soil. One of them is landfarming, in which environmental and nutritional conditions are adjusted to let the proliferation of degrading microorganisms. The polluted soil is spread out in a layer of about 0.5 m in thickness on top of a specially constructed impermeable sublayer provided with a drainage system. The aerobic microbial degradation of pollutants in this layer is stimulated by regularly cultivating the layer to enhance oxygen transfer. Bioremediation process consists in ensuring adequate water, nutrients, oxygen and soil mixing to promote the biological activity of microorganisms. The presence of large number of adequate microbial species is the key to successful bioremediation. The use of aucthoctonous microorganisms is in general accepted as an effective way to biodegrade oil compounds in soil. In most cases microorganisms are already available at the contaminated site. It is also accepted that the introduction of exogenous bacteria may have great difficulties in finding soil niches in which to survive. Basically, landfarming is a relatively simple method and makes treatment times of 1 two 2 years acceptable. One of the limitations is *bioavailability* which is primarily determinated by the sorption of the contaminants from the soil particles and not by microbial activity. A low bioavailability means that the biodegradation rate is too low for practical application and/or that the residual concentration of the contaminant in the treated soil usually remains above the standards for clean soil.

An alternative technique to improve degradation rate is the aerated accumulation technique which consist in soil piles up to 2.5 meters in height mechanically mixed to maintain aerobic conditions by convective air movement and diffusion. Piles are mixed in a cycling period of seven to fifteen days by using excavator machinery. The volume of the piles range from 500 m^3 to 5000 m^3. An impervious bed is constructed on which the contaminated soil is placed. This degradation system lets improve the control of moisture and let us to maintain the temperature generated by microbial activity. As a consequence of it, an increase in the overall kinetic of the degradation process can be observed.

2. Analytical methods

TPH, Norm EPA 418.1
Kjeldahl Nitrogen: Normalized Methods for the analysis of drink and residual waters 4500 N_{ORG}B, Method Macro Kjeldahl. Modified*.
Assimilable Phosphorus: Normalized Method for the analysis of drink and residual waters. Ascorbic acid Method. Modified*
Soil Moisture (%): ASTM 2216-71. Modified*
pH: ISO 10390
Aerobic Hydrocarbons Degraders Microorganisms: Methods of Soil Analysis part 2 - Chemical and Microbiological Properties. 2º Edition. American Society of Agronomy, INC 1982. Modified*
*Modifications were done according to the sample nature.

3. Results and Discussion

Full-scale remediation

As a result of the pilot scale trials, full-scale remediation processes were implemented. Table 1 shows main characteristics for the selected remediation cases. In figure 1 are compared biodegradation processes by using land-farming technique and aerated accumulation technique for similar soils, contaminant and climatic conditions. Strong differences in biodegradation can be observed. In the first case it took six months to reduce de oil concentration up to 25 %. In the second case a reduction of 58 % was achieved in less than three months. The type of soil also influence markedly biodegradation. In figure 2, two types of soil are compared: silty sand and clayed silt. As can be observed, in the first case 64 % of the oil was degraded in three months while for the second case six months were needed to get an acceptable end point. Figures 3 and 4 shown the degradation at different point in the pile, one of them at the surface (first 50 cm) and the other at different depths in the pile. In both cases biodegradation tends to be the same in all the height of the pile with the progress of the process. Limitation in nutrients (source of Nitrogen and Phosphorous) is reflected in the degradation curves shown in figures 5 and 6. In both cases the addition of a new amount of nutrient stimulated biodegradation.

In connection with the microbial activity, figure 7 shows comparatively the evolution of microbial aerobic population in landfarming and aerated accumulation processes. The initial concentration for the first case was 1.E+06 and the maximum value was close to 1.E+07. In the second case, the initial concentration was 1.E+05 and, in a period of 2.3 months, reaches 1.E+11. This dramatic change in the concentration of microorganisms in soil makes possible to complete a remediation process in a short time. This is an important advantage of this technique.

Another important factor affecting microbial activity of the soil under treatment is moisture content. Figure 8 shows the evolution of aerobic microbial population with time under different moisture conditions of the soil. It can be noted that at low humidity (10 %) the microbial concentration reaches the highest value (1.E+10) while when moisture content increases up to 15 % microbial concentrations drop up to 1.E+07. Figure 9 shows another case in which microbial population follows similar behavior. An increment of the temperature of the soil can be observed as a consequence of microbial activity (figure 10 and 11). The average increase in temperature is about 10°C to 15 °C. It can be noted that for a wheather condition of –7°C the temperature of the pile was mantained in the range of 10°C to 12°C.

4. Conclusions

Full-scale remediation processes have shown the feasibility of applying aerated accumulation technique for the treatment of oily contaminated soil under the conditions of the study region. In all the cases a reduction of the contaminant in soil in shorter times (two or three times) than other biological techniques like land-farming was observed. Favorable environmental conditions like temperature and humidity let microorganisms grow rapidly at the expense of the contaminant. It was not necessary to add water to the piles along the remediation processes and temperature increased spontaneously. An average of 10°C to 15°C was maintained during the remediation processes above the air temperature. The concentration of aerobic microorganisms was higher than that obtained in equivalent land-farming processes.

5. Acknowledgments

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6. References

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Table 1. Main characteristics of full-scale remediation processes				
TPH (g/kg)	53.6	27.8	15	26
N content (mg/kg)	301	348	348	511
P content (mg/kg)	0	0	1	0
Microbial content (CFU/g)	< E06	E05	< E06	E06
pH	7.6	8.1	7.7	8
Height of piles (m)	1.5	0.85	1.5	3
Soil types	Silty Sand	Clayed Silt	Silty Sand	Silty Sand

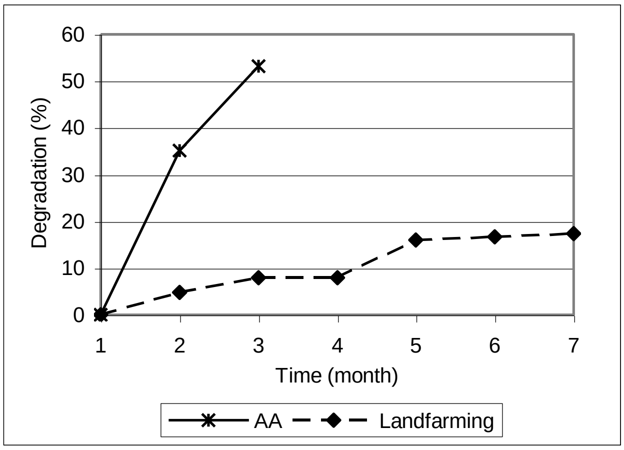

Figure 1. Biodegradation: aerated accumulation and landfarming.

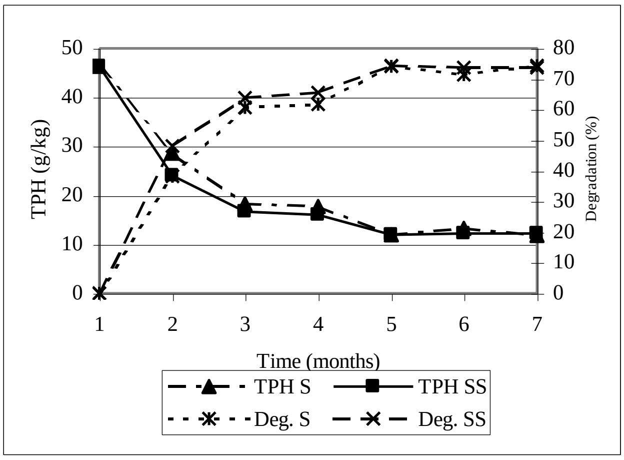

Figure 3. Effect of the depth in biodegradation at the surface

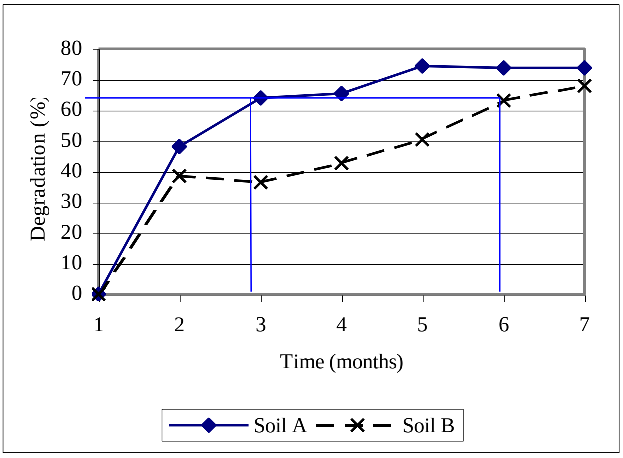

Figure 2. Biodegradation for different types of soil

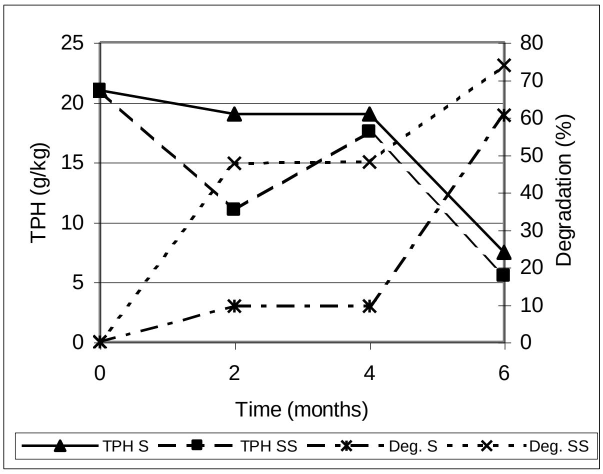

Figure 4. Effect of the depth in biodegradation.

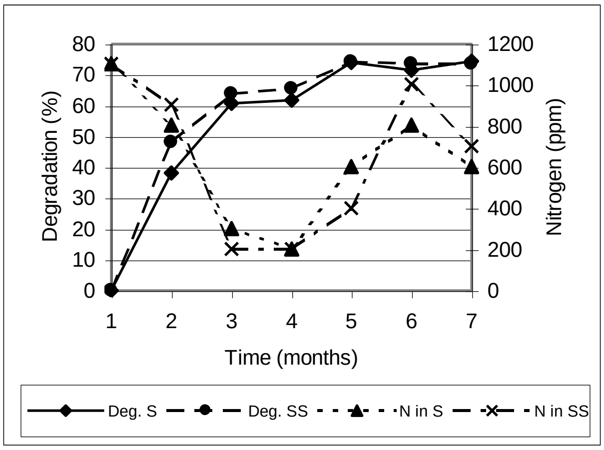

Figure 5. Effect of Nitrogen concentration on biodegradation

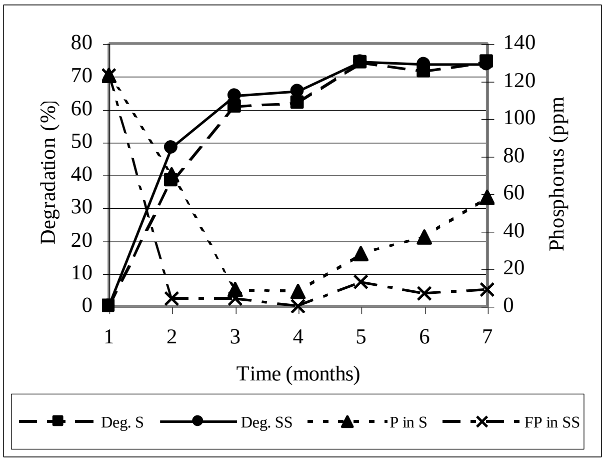

Figure 6. Effect of Phosporous concentration on biodegradation

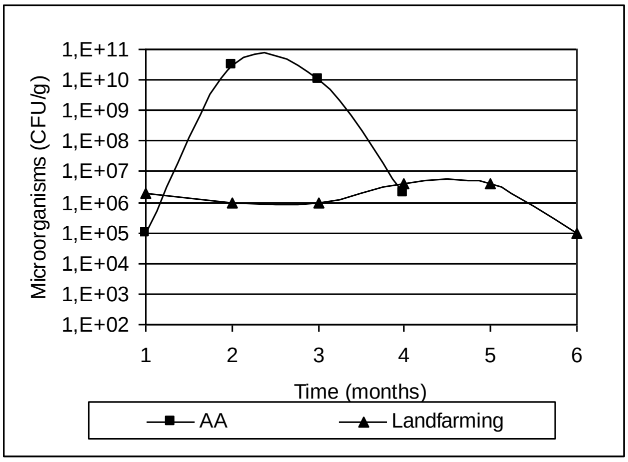

Figure 7. Evolution of microorganisms concentration in landfarming and aerated accumulation techniques

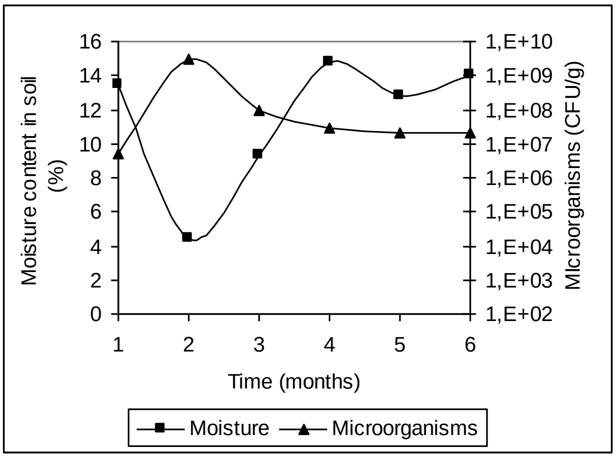

Figure 8. Effect of moisture on microorganism concentration in soil.

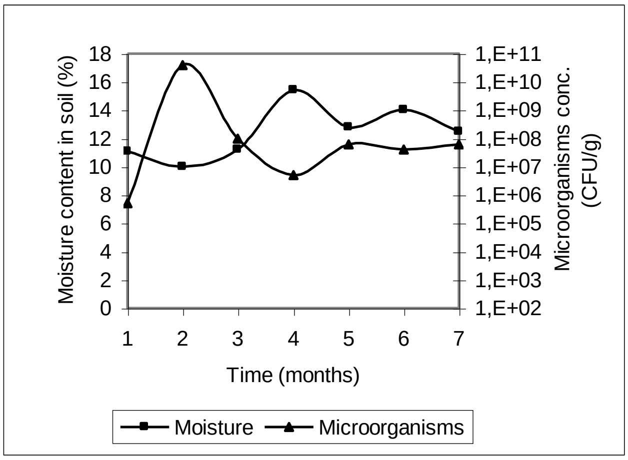

Figure 9. Effect of moisture on microorganism concentration in soil-mud mixture

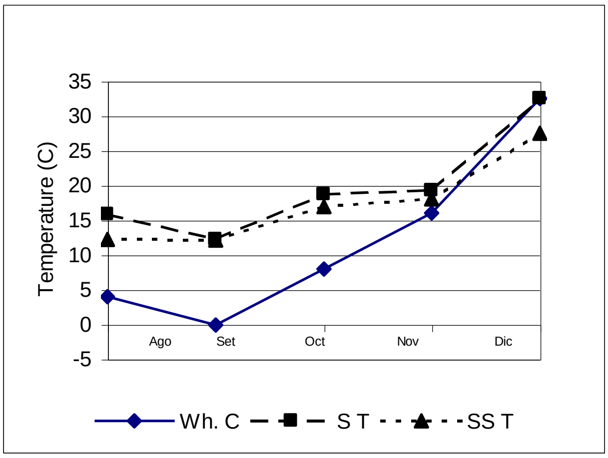

Figure 11. Evolution of temperatures on soil

Wh. C: Weather Conditions
S T: Surface Temperature
SS T: Subsurface Temperature

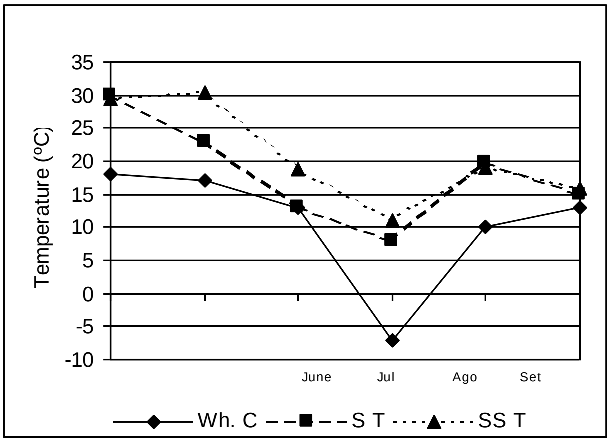

Figure 10. Evolution of temperatures on soil mud mixture

Wh. C: Weather Conditions
S T: Surface Temperature
SS T: Subsurface Temperature