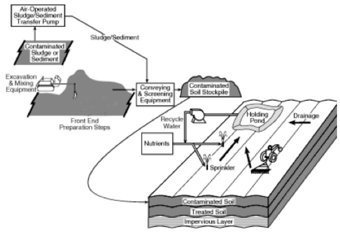
In situ bioremedation of hidrocarbons contaminated soils: case of an oil pipeline in Malaga



Biorremediación in situ de suelos contaminados por hidrocarburos: caso de un terminal de oleoducto en Málaga

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RESUMEN

- La biorremediación es una herramienta muy efectiva en algunos procesos de contaminación medioambiental, el objetivo de esta investigación es ponerla en valor. Su principal ventaja reside en la baja agresividad con el medioambiente y su capacidad de descontaminar in situ.
  Como resultado de nuestra investigación presentamos la novedad de utilizar nuestros métodos como la manera de evitar actuaciones más costosas económicamente, como la desorción térmica, o mucho más terribles e ineficaces como la identificación del residuo como peligroso, y su posterior almacenamiento y custodia sin darle solución definitiva.
  El artículo presenta los resultados y cómo se desarrolló el proceso de tratamiento, de unos suelos contaminados con hidrocarburos, en unos terrenos localizados en las obras del tren de alta velocidad entre Córdoba y Málaga. Obteniéndose en seis meses descensos por debajo de las 1500 ppm de TPH.
  También nos gustaría poner a disposición de la comunidad científica el éxito de la utilización de diversas mezclas, así como de las técnicas y propiedades que se deben realizar y medir. La coexistencia de biosulfatantes, fosfatantes y la novedad de probarlos con hidróxido de magnesio, los resultados de las interacciones de los microrganismos con el contaminante, y qué condiciones son ideales de aireación y de estimulación por mezcla, muestre la capacidad de degradación del hidrocarburo y su sostenibilidad.
- Palabras clave: ensayo miniatura de punzonado, SPT, aleaciones de aluminio, ensayo de tracción, límite elástico, resistencia a la tracción.

ABSTRACT

Bioremediation is a tool that can be effectively used in certain contaminated environments. Its main advantages reside in its low aggressiveness with the environment when applied "in situ", and in the capacity to destroy contaminants.

As a result of our research we are able to present the novelty of using our methods, as the way to avoid more expensive actions such as thermal desorption, or much terrible and ineffective, such as identifying the waste as dangerous, and its subsequent storage and custody without reaching to a definitive solution.

This article presents the results we reached to and how we proceeded in the treatment of soils contaminated with hydrocarbons on land located in the engineering work of the high-speed train between Córdoba and Málaga. Thanks to the way of proceeding we obtained, within six months, decreases below 1500 ppm of TPH.

We would also like to make available to the scientific community the success of using different mixtures, as well as the techniques and properties must be performed and measured.

Coexistence of biosulphants, phosphants and the novelty of treating them with magnesium hydroxide, the results of the interactions between microrganisms and the pollutant and what conditions are needed of aeration and stimulation by mixture, shows the degradation capacity of the hydrocarbon and its sostenibility.

Key-words: bioremediation, descontamination, hydrocarbon degradation, micro-organisms.

1. INTRODUCTION

Soil decontamination technologies arise from the growing existence of soil contamination and its disastrous effects on the environment.

One of the most common environmental impacts is the contamination of soils because of spillage of hydrocarbons.

There are currently varied and important soil decontamination technologies (Acuña, 2012) to resolve such a significant soil problem, but not all are satisfactory in terms of times, treatment conditions and end results.

Soil recovery activities should use the best techniques available (Alva, 2014) to minimise and eliminate risks.

During the outline of the new railway access to Malaga, between kilometres 1550 and 1950, the existence of oil hydrocarbons in the soil was determined. The origin of these hydrocarbons appears to be related to the activity of the former terminal of the Malaga-Puertollano oleoduct.

Spanish Royal Decree 9/2005, of 14 January, (Spanish Royal Decree 9/2005) sets out the list of potentially soil contaminating activities and the criteria and standards to declare soil contaminated.

In accordance with the Spanish Royal Decree, soil can be declared contaminated by competent authorities when the risk analysis indicates that the concentrations of organic compounds entail an unacceptable risk to human health. In those cases, in which there is no risk analysis, competent authorities may declare soil is contaminated when the concentration of total petroleum hydrocarbons (TPH) exceeds 50 mg/kg.

In this work, interest is focused on potentially contaminated soils in the section for integration of the railway in Malaga, in the area annexed to the former terminal of the Malaga-Puertollano oleoduct.

NIVEL	DESCRIPTION
Concentration < GRL	Conditions acceptable for the proposed soil use
Concentration> GRL TPH > 50 mg/kg	Unacceptable conditions for the proposed soil use. Risk analysis required to evaluate the risks entailed by the proposed soil use. The authorities may declare soil contaminated.
Concentration 100 > GRL	Unacceptable conditions for the proposed soil use. Sanitation plan by the authorities will be required.

The absence of volatile organic compounds such as benzene, toluene, ethyl benzene or xylene and the existence of polycyclic aromatic hydrocarbons at concentrations less than those determined as Generic Reference Levels (GRL) by Spanish Decree 9/2005, is of interest.

The problem of decontamination of soils can be treated from two perspectives: techniques for isolation of the contamination and decontamination techniques; we chose the latter and for us this was the best proposal. Therefore, carrying out the work will be focused on development of bioremediation techniques. The current scope of application of bioremediation is broad and each one of the material states of solid, liquid and gas may be considered at issue.

Bioremediation is therefore not very intrusive technology in the setting and, in general, does not require complex structural and mechanical components. It is a comparatively economic approximation because it is a "natural" process (in the sense of using the setting's microbiological resources) and is more susceptible to being accepted by public opinion.

Bioremediation (Plaza, 2001) also has some disadvantages and limitations. For example, incomplete biodegradation can lead to acceptable metabolic intermediaries with a contaminant power similar or even higher than the starting product. In our case, there were no problems associated with this pathology, nor were there any contaminants that are resistant or inhibit bioremediation.

The factors that determine the efficacy of bioremediation, can help to foresee the degree of attaining objectives considered in the process for a specific situation, mainly biodegradability of the contaminant because aliphatic hydrocarbons and linear alkanes are broken down quickly, ratified structures are more difficult to break down than linear chains. Secondly, the existence of appropriate microbial communities which may be autochthonous micro-organisms. In this case, we would be referring to intrinsic bioremediation or natural attenuation. Finally, the availability of the contaminant. For degradation of the contaminant to occur it is necessary for interaction with the cell in an aqueous medium. Initially, this will be with the outside part of its wall to be subsequently transported inside the cell. Many organic contaminants like most oil components, PCBs, PAHs (naphthalene, pyrene, fluorene, etc.) are hydrophobic and tend to adsorb in the soil, specifically the organic fraction (humic, fluvic acids and humin). This is one of the causes, for example, of the persistence of many pesticides. Therefore, a critical aspect for availability of contaminants is soil composition, which will determine both the kinetics of absorption and the absorption of contaminants and their own capacity to be mobilised by the micro-organisms and enter into contact with them.

The nature and conditions of the contaminated setting are the properties of the setting that enable or limit microbial growth and metabolism of the compound. Among them we can cite permeability that hinders or enables the existence of gradients and transfer of the contaminant to microbial populations; temperature, that determines both metabolic rates and the physical state of the contaminant; the existence or absence of organic nutrients, oxygen or other potential electron acceptors; the capacity for water retention and hydraulic characteristics in the case of soil; pH and flow characteristics in the case of underground waters; the degree of contamination, etc. At times, it will be necessary to amend some of these parameters, for example by adding nutrients or ventilating. We opted for this practice that corresponds to the term biostimulation.

There are three important concepts from a methodological point of view: attenuation, biostimulation and bioaugmentation.

Natural attenuation is what is performed on many compounds by autochthonous micro-organisms, mainly bacteria, from the medium affected. These use their enzyme potential to mineralise contaminants (that is, biodegrade them completely to CO2), or simply break them down to intermediate products, either in an aerobic or anaerobic setting.

The intrinsic capacity for natural attenuation of a setting depends, therefore, on the "metabolic skills" of the native micro-organisms, type of contaminant and the geochemistry and hydrogeology of the area affected.

In the presence of oxygen, contaminants are converted to carbon dioxide and water with a high yield in terms of production, energy and microbial cellular mass.

Under optimal conditions with natural attenuation, contaminants will be broken down fully or transformed into less harmful or innocuous compounds. This method is, therefore, the most appropriate strategy for bioremediation with the obvious advantage of its lower cost.

Biostimulation (at times called enhanced bioremediation) consists of adding electron acceptors (oxygen, nitrates, etc.), although in others the addition of nutrients such as nitrogen and phosphorus may be required or pH adjustments or even providing co-metabolites.

Bioremediation requires that these enter into contact with the impregnated area and for their concentration to be sufficient to support the maximum growth planned for the degrader population throughout the remediation operations, pump & treat systems will be necessary.

Nutrients or additives during biostimulation methods (Rodríguez, 2012) may be added in the form of briquettes or slow-release granules, liquid oleophilic fertiliser, natural products with nutritional properties and surfactant capacity (for example, algae extracts), biosurfactants of bacterial origin, biodegradable, chemical origin surfactants combined with mineral salts, etc.

Bioaugmentation consists of adding specialised micro-organisms to the setting with the purpose of facilitating elimination of contaminants and boosting and optimising remediation. The risks associated are uncontrolled growth and proliferation and the possibility of gene transfer introduced into autochthonous micro-organisms with the risk of altering the community's gene pool.

Bioremediation techniques can be applied in two ways which may be combined in pump & treat systems for underground waters. the degree of contamination, etc. At times, it will be necessary to amend some of these parameters, for example by adding nutrients or ventilating. We opted for this practice that corresponds to the term biostimulation.

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Bioremediation techniques can be applied in two ways which may be combined in pump & treat systems for underground waters, "in situ" bioremediation consisting of treating the waters, soils, or sand contaminated without moving them from their location "ex situ" bioremediation, treatment processes (biostimulation and bioaugmentation) applied after excavation of the contaminated setting either in the form of sludge and simple bioreactors (bioslurry techniques for soils) or in solid-phase, in treatment plants by means of ploughing techniques (ploughing or landfarming on impermeable laminas with suitable covering) or composting, mixing the residue with other cellulose-like materials (for example, in biopiles with air injection such as those in Figure 1).

Once we reach this point, in which a bioremediation strategy is implemented, demonstrating that it is effective on land is not an easy task. Bioremediation is not an infallible solution and its successful application requires a "bioviability study that would include, if performed exhaustively.

Our decision was to investigate the functionality of the Landfarming technique, which indicates that the technique chosen presents limitations because of the need for lengthy treatment times that hinder its application.

Therefore, in this work, technologies will be investigated and carried out that improve this process by means of synergic effects, which among other advantages, markedly reduce the residency times set out.

2. TOOLS AND METHODS

The solution we have choosed to solve our problem is based in the treatment of biorremedation (Alexander, 1994) for contaminated soils.

We have made a chemical study to evaluate the state of the pollutants existing and their variation. This study is based on Fourier transform infrared spectroscopy (FTIR) technique. With this we determinate to what extent biodegradable fractions are present and if there has existed a natural attenuation process.

We made a microbiologic research about the microrganisms that are present by detection and type of bacterias, we contracted a specialist laboratory, evaluating the number and quality of those microrganisms (practically all bacteria) present in the envairoment which has been studied. In this way we were able to afirm that there is a capacity for descomposition of the pollutant, reaching to the objective that these bacteria assimilate the contaminant hydrocarbon in their organisms.

The test land to manage or treat has the following lithology, a ballast and filling of the former railway line, a highly permeable layer and moderate condition. Sandy reddish clay is mostly affected. There is sand and gravel where a groundwater level appears with semi-confined water with free product.

The unit of interest is sandy reddish clay, which must mostly be excavated and has a high crude factor. Its content of fine hydrocarbons is between 37 and 100%, hydraulic conductivity of 10-4 cm/s and humidity 18%. Dry and humid density is 1.8 and 2.0, respectively. We can consider an average fine hydrocarbon content greater than 40%.

The kind of product present both in solids and groundwater level corresponds to heavy products, with a distillation curve of between 50 and 600ºC; 90% is distilled at 500 ºC.

The dimensions of the area affected are 40 x 140 x 4 m. This means 22,400 m3 which considering humid density is equivalent to 44,800 tonnes, of which approximately 30,000 tonnes need to be treated.

This consists of extending the land extracted in thin layers and stimulating the activity of existing microbes in the soil to treat to increase the breakdown of contaminants by using ventilation and the addition of nutrients, minerals and water.

This was performed in prepared land cells with an impermeabilisation system onto which a drainage network was installed, covered by a draining soil layer (sand and gravel). Contaminated soil was extended onto the latter, which was periodically ploughed and turned for its ventilation and homogenisation.

The soil was irrigated periodically with a solution containing nutrients and mineral salts. The drainage system was connected to an effluent treatment plant. The leachate may be recirculated at times until all contaminants are fully destroyed.

The developments associated with this work are technological adaptation and functional validation of the landfarming system for this kind of contaminated soil, the development of additional meas-

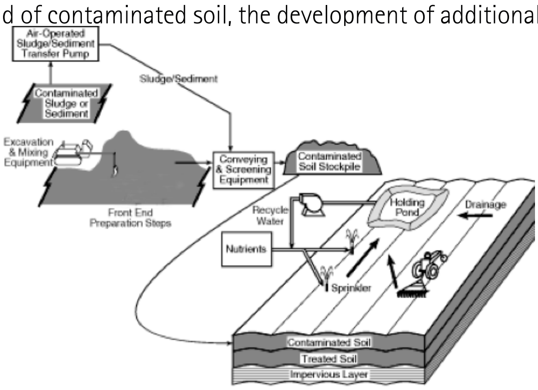

Fig. 1: "Landfarming outline"

ures for synergic effect with the landfarming technique that will enable speeding up the biological treatment process and reduction of spatial needs to perform the treatment. Finally, the complete removal of contaminants.

The purpose of this monitoring is to fully characterise the soil. Therefore, a total of 84 soil and water samples were taken by means of sand pits and probes (according to the sampling plan set out) and they were subsequently analysed in the TPH laboratory (Vallejo, 2007) by chromatography, TPH in chains and aliphatic-aromatic TPH and TPH by FTIR.

Regarding hydrogeology, it is notable that the alluvial group is a free aquifer system. The groundwater level appears at around 5 m in depth and flow direction is north-east to south-east.

Sampling points were taken on a 25-m staggered mesh between knots that covered a total length of 400 m. In some specific cases these points had to be moved to avoid existing machinery at work. At no time was the 40-m distance between one point and another exceeded. The sand pits reported during reconsideration of fieldwork with the denominations C6, C9, C11 and C15 could not be carried out because of the variation in civil engineering work and with the purpose of not interfering with this.

A series of water samples was taken in control piezometers, under the identifications: AS1, AS2, AS3, AS4, AS5, AS6, AS7 and AS8. A groundwater level control was established paired up with the sample and some of the pits.

A total of 76 soil samples was taken that were stored in one quarter litre glass jars placed in fridges at approximately 4ºC. They were sent urgently duly sealed, to the laboratory and a chain of custody was formalised to guarantee their correct transport and transmission.

Water samples were stored in amber glass containers with Teflon seal. They were filled to the top and stored in fridges at approximately 4°C.

A total of 60 samples gave a hydrocarbon concentration result under the generic reference level (50 mg/kg). They are, therefore, considered outside the contamination range.

Based on these considerations and considering the interest of performing experiments with magnesium hydroxide Mg(OH)2 as an additive, it was decided to undertake the corresponding treatments. Therefore, soil excavated in Malaga was transferred to the Los Barrios treatment plant in Cádiz, where land was approved to undertake biological treatment.

The design and execution of treatments lead us to the following project objectives: reduce as much as possible the concentration of hydrocarbons present in land to treat over a period of 5 to 6 months, verify the effectiveness of several alternative treatments with a special focus on the use of magnesium hydroxide. As an additional and complimentary aim, it was considered of major interest to work on soil selected given the weathering presented by its hydrocarbons.

This was a volume of earth of approximately 500 to 600 m3, combined with a mean number of 3000-3500 ppm of hydrocarbons.

The area used for landfarming was land of approximately 6000 m², according to data provided by the managers of the industrial waste plant of Los Barrios (Cádiz). There was a total of nine rectangular or square lots here of approximately 200 m2, in which small piles of approximately 30 to 40 cm soil depth to treat, were piled on top of one another. In total, there will be approximately 60 m3 of soil in each lot of the 500 to 600 total lots to treat.

All lots were on impermeable land used and approved as a biological treatment area. The total construction was given an approximate slope of 1% that led to a leachate collection pit. The land subsoil was protected by placing a 1-1.5 mm thick HDPG (high density proteoglycan) lamina. This was coated with a geotextile and then the soil to treat was deposited in successive layers until the total scheduled for each pile was available. To separate areas sufficiently wide vials were used that also helped to avoid cross contamination.

Therefore, the following treatments were applied on the nine lots:

P1: Control lot, the soil left alone without irrigation, turning or any kind of additive.

P2-P9: Treatment lots all had a common irrigation and turning system reported below:

P2: Irrigation and turning only.
P3: Mixture of soil with Mg(OH)2
P4: Application of S-200
P5: Application of SRF.
P6: Application of SRF + Ivey-Sol Surfactant
P7: Mg(OH)2 + S-200
P8: Mg(OH)2 + SRF
P9: Mg(OH)2 + SRF + Ivey-Sol Surf.

Lots of approximately 80 t (approximately 50-60 m3 in 20 x 9 x 0.3) were considered as starting data. Initial humidity of 8.5%; initial levels of contamination of approximately 3200 ppm of TPH from weathered hydrocarbon mixture. Very sandy texture soil.

Lot 1: Control (natural attenuation)

Once the amount of soil corresponding to the slot was available, no handling was carried out during the entire process, only periodic sampling work.

Lot 2: Irrigation and turning (I&T)

Once the initial soil humidity was determined (approximately 8.5%) this was completed up to a little more than 20% by means of applying 10,000 litres of water using irrigation with 5000 L. The earth was then mixed, the remaining 5000 L applied and the earth finally mixed again.

Lot 3: Slow release fertiliser (SRF)

An approximate dose of 55 g/m2 was scattered onto the lot as follows: half a bag of Sierrablen (10 kg) initially to then irrigate with 5000 L of water and mix before adding another half a bag (10 kg more) with irrigation of 5000 L and additional turning.

Lot 4: Magnesite.

A total of approximately 3.125 tonnes of magnesite were poured onto the lot, watered with 5000 L and turned. After applying another equal dose of magnetite, it was watered with another 5000 L of water and turned.

Lot 5: Magnesite + SRF

The same as Lot 4 but subsequently adding a dose of 10 kg (half a bag) of Sierrablen after each application of magnesite.

Lot 6: Magnesite + S-200.

As for Lot 4 but with the following modification in irrigation: the 10,000 L of water incorporated 500 L of IveySol. Therefore, in each deposit of 1000 L, 50 L of IveySol had to be added whilst stirring the pure product well and then also stirring so that it was dissipated in water as much as possible.

Lot 7: Magnesite + SRF + Ivey Sol.

Like Lot 5 with the following modification in irrigation: The 10,000 L of water incorporated 500 L of IveySol. Therefore, in each deposit of 1000 L, 50 L of IveySol had to be added whilst stirring the pure product well and then also stirring so that it was dissipated in water as much as possible.

Lot 8: SRF + IveySol

Half a bag of Sierrablen (10 kg) initially to then irrigate with 5000 L of water and stir before applying another half a bag (10 kg more) with irrigation of 5000 L and additional turning. The water had IveySol surfactant diluted as for Lot 7.

Lot 9: S-200

This was first irrigated with 5000 L and then the earth was mixed. The remaining 5000 L was applied, and finally mixed again. The 10,000 L of water incorporated 250 L of S-200. Therefore, in each deposit of 1000 L, 25 litres of S-200 had to be added whilst stirring the pure product and then also stirring so that it was dissipated in water as much as possible. Apart from sampling, the following tasks were periodically carried out to maintain the lots.

Ploughing: by means of mechanical mule once a week and whenever sampling had to be carried out subsequently (except Lot 1 that was never ploughed)

Irrigation: samples were taken from various lots once a week and humidity was determined. If the mean value did not reduce from 15% to 70% it was not necessary to perform irrigation. If it fell below this level it was irrigated with the volume of water necessary to place the lots (except Lot 1) above 20% humidity.

Finally, we must add that in the lots where SRF was applied a "booster" dose of another 20 kg of fertiliser was introduced three months after work commenced.

The most important parameter when following up the variation in land farming is logically the contaminant content or TPH. Quantitative analysis of TPH is currently performed in 99% of cases by means of GC-FID (gas chromatography-flame ionisation detector). This method requires prior extraction of hydrocarbons using the matrix (oil).

Sample (mg/kg) / Depth (m)	C12/M2	C13/ M1-M2	C14/M1-M2	C27/ M1-M2	C28/M1.M2	C29/ M1.M2	C30/M1-M2	S6/M1-M2-M3	S7/M1-M2
1,5									
1,75									
2									
2,25									
2,5									
2,75									807
3							5000		
3,25					4600			1400	
3,5		1100				59			
3,75									
4			5000						
4,25		2300							6230
4,5									
4,75						1400			
5	630		5000						
5,25				2700			1900		
5,5				320		1000		2000	
5,75					83				
6									
6,25									
6,5								69	

Table II: "Results of hydrocarbons concentration regarding depth"

Gas chromatography (GC) is an ideal method for qualitative analysis of light and medium fractions of crude oil and its derivatives. The contribution of mass spectrometry (MS) enables identifying the compounds that contain samples, working with ions characteristic of each family of compounds or individual compounds. The latter entails simpler location. The method followed for extraction of hydrocarbons was the EPA Method 3540C: Soxhlet Extraction (extraction of compounds from the sample by means of Soxhlet).

In the laboratory, as these are soil samples micro-organisms were extracted using a 0.1% solution of sodium pyrophosphate and some subsequent dilutions of extracts. These dilutions were seeded in duplicate in two kinds of different plates with the following culture media: GAE that contains glucose as its main component which enables counting total heterotrophic micro-organisms and the Bushnell-Hass (BH) medium with crude oil that enables counting tolerant micro-organisms (some degrading) because this product uses carbon as the only source.

Regardless of the medium they contained, they were cultured at 30°C for three days for the GAE medium, and for at least one week for the other. After this time counts were performed and existing microbial variety in the plates with GAE was measured.

To complement this, in the same treatment plant where landfarming experiments were performed the following parameters were monitored:

Ammonium: ammonium was determined by means of colorimetry using photometers. ISO 7150/1.

pH: pH was determined in leachates. Equipment used: pH-meter

Conductivity: conductivity was determined in leachates using a conductivity meter.

Anions (fluorides, chlorides, nitrites, nitrates and sulphates) using ion chromatograph.

3. RESULTS

As a result of the previous microbiologic research, we obtain an interesting and useful soil for agriculture and golf courses in the area, as it is highly fertilized in the compounds used, phosphatants and sulphatans, as well as by the turning and aeration treatment carried out, concluding that the residual hydrocarbon contents they are not dangerous.

From the agricultural research in the affected soil we certify the existence of nutrients and the rest of the parameters which are necessary to determinate that conditions for biorremedation are adequate. We have determinated the importance of adequate climatology, such as that existing in southern Spain.

Result of the samples analysed by means of the FTIR technique. Samples C12/M2; C13/M1-M2; C14/M1-M2; C27/M1-M2; C28/M1-M2; C29/M1-M2-M3; C30/M1-M2; S6/ M1-M2-M3 present TPH concentrations much higher than the GRL (as shown in the Table II) where Spanish Royal Decree 9/2005 establishes GRL as 50 mg/kg for industrial use soils.

Samples C13/M2; C27/M1; C28/M1; C30/M2; S6/M2; C1/M2; C16/M2; C4/M2, analysed by FTRI again reveal a TPH concentration much higher than the established GRL.

The water samples analysed return to a value lower than 200 µg/L for the TPH concentration.

During the preliminary study, various information was obtained and the most notable conclusion was that bioremediation treatment by means of landfarming, biopiles or similar technique was possible, although contaminant conditions did not appear to be the most suitable. Indeed, the virtual entire absence of linear hydrocarbons and in general the major weathering of the product that affected soil, hindered expecting significant results on TPH reduction in a short time-period however suitable the treatment may have been. Nonetheless, from the microbiological point of view, the situation was more optimistic because of the number of micro-organisms detected and their specialisation. It was also added that the sandy texture of the land unquestionably favoured the treatment and that although nutritional levels were low, appropriate biostimulation would resolve this problem. As another positive point, it may be highlighted that the absence of BTEX or naphthalene, together with, in general low total concentrations, meant that the chosen treatment did not in principle mean steam or similar uptake systems.

All these determinations were performed on the leachate from Landfarming samples. This process consists of leaching a 10% sample in Mili-Q water for 24 hours.

With these values, it is now possible to also state that any of the treatments used significantly improves (at least by 5.5%) not only monitoring but also simple ploughing and irrigation of soils (P2), see Figure 2 and 3.

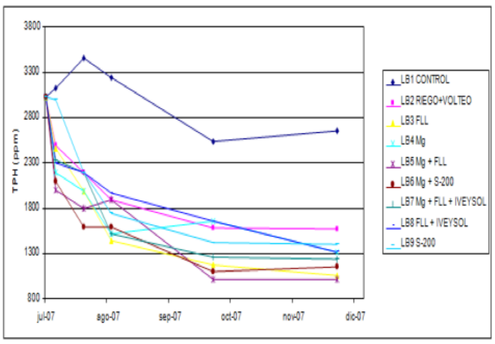

Fig. 2: "Variation in total TPH in all lots over the 5 months' duration of treatment"

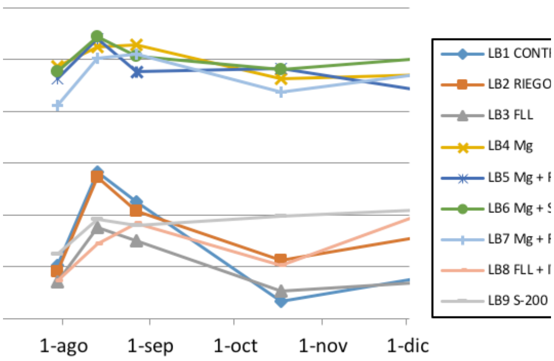

Fig. 3: "Variation in total pH for all lots over the 5 months that treatment lasted"

The IVEYSOL surfactant does not improve the yield of SRF combinations and especially Mg + SRF, whereby it is a product that has not provided correct behaviour.

Something similar occurs with the S-200 fertiliser whose yield alone is less than that of SRF although it appears to have a better combination with the Mg(OH)2.

As for the operation of Mg(OH)2 its yield is less than SRF, but despite this appears to be a good option.

4. DISCUSION

We have contrasted our successful results with the latest publications and research related to the subject, concluding that our proposal is competitive and useful to solve the proposed problem, since the compounds and the method used and the reduced amounts are similar to those that are being obtained with the current methods.

On the one hand, positive aspects of our research carry us to conclude that choosing biorremediation in front of other techniques, as thermal desorption and custody of dangerous wastes, is highly beneficial for the environment and more economic.

Readers can also observe that the actions of adding economic products with irrigation and turning produce in just six months the desired results.

It has been proved that the used of this technique is also useful in highly pollutant concentrations and also in old hydrocarbons.

SRF or slow-acting fertilizer produce optimal results being the cheapest one.

On the other hand, we can conclude that some negative aspects of using magnesium hydroxide are that it affects to the pH and for that reason it can not be used in basic soils or in mixtures with other components that correct this action such as phospho-plasters that present a serious environmental problem in Huelva.

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