Modelling hydrocarbons transport in the ground: a case history

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Abstract

Computer programs (SEEP/W and CTRAN/W) have been applied to estimate the volume of contaminated soil by hydrocarbons in a petroleum field. The model implies the difference between saturated and non-saturated conditions. In addition the site characterization has been carried out using different geotechnical techniques.

Introduction

The continuous emission of contaminants in the petroleum field Carrasco (Bolivia), affected an approximate area of 2500 m^2, which can be estimated from the observed superficial pollutants storage identified as Total Petroleum Hydrocarbons (TPH).

A waste pipe pours the residues originated at the refinery and deposits them in a natural channel that transports and assimilates the toxic compounds which are finally deposited in Izozog River. The channel has a length of 1100 m between the source of emission and the river. Throughout the entire channel, a moderate environmental deterioration can be observed; however, in two specific regions exhibit greater environmental degradation.

Geotechnical characterization

The geotechnical characterization was carried out in order to establish the general profile of the region, detecting also the groundwater level and the depth that encompasses the contamination in the subsoil. This work was accomplished through sampling and perforations with an average depth of three meters below the surface. With a geophysical techniques (Sharma, 1997) made possible the attainment of the soil profile up to 32 meters. Finally, the coefficient of hydraulic conductivity was determined using 6 tests in the field (Clayton, et al., 1995), giving a real approximation of the infiltration conditions in the soil of the area, sand and clay.

Geotechnical Modelation

For the geotechnical modelation, specialized computer programs have been used (SEEP/W and CTRAN/W of Geoslope International), using a total of 764 nodal points that contain 563 differential elements to define the channel, with the parameter obtained in the geotechnical characterization. Additionally, the geometry has been established from a topographical survey. The initial concentration of the contaminant was defined by chemical tests.

Considering that the emission of the waste is continuous during all year around and, it generates a superficial flow on the channel, the analysis of Advection-Dispersion has been adopted as the prevailing condition of the superficial and underground flow (Rowe, 1987)

The mathematical evaluation of the problem has been split into 2 parts. In the first stage the movement of the pollutant is analyzed in saturated conditions. Then, the same analysis is carried out supposing unsaturated conditions (50% degree of saturation), adopting the functions of water content and hydraulic conductivity in agreement with the coefficient of permeability found in the field and specialized bibliography (Ho, 1979).

The results obtained in the advection-dispersion analysis were developed from concentration equipotential lines whose minimal value was governed by the maximum quantity of pollutant present in the soil (20 mg/l), according to Bolivian laws.

Figures 1 and 2 present the pollutant processes in the subsoil for the saturated and unsaturated conditions respectively. In either case, a contamination time of 6 months is considered. The movement of the pollutant in saturated conditions progresses approximately 8 times more rapidly than its movement in unsaturated conditions.

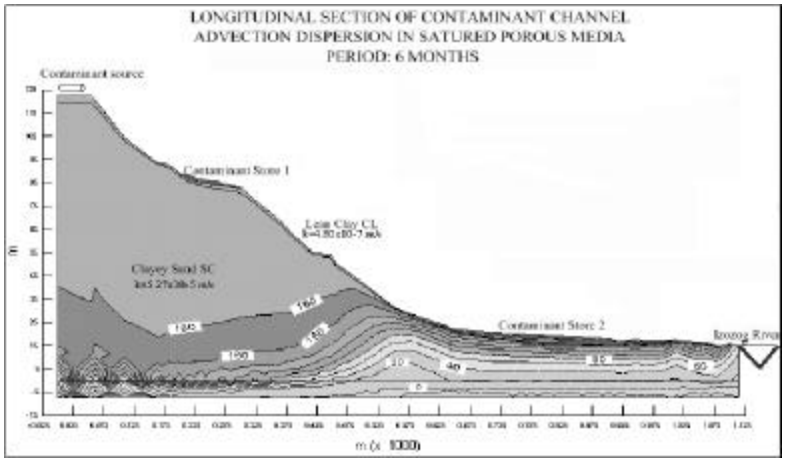

Figure 1. Advection-Dispersion analysis in satured porous media. Period of evaluation: 6 months.

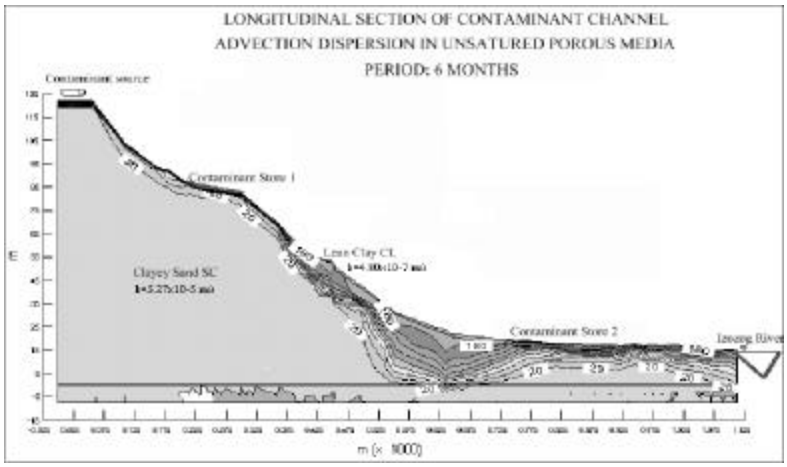

Figure 2. Advection-Dispersion analysis in unsatured porous media. Period of evaluation: 6 months.

The contamination analysis in unsaturated conditions was found to be similar to the conditions in the field. An evaluation of the possible movement of the compounds for different time intervals was carried out. Possible affected-soil volumes for periods of 1, 5 and 10 years are presented in Table 1.

Period of contamination (year)	Length of the contaminated zone (m)	Depth of contamination (m)	Width defined by the cross-channel section (m)	Volume of contaminated soil (m^3)
1	350	15	7	36750
5	350	30	8	84000
10	450	40	9	162000

Table 1 Quantities of Soil Affected by TPH (Until 20 mg/l)

Summary

The geotechnical profile of the area of study has been determined using physical and geophysical procedures in field. According to chemical tests, the contaminant present in the area is the total petroleum hydrocarbons. The contaminant concentration is higher than the allowed by the Bolivian laws.

The analysis consider the unsaturated flow movement as representative of the conditions in the field and the prediction of movement of contaminant. The estimation of some unsaturated conditions in the modelling process can reduce the reliability of the results. However, this consideration, made it possible to simulate the flow according to field observations. At this time, the verification of the results of this modeling is in progress.

References

Mariscal, V. R., Salinas P. M. (1999) Migration of contaminants into the soil. Civil engineering thesis, Facultad de ciencias y tecnología, Universidad Mayor de San Simón, Cochabamba-Bolivia.