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Bioremediation and Phytoremediation of Soils Polluted With Hydrocarbons: Assumptions and Comments

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Abstract

The studies reported in the literature dealing with remediation of soils polluted with hydrocarbons (HCs) very often conclude that the soil was remediated by following some specific actions, microorganisms, plants or both. However, when affirming this, attention should be taken, since environmental regulations related to HCs as pollutants commonly differ from one country to another. In addition, some other research reports on remediation lack of a local environmental regulation, which could indicate the concentration of HCs, permitted in soils. The present short review highlights the importance of these concepts.

Keywords: hydrocarbon, environmental regulation, bioremediation, phytoremediation

1. Introduction

According to national or international environmental regulations, a soil is contaminated with hydrocarbons (HCs) if the concentration is above a specific value (Kumar et al., 2011; Sharma, 2012). The level of HCs in impacted soil is due to anthropogenic reasons and the pollutants are commonly present as solids or liquids (Thapa et al., 2012; Nwoko, 2010; Haritash & Kaushik, 2009; Johnsen et al., 2005). Depending upon the nature and concentration of HCs spilled on soil or in water, physical separation is sometimes possible, which include washing, encapsulating and vitrification, followed by chemical processes, such as immobilization, precipitation and oxidation. The remaining HCs are finally bioremediated or phytoremediated, or both (Juhasz & Naidu, 2000; Gerhardt et al., 2009). The latter stage could be left to nature, or intentionally promoted by applying some specific microorganisms or plants, or both, able to eliminate the pollutants. Research reports in the literature apply bioremediation (BIO) or/and phytoremediation (PHYTO) to soils impacted with relative high concentrations of HCs; however, the maximum concentration of HCs, where bio or phytoremediation should be applied, is undefined. Furthermore, the lack of an environmental reference to indicate that the soil was remediated generates doubts about the results. And to add complexity, many countries have different environmental regulations related to specific HCs. This contribution selectively analyzes some papers to demonstrate the problem and highlights the urgency to have common environmental regulations when dealing with pollution of the environment.

2. Assumptions and Comments

Some research studies related to pollution of soils with HCs treated with BIO or PHYTO and use a vegetal and plant growth promoting microorganisms (PGPM) to solve the problem. However, this strategy could be unsuitable when the vegetal is not well selected and/or when the level of contamination is still far above the maximum permitted by the local environmental regulation. The Mexican environmental regulation (NOM-138-SEMARNAT/SS, 2012) allows the presence of 4400 ppm of HCs in soils. But specifically, only 200 ppm of light, 1200 ppm of medium and 3000 ppm of heavy fraction are permitted. Above 4400 ppm of HCs the soil is considered as polluted and remediation is required. Table 1 presents some assumptions commonly found in research papers related to soils contaminated with HCs.

Table 1. Common assumptions reported in studies related to bioremediation or/and phytoremediation of soils polluted with hydrocarbons

Assumptions	Comments
Contamination was remediated by a biological action.	It might not be the case, since biological remediation is a function of the nature and concentration of pollutant.
The environmental problem was remediated by physical or mechanical actions.	It is usually untrue, since the concentration of contaminant could still be severe.
The application of qualitative and quantitative methods could indicate that the soil was remediated.	To assure that the problem was solved, The use of bio-indicators is highly recommended.
The soil was remediated since the analysis fulfills the requirements of a local environmental regulation.	All countries should be subjected to general international environmental regulations.

Table 2 shows some selected studies where remediation of soil was assumed but the final HCs concentration in the soil was above 4400 ppm, the level permitted by the Mexican regulation (NOM-138-SEMARNAT/SS, 2012). In addition, even if the contamination level was below 4400 ppm, it could be treated as contaminated soil by other more severe international regulations. Table 2 also shows the lack of common criteria to consider that the soil was remediated. It is worth mentioning that the US Environmental Protection Agency for contamination of soil with HCs (Ohio EPA, 2010) indicates a maximum allowable concentration for each compound separately, instead of grouping the HCs as the NOM-138-SEMARNAT/SSA1-2012. It is worth commenting that the spills of HCs to the environment commonly occur as mixtures of HCs instead of a single compound. In addition, since fossil fuels strongly support the development of all societies in the world, proper remediation of the environment contaminated with HCs constitute a great challenge.

Table 2. Some research studies related to soils contaminated with hydrocarbons which concluded that the soil was remediated. The final concentration reported was above 4400 ppm*, and a bio-indicator test was not performed

Pollutant	Initial concentration (ppm)	Final concentration (ppm)	Treatment	Duration (days)	Reference
Petroleum	30,000	17,700	Biostimulation (BIS)-mineral fertilization (MIFE)	28	(Vallejo at al., 2005)
Used motor oil	40,000	12,320	BIS-MIFE	42	(Abdulsalam and Omale 2009)
Petroleum	30,000	15,300	BIS- fertilization (FE)	195	(Asquith et al., 2012)
Petroleum	50,000	31,000	Phytoremediaton (PHYTO) *Brachiaria brizantha*	120	(Merkl et al., 2005)
Petroleum	40,000	9,500	PHYTO-*Sorghum vulgare*	90	(Shirdam et al., 2008)
Petroleum	23,000	16,100	PHYTO-*Vicia faba*	90	(Diab, 2008)
		19,130	PHYTO-*Zea mays*	90	
		19,850	PHYTO-*Triticum aestivum*		
Petroleum	75,000	44,000	PHTYO-*Glycine max*	105	(Njoku & Akinola, 2009)
Petroleum	50,000	6,000	PHYTO-*Vigna unguiculata*	60	(Tanee and Akonye, 2009)
Residual motor oil	25,000	8,175	PHYTO-*Jatropha curcas*	180	(Agamuth et al., 2010)
Petroleum	40,000	17,920	PHYTO-*Zea mays*	120	(Zand el al., 2010)
Petroleum	45,000	31,000	PHYTO-*Zea mays*	30	(Merkl et al., 2005)
		32,000	PHYTO-*Avena sativa*	30	
Light oil	81,500	49,878	PHYTO-*Cyperus rotundus*	180	(Basumatary et al., 2012)

Petroleum	75,000	27,000	PHYTO-*Sorghum bicolor*	90	(Asiabadi et al., 2014)
Diesel	50,000	25,000	PHYTO-*Lolium perenne*	90	(Chuluun et al., 2014)
		21,300	PHYTO-*Lolium perenne*+BA	90	
Petroleum	50,000	25,700	PHYTO- *Festuca arundinacea*	150	(Tang et al., 2010)
Diesel	8,786	4,501	PHYTO- *Zinnia elegans*	180	(Ozawa et al., 2015)
Light crude oil	100,000	90,000	PHYTO- *Sorghum bicolor*	45	(Minai-Tehrani et al., 2012)
Gasoline	30,000	5,010	PHYTO- *Scirpus mucronatus* inoculated with *Serratia marcescens*	72	(Almansoory et al., 2014)
Residual lubricating oil	25,000	8,475	BIS-organic wate-mushroom compost-*Hibiscus cannbinus)*	90	(Abioye et al., 2012)
	10,000	8,225			
Petroleum	60,600	32,118	Bioaugmetation (BA)- *Rhizopus* sp	35	(Mancera-López et al., 2008)
		36,360	BA- *Penicillium funiculosum*		
		33,330	BA-*Aspergillus sydowii*		
Oily-Sludge	69,700	5,530	BA-BIS-*Acinetobacter baumannii* y *Burkholderia cepacia*, and nutrients	360	(Mishra et al., 2001)
Petroleum	20,000	10,076	PHYTO *Mirabilis jalapa*	127	(Peng et al., 2009)
Petroleum	75,000	4,500	PHYTO *Sebastiania*	424	(Toledo Ramos et al., 2009)
Petroleum	40,000	32,748	PHTYO *Impatiens balsamina*	120	(Cai et al., 2010)
Petroleum	40,000	28,948	PHTYO *Pharbitis*	127	(Zhang et al.,

			nil		2010)
Petroleum	100,000	80,000	PHTYO *Medicago sativa*	120	(Minoui et al., 2015)
Weathered petroleum	60,700	6,070	PHTYO *Cyperus laxus* inoculated HCs-degrading microorganisms	180	(Escalante-Espinosa et al., 2005)
Petroleum	61,900	25,998	BA-PHYTO microbial agents and *Lolium perenne*	162	(Tang et al., 2010)
Petroleum	50,000	20,000	BIS (MIFE and rhamnolipid (biosurfactant)	45	(Millioli et al., 2009)
heavy mineral oil	7,490	6,130	BIS (MIFE, pine sawdust, rice hay, and pig manure compost)	105	(Lee et al., 2008)
used lubricating oil	150,000	67,500	BIS (brewery spent grain)	84	(Abioye et al., 2012)
		76,500	BIS (banana skin)		
		96,000	BIS (brewery spent grain)		
unused motor oil	100,000	26,530	BIS (cow dung)	49	(Bahadure, et al., 2013)
spent motor oil		25,090	BIS (spent fruit residue)		
Diesel	32,100	BIS (natural gum and surfactants)		66	(Hernández-Espriú et al., 2013)
		6,898	Maranil LAB		
		9,222	Texapon 40		
		12,798	Surfactant-SDS		
		16,631	Surfacpol G		
		5,778	Guar gum		
Spent Motor oil	25,000	14,345	BIS (cow droppings,	60	(Onuoha, 2013)
		8,750	poultry manure,		
		15,345	goat droppings)		
Diésel		8,500	BIS (brewery waste	28	(Agarry and

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			effluents and bioventing)		Latinwo 2015)
Crude oil	100,000 150,000	5750 4795 7260 7350	BIS (plantain peels guinea corn shaf)	56	(Romanus et al., 2015)
Gasoil	40,000	8,800	BIS (MIFE and BA by two indigenous bacteria)	45	(Najirad et al., 2012)
Crude oil	52,000	10,600	BIS (MIFE, saw dust, cow and sheep dung and BA (by specialized microbial consortium)	90	(Burghal et al., 2015)
Crude oil	170,000	65,000	BA (by biological product: Amnite P300 (*Pseudomonas Putida* and *Bacilli Subtilis*)	118	(Benyahia et al., 2005)
Mineral oil	35,026	5,186 6,966	*Acinetobacter calcoaceticus* *Microbacterium lacticum)*	120	(Aytkeldiyeva et al., 2008)
Spent diesel oil	50,000 10,000 150,00	7,795 34,130 83,595	BA (by *Pleurotus pulmonarius)*	60	(Adenipeku, 2008)
Crude oil	50,000	12,900	BA (by *Bacillus subtilis* and *Acremonium* sp)	180	(Ma et al., 2015)

Biostimulation and mineral fertilization=BIS-MIFE; Fertilization =FE; Bioaugmentation= BA; Phytoremedatio=^PHYTO, *Concentration of HCs permitted by the Mexican regulation number NOM-138-SEMARNAT/SSA1-2012.

3. Conclusion

The strategy to follow for the remediation of a soil polluted with HCs depends upon the concentration and chemical nature of the pollutants. If the concentration of HCs is very high, physical removal, followed by chemical and biological treatments are strongly recommended. Furthermore, during the biological treatment, phytoremediation, or simultaneous bioremediation-phytoremediation and the use of PGPM are also highly advisable. The quantitative and qualitative analysis of soil to measure the HCs levels and remediation should always be complemented with bio- indicator tests. To unify criteria related to pollution of the environment, it is urgent to define international environmental regulations to be followed by all countries.

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