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Choice of Remediation Technology for a Contaminated Soil by 1,2-Dichloroethane (DCA)

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Abstract:

In Mexico, there are 635 sites contaminated by hazardous waste, due to the fact that a few years ago there was no legislation to support and guarantee environmental protection. This led to decades of contamination of soils and bodies of water. In the following case study, landfills were identified where 1,2-dichloroethane was stored, generating contaminated soil in this location, even affecting subway water bodies. The aim of this work is to identify the technologies for the remediation of contaminated soils, taking into account the affected site, the characteristics of the residue, costs and time, in order to determine the most effective and ideal technology. The Federal Remediation Technologies Roundtable (FRTR) will be considered as the counterpart for the selection of treatment technologies, published by the Remediation Bureau. The best technology for site remediation is "Soil Vapor Extraction", being the most ideal and efficient in terms of time and cost, and generating a high impact remediation outcome. The counterpart (FRTR) is considered to be a support tool that provides the most appropriate technologies for the remediation of a contaminated site.

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INTRODUCTION

Soil pollution is a constant chemical degradation that is reflected in a partial or complete loss of productivity of goods, mainly consumer goods, as a result of the accumulation of toxic substances that exceed their background contractions, which result in negative modifications to their physicochemical properties [1].

Within human activities, the point sources of origin of hydrocarbons are those that have caused the so-called environmental liabilities due to their various activities in their exploitation, production, storage and transportation. All of these have caused direct damage to the environment, air, surface water, groundwater or soil. In addition to the above, organic pollutant sources derived from anthropogenic practices such as agriculture, pest control, commercial industry and fishing have been identified [1-4].

Among the organic compounds are the so-called Volatile Organic Compounds (VOC), such as benzene, toluene, xylene, dichloromethane, trichloroethane and, as presented in the case study, the site contaminated by the waste 1,2-dichloroethane (1,2-DCA), belonging to this group of (VOC), where during the construction of an industrial plant, totes with this waste were found stored.

The industrial production of these compounds has been very extensive over the years due to the diverse applications they have. A clear example of this is benzene, which is cataloged as carcinogenic, as well as a cause of anemia and leukemia; in 2020 alone, the market size volume was about 52.9 million tons [5].

A production of 14 million tons was generated [2].

The main route of 1,2-DCA involvement is by inhalation, since it volatilizes at room temperature [2, 6]. Therefore, the Department of Health and Human Services (DHHS) has determined that it is reasonable to predict that 1,2-dichloroethane causes cancer [7].

In Mexico, the Secretariat of Environment and Natural Resources (SEMARNAT) reported through the Contaminated Sites Information System (SISCO) that 635 contaminated sites have been registered in the country. Contaminants coming from the soil, mostly of anthropogenic origin and the other part in natural phenomena [8].

Therefore, the objective of the present work is to propose the best remediation technology for a soil contaminated by 1,2-dichloroethane considering the properties of the soil and the contaminant.

METHODOLOGY

The study site is located in the state of Colima, Mexico (Figure **1**), where years ago there was a plant that handled 1,2-dichloroethane in its process, and it was found that the disposal of hazardous waste was stored in pits with totes.

Figure 1: Location of the state of Colima within Mexico. Source: Own Elaboration.

During the first phase, the soil was sampled and more than 100 containers were found at a depth of four meters, all of which showed cracks.

In a second phase, soil sampling was carried out to determine the stratigraphy up to 17 m depth and 1,2-DCA concentrations were found in the first 12 m of the soil.

The physical and chemical properties of 1,2-DCA are shown in Table **1**, in which this type of substance is characterized by its high volatility at room temperature and pressure.

Table 1: Physical and Chemical Properties of 1,2-DCA

PROPERTY	DESCRIPTION
Molecular weight	98.96 g/mol
Melting point	-35 °C
Boiling point	84°C at 1.013 hPa
Flash point	13.0 °C –closed cup
Vapor pressure	33.3 hPa (25.0 mmHg) at 0 °C 86.0 hPa (65.0 mmHg) at 20 °C 312 hPa (234 mmHg) at 50 °C
Relative density	1.23 g/ ml
Density at 20ºC	1.25 g/ml
Solubility in water	8.69 g/L at 20°C –slightly soluble
$Log(K_{ow})$	1.5
$K_H(atm\text{-}m^3/mol)$	0.00091

Source: (SIGMA-ALDRICH, 2023) [9].

For the study case, the following will be considered: 1) The matrix for the selection of treatment technologies published by the Federal Remediation Technologies Roundtable (FRTR), available on the website of the United States Environmental Protection Agency (USEPA) and 2) The stratigraphic characteristics of the affected site and the physicochemical properties of the contaminant.

RESULTS AND DISCUSSION

As results, the soil stratigraphy is presented (Figure **2**), showing that sandy clays predominate in the first 8 meters of depth.

Likewise, Table **2** shows the concentrations of 1,2-DCA found at different depths. These show the environmental impact of the site under study.

Table 2: Concentrations at Different Depths

DEPTH (m)	1,2-DCA CONCENTRATION (mg/L)
2.0	8.9
4 .0	9.0
6 .0	9.1
8 .0	9.2
10 .0	9.3
12 .0	9.3

Source: (Own elaboration, 2018).

According to the FRTR matrix (2021) [10], the technologies with the highest effectiveness in the removal of 1,2-DCA in soil are presented in Table **3**; the score obtained is also shown. The factors considered in the evaluation of the technologies were

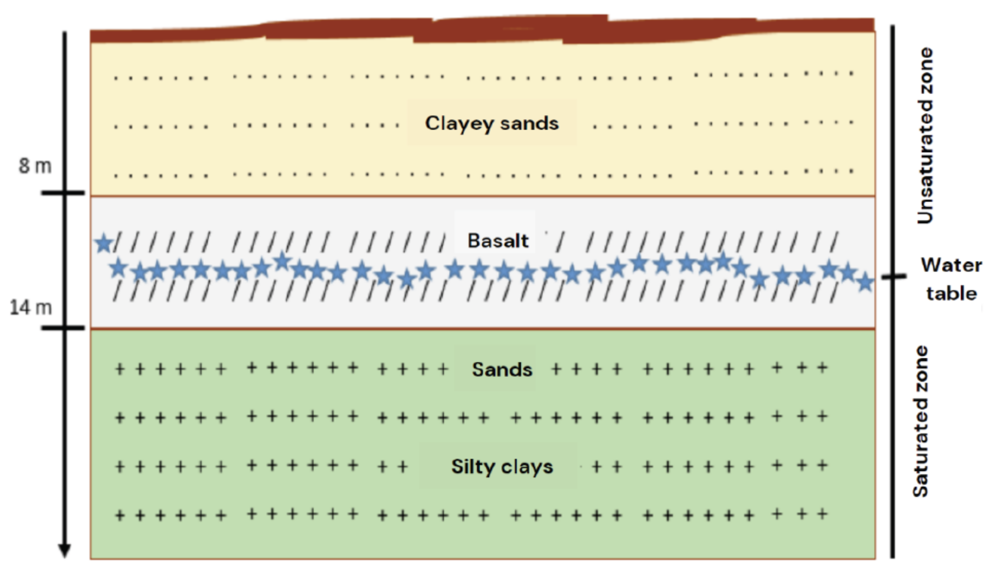

Figure 2: Stratigraphy of the contaminated site. Source: Own elaboration.

the following: development status, treatment train, operation and maintenance, costs, time, availability and halogenated VOCs.

Table 3: Effective Technologies for the Treatment of Volatile Organic Compounds

SOIL, SEDIMENT, BEDROCK, AND SLUDGE	SCORE
3.1. *In-situ* Biological Treatment	
Bioventing	7.5
Enhanced bioremediation	5.5
3.2. On-site Physical/Chemical Treatment	
Soil rinsing	5
Soil vapor extraction	5
3.3. *In-situ* Heat Treatment	
Heat treatment	4.5
3.4. *Ex-situ* Biological Treatment (assuming excavation)	
Biopilas	7.5
Tratamiento biológico con lodos	3.5
3.5. Tratamiento Físico/Químico Ex-situ (asumiendo excavación)	
Deshalogenación	2.5
3.6. Tratamiento térmico Ex-situ (asumiendo excavación)	
Incineración	4.5
Desorción térmica	5

Source: (FRTR, 2021) [10].

The technologies most recommended by the FRTR for the treatment of contaminated soil in the case study are: bioventing, biopiles and enhanced bioremediation. However, they are discarded, although they offer the best advantages according to Solanas (2009) [11], since they eliminate the contaminant and do not transfer it to another medium, without leaving aside the low cost. However, they have not been applied in cases of soils contaminated by 1,2-DCA.

Regarding soil rinsing, the EPA (1996) [12] considers it an aggressive technology as it removes the contaminant with chemical products that modify the physicochemical properties of the soil, deteriorating it and modifying its future use, the EPA has reduced the implementation of this technology due to the difficult scaling from laboratory to field.

Regarding thermal desorption as possible to execute, Shanghai Yu Kai Energy Technology Co., Ltd., (2010) [13] and the Occupational Safety and Health Administration (2003) [14] mention the need for excavation of the site and considering the high volatility of 1,2-DCA it is not feasible due to the risk and high probability of uncontrolled emissions.

In the case of soil vapor extraction, which is feasible considering that FRTR (2021) and Hillel (2005) [10, 15] mention that it is suitable for volatile compounds with vapor pressure greater than 0.5 Millimeters of Mercury, and in the case of 1,2-DCA it meets the requirement, since its vapor pressure is 65 Millimeters of Mercury (at 20°C). In addition, according to the Superfund Site Remediation Report (2012), issued by the EPA, this technology is the most widely implemented for volatile organic compounds due to its performance and costs, and there is a history of its use in sites with chlorinated VOCs, achieving successful results.

Finally, vapor extraction was selected for soil remediation in this study case, as it represents the best option with respect to the others, in terms of cost and contaminant removal efficiency.

CONCLUSIONS

According to the study carried out, the technologies with the highest probability of success in remediating soils contaminated with 1,2-DCA were identified, considering the properties of the affected soil and the characteristics of the contaminant, proposing vapor extraction as the best treatment technology.

Regarding the pollutant 1,2-DCA, its properties, uses, applications and toxicology were studied, which allowed us to know the interaction of the pollutant with the lithological environment.

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