REMEDIAL ACTION FOR A INDUSTRIAL OPEN DUMP-PROPOSED ACTIVITIES AND PROSPECTIVES

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ABSTRACT

This paper describes a methodology used to investigate an industrial open dump in its contamination aspects and the possible time of groundwater quality recovery, after the implementation of several remedial actions. After 11 years of use of the site for dump residues, by the combined use of modelling and geophysis, it was determined that the contamination plume was 65m wide and more than 300m long. The main pollutants are fluorides and salts. The remedial scheme proposed is basically regrading, impermeabilizing the top. As the industry needs a place to dispose off its residue, it was determined that the best option for the new landfill site is to continue using the area. The residue must be pre treated to imobilize the fluorides, and the landfill will be impermeabilized at the bottom and at the top. The modelling showed that, in monitoring well 120m bellow the site, in 3.5 years after the implementation of the measures the contamination will be only 20% of the initial and after 6.5 years, the quality of the water, at that point, will be equal to that of the background.

KEYWORDS

Groundwater, modelling, industrial waste, geophysics, fluoride, salts, site evaluation, remedial action, landfill, open-dump.

INTRODUCTION

The work has started basically because the industry was asked by the State Environmental Control Agency to improve their dump site, which has been used since 1979. As one of the possibilities was to continue the disposal in the old site and the time available was short, a quickly environmental evaluation was made. For this, the use of geophysical tecniques was very important, but for better evaluation of the hydrogeology, the geophysic was complemented with conventional sounding. After the remedial scheme be defined, a model was applied to have an first ideia of the effectiveness of the proposed measures. Although 4 monitorings wells had been built,only one simplified sampling was done, and, certainly more data of the local groundwater hydraulics and quality should be got. The proposed action including the new sanitary landfill design, is now being analyzed by the local authorities.

METHODOLOGY

The methodology used to study the problems caused by the site, as well as the suitable remedial action, was partly based on that sugested by USEPA (1987) for evaluation of soil and groundwater releases from solid waste disposal facilities. As the initial objective was not to study the contamination caused by the facility, but get data to develope a design for a new landfill for the wastes generated by the industry, only part of the data were collected. Bellow the methodology followed is shown in more detail.

Problem evaluation

Source characterization-the industrial process was studied so that, it's been possible to define the main pollutants, its rate of generation the main sources, existence of tracers associated, like chlorides and the physical form of the wastes.

Site situation-based on industry personnel information, the history of the waste deposition (date of starting and amount deposited) was got. To evaluate the present extent of the site, a new topographic survey were done. By comparison with an old one, it were possible to find the volume deposited and the original soil surface.

Pollutant characteristics-with the type of pollutants that could be found in the wastes streams defined, their soil and water legal limits were collected from the legislation, as well as the main chemical and toxicological properties. Properties like solubility, reactions in water, effects on humans, plants and animals, etc. The main objective of this step is to determine the mobility of the components and its possible effects on the biota, so that it is been possible design a good monitoring program.

Environmental setting

Subsurface geology-to define the local geology it were used the following methods: site inspection,previous studies of the area, 5 resistivity vertical soundings were done to get a insight about the stratigraphy, water level and bedrock depth and 5 soil borings to get more precise information about the stratigraphy and water level, than those got by geophysics.

Climate-the data were gathered from the nearest metereological station. The problem is that not all stations have the same data, so in this case, the precipitation figures from 1975 to 1989, were collected from the E4-129, situated in the same city of the site, but the evaporation was from the E3-251HM, situated in the city of São Paulo, 40 km south, and from 1975 to 1985.

Water flow-the direction and gradient of the groudwater was determined by the levels found in the soil borings coupled with the topographyc map of the area. The transmissivity was adopted from pumping tests in wells located in the same aquifer. The surface drainage pattern was defined by the use of a IBGE 1:10000 map that includes the site, rivers and creeks nearby.

Vegetation-As part of the new topographic evaluation of the site the total natural vegetation area was evaluated. For the situation in the neighborhood were used the IBGE map cited above. The extension of damaged plants were determined by visual inspection.

Contaminant receptors- to find the soil use of the neighborhood and water abstraction points were used the visual inspection of the area and the data present in the IBGE 1:10000 map .

Contamination extension-to optimize the number and location of the monitoring wells network ,and based on the fact that the residue deposited had a high salt content, the groundwater pollution plume extension was determined, in a first approximation, by the use of electromagnetic sounding.Based on the results of this work, 5 monitoring wells were located. At this time, the wells were already built, but only one partial sampling and analysis were done.

Besides, the contamination of the soil is due to the physical tranportation of the residue particles, so contamination extent was easily determined by visual inspection, as the residue has a caractheristic gray color, making a clear contrast with the natural soil. The extent of the problem is associated to the drainage of the area and vegetation damage.

Remedial action proposal

Taking in account all the situation presented in the problem evaluation, by putting together the environmental settings, the residue and site characteristics, the contamination extent and the kind and amount of the pollutant receptors, and considering the necessity of the industry to have a place to dispose its residue with less environmental impact, it was chosen a remedial action scheme.

Prognosis of the proposed action

To have an approximate quantitative evaluation of the effectiveness of the remedial action proposed, and taking in account that there are a relatively low amount of data, it was applied a simple mathemathical model .

SOURCE CHARACTERIZATION

Residue Characteristics

The residue comes from a secondary aluminum smelter, which also produces fluorides salts. The monthly ingot production was around 900 t, and the salt production was 60 t.
The main residue from the smelting is slag, and from the salt production is a residue named silica sludge. The slag is basically composed by Al2O3 and salts (NaCl and KCl). The silica sludge is originated from the reaction between titanium oxide or boric oxide and fluorsilissic acid. The table bellow show the main characteristics of these residues.

TABLE 1 Residue Characteristics

Residue	Production	Composition (%)	LEACHATE QUALITY(mg/l)*
slag	96.9 t/mo	Al2O3 - 60-70 SALTS - 10-20 Al - 0-02 OTHERS - 2-05 MOISTURE - 3-28 SP.GRAV. - 0.9t/m3	Cl-232-11700 F-19-39 K-9.65-4860 Na-11.34-8650 pH-9.1-9.25
silica sludge	13.8 t/mo	SiO2 - 21-23 B - 0.06-0.12 Al2O3 - 0.21-0.24 Fe2O3 - 0.09-0.12 F - 0.30-0.60 MOISTURE - 75.9-78.3	F -2400 pH -1.5

* - Leaching test executed under NBR-10005.

From the table the components of interest under the point of view of water pollution, that appeared in the leachate of the residue in significative levels were fluorides, chlorides and sodium. The water quality standard for fluorides stablished by CONAMA, 86 for waters to be use for drinking whithout treatment, is 1.4mg/l and for chlorides is 250mg/l, so the fluoride in leachate from silica sludge is 1700 times the standard and 28 times greater for that from slag. These ratios make the groudwater pollution potential of these residues high. Finally, by ABNT,87a, the silica sludge is considered hazardous waste, cause its leachate fluoride content( ) 150mg/l).

Disposal site

The area has been utilized for waste disposal since 1979. It is estimated that the total amount deposited since then was 2200t. Figure 1 bellow show the site.

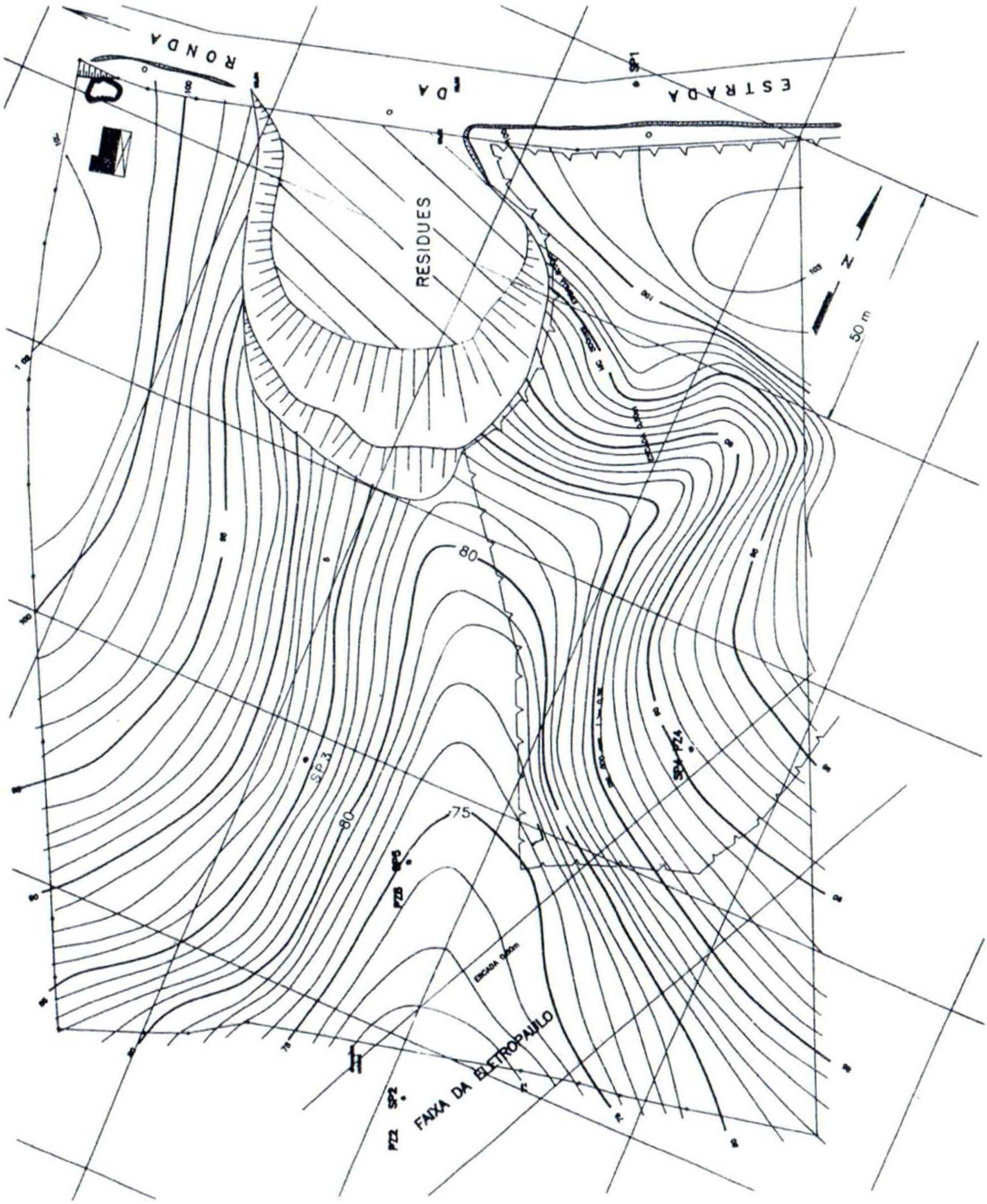

Fig.1. Disposal site with soil borings localization.

From the figure become clear that the deposit was made in a valley, with the residue occupying aproximately an area 65m wide, 60m long, and with 20 m high in its deep part. The residue is simply dumped from the top by trucks. Sometimes a tractor is used to uniformize the topography. No cover material is used. Borings done at the site showed that the in-situ density was 1.36 t/m3, the hydraulic conductivity was 8.8*10-5 cm/s and the natural moisture was 27%.

PHYSICAL MEDIA CHARACTERIZATION.

Local Geology

Lithological Aspects

In the study area, outcrop rocks belongs to the Cantareira Facies (Hasui *et al*.,1978; IPT, 1981; DAEE, 1982) of the SIN-TECTONIC GRANITE SUITE. This rocks compose a occurrence of great magmatic event of Late Proterozoic, and are characterized by large distribution in area of batholits and stocks. The rocks, of catazonal and mesozonal origin, present allochthonous and para-authochthonous characters and have diversified textural and compositional features. The granitic-gneissic type is more commom.

In the outcrops and boulders, next of the waste deposition site, the same rock class was observed. The presence of megacristals of K-feldspars gives a porphyritic texture. Hasui *et al* (1978) describe that the foliation of this granitic-gneissic rock follows the same regional trend observed.

The geophysical vertical electrical sounding distinguished 3, 4, and 5 eletric layers. The interpretation of this feature is, from down to up, inalterated granite, saturated zone of alterated soil, and unsaturated zone of alterated soil. Eventually, each geological layer can generate 1, 2 or 3 different eletric horizons.

The 5 geophysical eletrical sounding permitted to draw a scenario where the top of the inalterated rock is at average depth of 20 m (11.8 to 24 m) at central part of the depression.

This feature is similar to the results obtained by the percussion borings (SPT). The overburden material of the granite is than alterated θєá≤θ⌠⌡ soil.

In the South of the study area occurs quaternary sediments, out of limit of industrial plant, associated with flood plains. This sediments overlaps the granite and its alteration.

Structure Features

The most important tectonic feature of the study area is the EW Taxaquara strike-slip fault. Along this fault, an intensive cataclastic dynamic metamorfims generated mylonites and ultra-mylonites rocks as well as various subvertical planes of blocks movimentation. The same stren related to this fault products, either, a large zone of mylonite granite-gneisses (Hasui *et al*., 1978).

Locally, the analysis of the aerial photography lineaments made it possible to distinguish a preferential orientation NW-SE and N-S of the minor structures.

Groundwater hidrology

The granitic rocks, as well as other pre-cambrian lithologies of the State of São Paulo, form the hydrogeological unit called Cristaline Aquifer (DAEE, 1975), in which the groundwater occurence is retricted to the discontinuities provoked by tectonic strenghs, like faults and fractures (secundary porosity), and to the saturated altered soil.

According to DAEE (1975), the Cristaline Aquifer presents a very heterogeneous behaviour because of its complicated geology. The mean transmissivity is 3,5 m2/day and the most important production rates are associated to faults and fractures. Wells located at drainage lineaments boundaries showed specific capacity 50% higher than the one located out side such features. Mean values, regadless of structural features, are of 0.3 m3/h/m, varying from 0.06 to 0.69 m3/h/m.

The vertical electrical sounding and the monitoring wells defined the depth to the water table in the altered soil. The mean obtained in the depression axis studied was 3.0m. Mean groundwater hydraulic gradient was 0.07 m/m at the centre of depression showing a moderate value, probably result of the high specific capacity soil value. Figure 2 shows a profile along the depression axis, where gradients values are indicated as well as the depths to the water table and bedrock top.

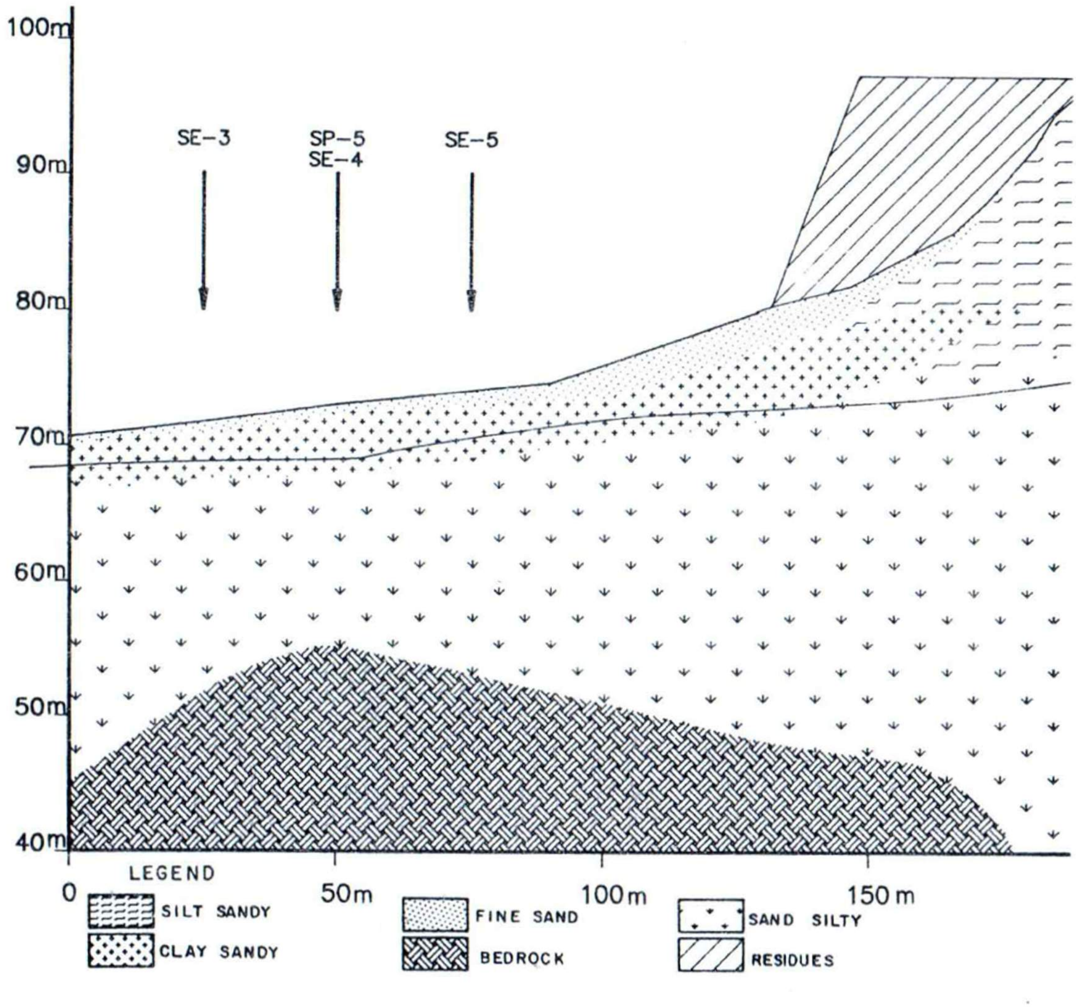

Fig.2. -Hidrogeology of the site.

Percussin drilling (SPT) did not agree to electric soundigs when of the analysis of hills of the depression. Gradients betwen points SP-5 and SP-3 were 0.003, significatively smaller than those between SP-4 and SP-5, of 0.03

m/m. The water levels showed a water flow from SP-4 to SP-5 and from SP-5 to SP-3, the opposite from the expected from the topography.
Such type of altered soil allows to estimate hydraulic conductivitis between 0.1 to 1 m/day having saturated thickness around 15 m in the central part of depression and 0.5 m, at the hills.

Contamination situation

The results of the eletromagnetic sounding are shown in figure bellow.

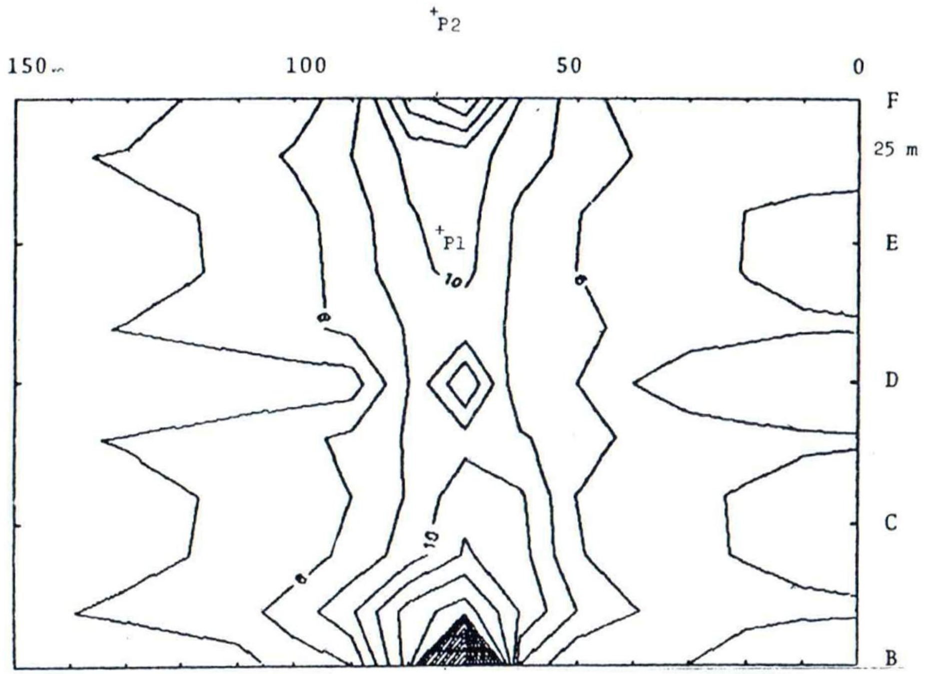

Fig.3. -Isocondutivity map-EM-34/10mH investigation depth-7.5m ,and sampling points.

The residue deposit is ending just at the profile B, from 50 to 110 m at the figure, and the groundwater flow is from B to F, aproximately transversal to the profile sounded. From the figure is clear that there is an increase in the condutivity along the axis indicating that the pollution plume (considering the area with condutivities greater than 6 milimho/m) is at least 60 m wide and more than 100 m long. Others measures, not shown here, indicated that the area of high conductivity diminishes at the 15m sounding depth, meaning that the contamination is greater at the high parts of the aquifer. Other interesting point is the appearance of spots of high values at profile D and F.Samples collected at points 1 and 2 confirmed that the ground water is contaminated at these points, at least by dissolved solids. At point 1 TDS was 110mg/l and at point 2, 350 mg/l, measurements done nearby found values around 70mg/l. The TDS(total dissolved solids) was measured in field using electrodes. The ph was 5.9 at point 1 and 6.0 at point 2. The run-off has carried out the waste material along the base of the valley for more than 200m. The existing vegetation along the drainage pattern was dead, certainly because the high fluoride content of the waste. Brown, 1983 points out that 100ppm of fluorides in irrigation water is toxic to some vegetables, as seen before, the leachate of this residue can have higher values of fluorides.

REMEDIAL ACTION PROPOSED.

There is a swamp area just 30 m from the point 2, figure 3, which is the discharge for the groundwater that comes from the site. The water from this goes to the Ribeirão do Colégio. There is only few phreatic wells nearby and the industries use surface water for their suply.These small use of the groudwater at the region, associated to the relatively low toxicity of the components of the waste, made reasonable to consider that an acceptable remedial action would be regrading the surface and interrupting the infiltration by impermeabilization. The regrading will enhance the run-off thus diminishing the infiltration. There is, by other side, necessity to control the erosion of the residue by the rain action, for this it was proposed to cover the residue with soil and to plant grass on it, allied with the diversion of the rainwater coming from the drainage area outside the site. For the waste particles already leached out, its been proposed that it will be excavated and reburied at the new landfill.The remaining infiltration will be cut off by imprmeabilizing the top with clay. Finally, considering that:

a) the industry needs a place to dispose its residue,

b) the topography is adequate,

c) there is no surface mater source at the site,

d) the geology is within the minimun standards required by the state authorities for industrial landfills (ABNT 1987b) and e) the area is already degraded, it was sugested that the landfill activities could remain, but with several environmental protection measures. Those are: impermeabilizing with clay the bottom and the top, leachate collection and treatment and pretreatment of the residue, silica sludge, with lime to imobilize the fluoride. Also will be operated a monitoring well net, to follow the expected changes in the groundwater quality.

MODELLING.

To evaluate the effect of interrupting the pollutant infiltration on the groundwater quality, it was used a relatively simple model(Cleary,1990). It is a two dimension one. The effect of the unsaturated zone was negleted. The data used is described bellow:

TABLE 2 - Model Inputs

PARAMETER	VALUE	BASIS
Source width(L)	65 m	System geometry
Initial contaminated depth(b)	20m	System geometry
Transmissivity(T)	0.3m3/h.m	Average in region
Hydraulic gradient(grad)	0.07	Measured
Effective porosity(ne)	0.20	Sand silty(USEPA,87)
Longitudinal dispersivity(al)	10 m	0.1 of distance of interest(100m)
Coefficient of transversal dispersion.(Dy)	1/3 Dx	Assumed

x direction is groundwater flow

Hydraulic conductivity(k)= T/b=0.36 m/day

Velocity(V)= -(k/ne)*grad=0.126 m/day

Coef.long.dispersion(Dx)= al*V=1.26 m2/day

Coef.transv.dispersion(Dy)=0.33*Dx=0.4 m2/day

It was considered that the problem started in 1979 and that the remedial action occurred in 1990, so at this date the source is interrupted. Figure 5 shows the relative concentration today in a plan view .

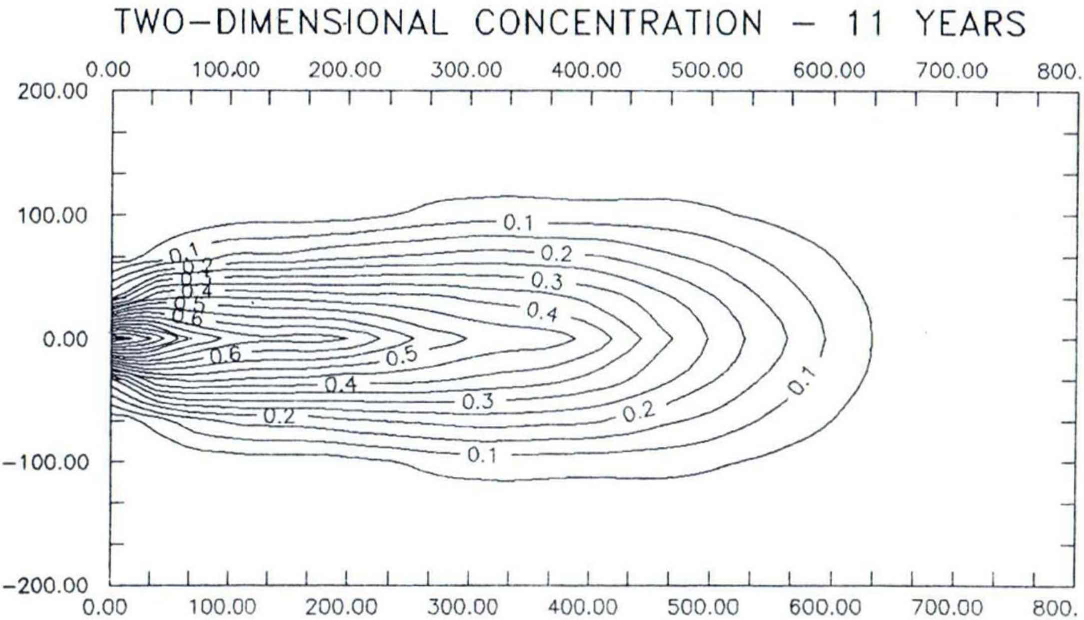

Fig.4.- Relative concentrations distribution in 1990.

The width of the plume is similar to that found with the geophysics, by other side should be noted that the groundwater discharges at a swamp area about 250m from the site, so actually there is no plume beyond this point.
The figure 5 shows the variation with time of the concentration at 120 m from the site. This is the location of one monitoring well.

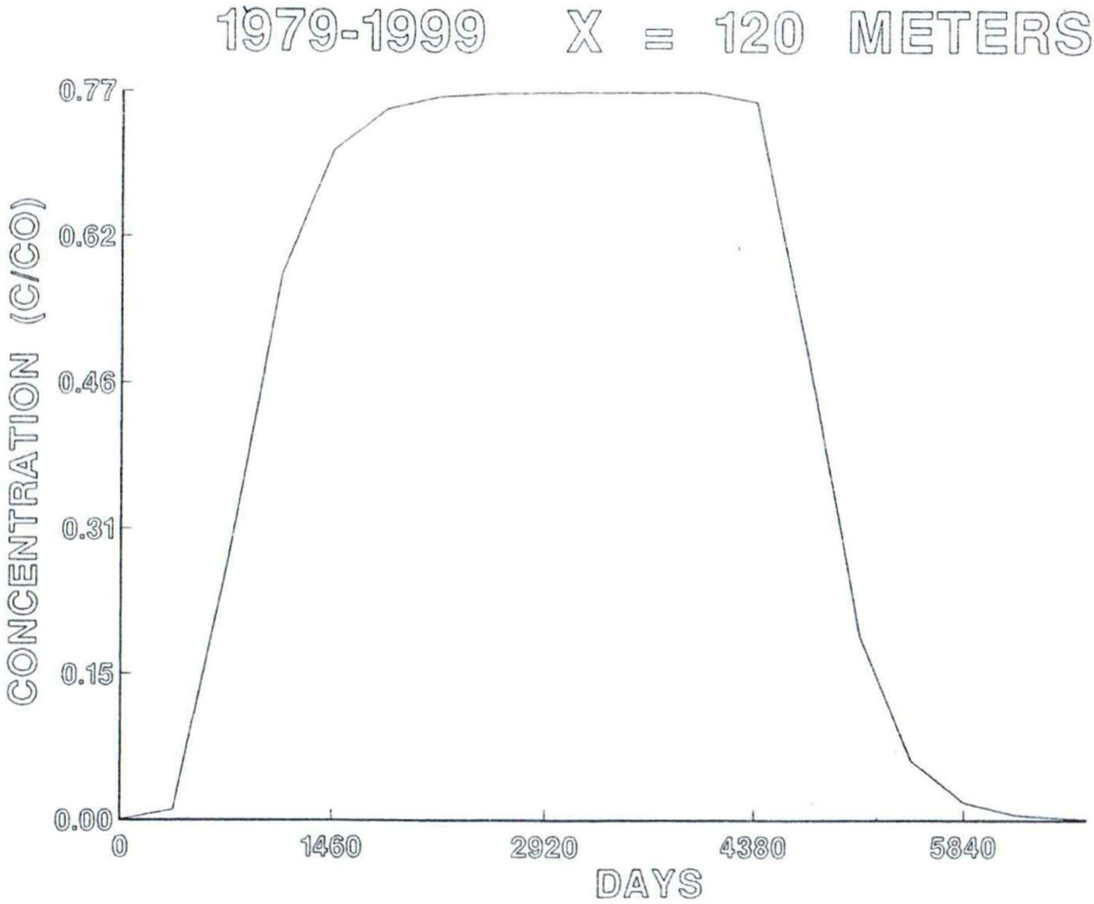

Fig. 5. Simulated relative concentration variation with time at point 120 m

The simulation indicate that 3.5 years after the infiltration be interrupted the concentration is only 20% of the initial one, and that after 6.5 years the values practically will be that the background. At this point should be pointed out that the groundwater velocity was not determined at the site, so if the real velocity be greater, the recovery time will be smaller, and by other side if the velocities are greater, the recovery will be slower.

CONCLUSIONS AND RECOMENDATIONS.

From the above it is possible to conclude that:

- the methodology used was adequate and conducted to good results.
- the quality of the groudwater can be naturally recovered with the remedial action scheme proposed.
- there are need to get more monitoring data to have better idea about the actual groundwater contamination.
- there are need to get real groudwater velocity figures to improve model output quality.

- geophysical techniques presented here a good tool to quickly evaluate the plume extension, but presented some problems to determine the groundwater level.

- for the situation modelled, the use of simple models showed adequate.

Based on this conclusions, it is recomended that:

- Be carried out slug tests to get real groudwater velocities,
- Be carried out an sampling program
- With the data above run again the model.
- Be implemented all the remedial action scheme proposed.

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