Geophysical techniques to evaluate environmental impacts by tannery industry

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Abstract

Bovine leather tanning produces a large amount of waste, mainly liquids that can present elevated values of total dissolved solids, Cr, Fe, among others. Due to the high organic load, the oxygen of the rivers can be depleted. The study scope was to investigate a tannery industry shallow subsurface using electrical resistivity and induced polarization geophysical methods. The refereed industry operates since 1993 and is located in Portão, State of Rio Grande do Sul, southern Brazil. This study aimed the geophysical mapping of the contaminant plume and also to determine the groundwater flow direction. Generally, the chromium occurs in its trivalent state in minerals, and can be oxidized to the hexavalent state (carcinogenic) in alkaline environments. Due the presence of acids and salts in tanning wastewater the amount of total dissolved solids increases substantially in soil and groundwater, turning them more conductive. Twelve survey lines were set using dipole-dipole array to acquire the geoelectric data. The results are displayed in depth models, allowing to characterize the plume by its low resistivity values (<60 Ohm.m), most of them corresponding with low chargeability values (< 3 mV/V). Contrasting with the residual soil and sandstone that are not contaminated. The models allowed to estimate the plume dimension and determinate its preferential flow direction, that matches the terrain topography.

Introduction

Chromium is the main chemical element used in the tannery industry being released to the environment, may causing problem to the public health as they have toxic effects even when present in low concentration. The main objective of the study is to investigate a tannery industry area subsurface using geophysical methods. The refereed industry operates since 1993. Research about the proper disposal of tanning wastewater is recent, as there are a few previous studies. Telford et al. (1990), Kearey et al. (2002), Milsom (2003), Reynolds (2003), demonstrate the main theoretical foundation of the methods. Electrical resistivity and induced polarization were the methods applied at this study, aiming to detect and outline the plume, determine its flow direction and ascertain the efficiency of the indirect methods. Due the presence of acids and salts in tanning wastewater the amount of total dissolved solids increases substantially in soil and groundwater, turning them more conductive. Therefore, it justifies the use of geophysical methods in this environmental context. In this context, researches of Cunha & Shiraiwa (2011); Nunes & Luiz (2006); Fachin et al. (2006); and Migliorini et al. (2006) are of major importance to understand this type of environment more prone to contamination.

Geology and study area location

At the study area region there are two different lithologies, the Botucatu Formation composed of fluvial-aeolian sandstones and the Serra Geral Formation withbasaltic and intermediate volcanic rocks (CPRM, 2006). The first formation constitutes the Guarani Aquifer System. Quaternary deposits are present in the region, correlated to the erosion of the cited rocks. According to CPRM (2005), those deposits are formed by residual soil gravity transported sediment (colluvium), alluvial fans and braided channels sediment. The geological map of the region is presented in figure 1, characterised by sandy alluvial deposits overlaying the Botucatu Formation.

Geoelectric methods

Electrical resistivity (RES) and induced polarization (IP) are used frequently in hydrogeology and in environmental contaminated sites. The data were acquired using Iris Instruments, composed of the multichannel receiver (ELREC PRO), the transmitter VIP 3000 W and non-polarizable electrodes. The method applied was the dipole-dipole array (AB=MN=10m), examining six levels of depth. The length of all SN survey lines is 140 m, while the EW ranges from 70 to 160 m. The figure 2 shows the survey line array, their names, the whole study area and the tannery location. ER and IP response to the subsurface geological setting, according to their propriety (Telford el al., 1990). Contaminants may change the electrical response of soils and groundwater. Therefore, the methods applied in this study can detect areas affected by contaminants. The resistivity and chargeability data are presented using depth models. The geoelectrical surveys use pairs of current-potential electrodes, through which apparent resistivity and chargeability measures are acquired (time domain). The main factors influencing variations in electrical resistivity of materials are the mineralogical composition, the porosity, the fluids composition, the total dissolved solids (TDS) and the temperature. The apparent resistivity and demand ability data, as well as the processed (inverted) data, are presented in profiles and 2D maps.

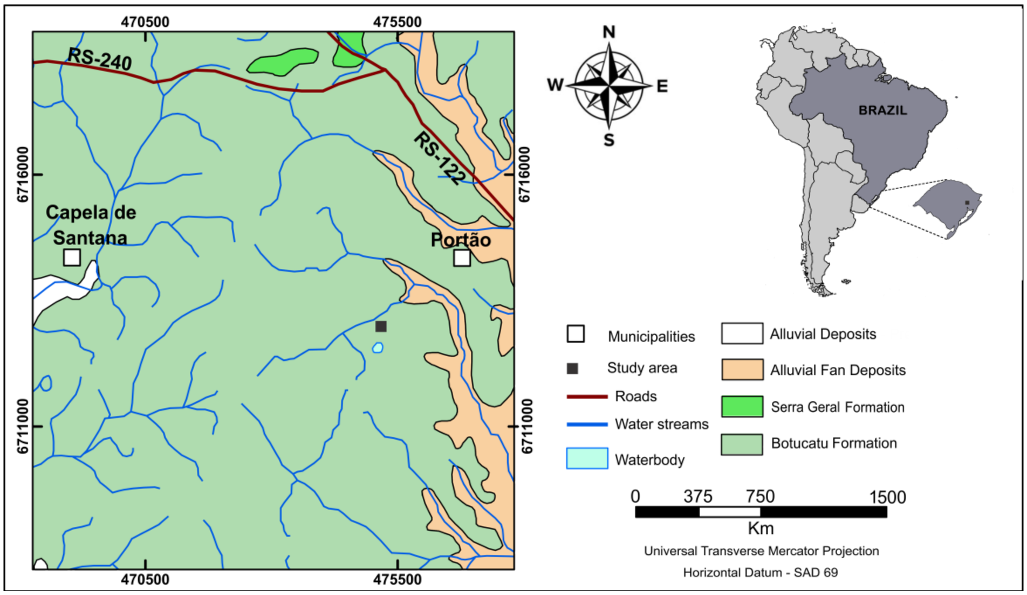

Figure 1 – Location/Geological map of the study area. Modified from CPRM (2006).

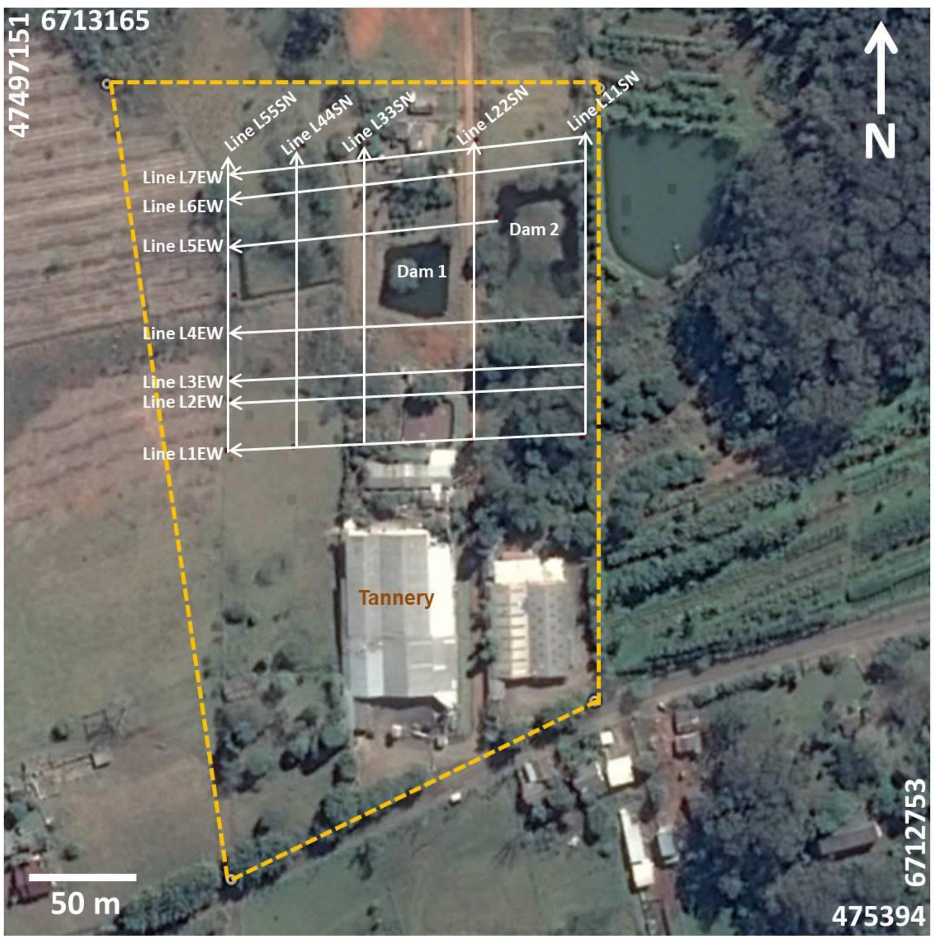

Figure 2 – Map of the study area, indicating the survey lines of geophysical methods (electrical resistivity and induced polarization). Google Earth (2015).

Results and Discussion

Survey lines near the tannery are the most representative, displaying geophysical contrasts (Figures 3 and 4). The figure 3 displays the RES and IP 2D depth models by inversion of the lines EW 1, 2 and 3. The upper profile at the figure 3A represents the L1EW resistivity while the other profile at the bottom represents the chargeability. According to the resistivity profile, the interval from 60 to 90 m is correlated with the contaminant plume, coinciding with the low IP values and the location of industrial effluent pond. At this model, there is low resistivity values extending downward, however, the values that characterizes the contaminant plume are < 60 Ohm.m for resistivity and < 3 mV/V for chargeability, limiting the depth of probable contaminant plume to 7 meters. Figure 3B as the 3A and 3C shows the resistivity 2D depth models above the chargeability model. At the L2EW profile there are resistivity values below 49 Ohm.m at the horizontal interval from 55 to 95 m with maximum depth of 5 m. The chargeability below 3 mV/V is placed from 20 to 80 m. Figure 3C represents the L3EW model, and its initial point is correlated with the position 20m of L1EW and L2EW, with total length of 140 m. The models allow identifying 3 layers: shallower layer (vadose zone, unconfined aquifer), middle layer (confining unit) and the deep layer (confined aquifer). The line 33 SN (figure 4) models, perpendicular to the previous one (figure 2), exhibit clearly the low resistivity and chargeability spatial distribution, suggesting the flow direction. Isoresistivity and isochargeability maps until level 7 were elaborated, with maximum depth of 37 m. However, only the maps that allow characterizing the contaminant plume aredisplayed, as after the level 4 (12 m deep) the anomalies do not reflect the contamination. The low resistivity values present deeper than 7 m are related to the confined aquifer, that has no influence from the vadose zone and the unconfined aquifer. Then, the figure 5 illustrate the maps of isoresistivity and isochargeability of all survey lines (EW and SN), at the following depths: n1 = surface, n2 = 3m and n3 = 7 m. The figure 5A exhibit the resistivity values at the surface, partially matching the chargeability anomalies (figure 5B). Figure 5A clearly show the contamination plume limited by the 60 Ohm.m isoline, suggesting that the flow direction matches the terrain topography. As occurs at the superficial level, at the level 2 (Figure 5C and D) the resistivity values distribution keeps the same pattern, limiting the plume to the area surrounded by values higher than 60 Ohm.m, apparently limited by the 22SN and 44SN survey lines (figure 5C). The chargeability pattern is similar (Comparing the figures 5B and 5D). The maps displayed at figures 5E and 5F, show the resistivity and chargeability values, respectively, at the level 3 that is 7m deep.

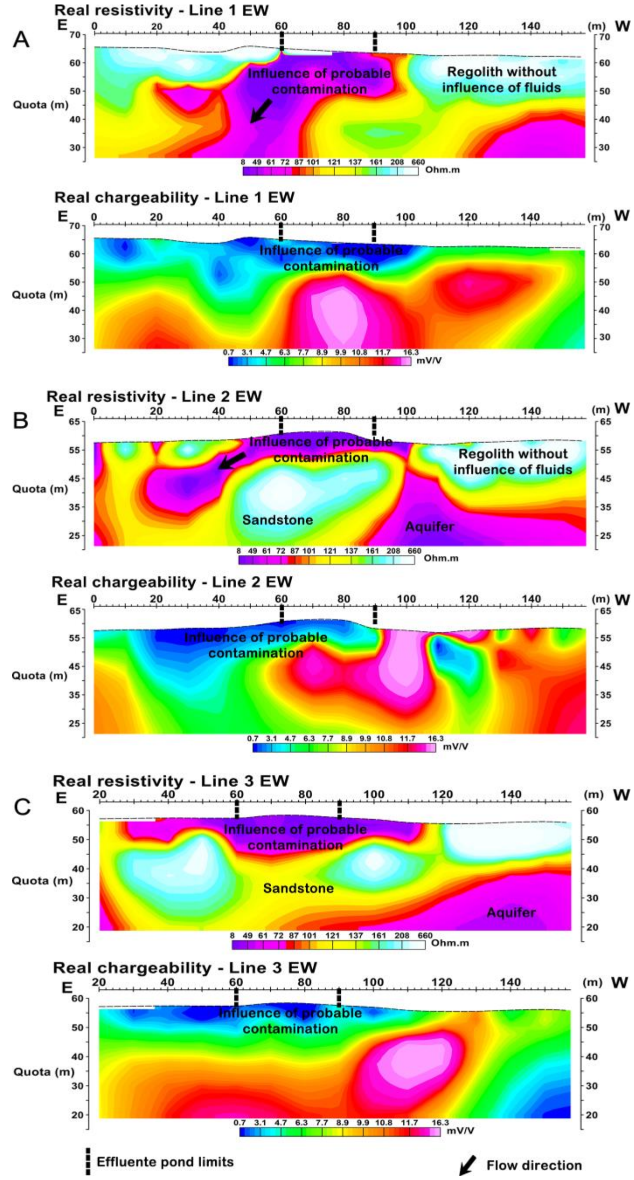

Figure 3 - Resistivity and chargeability 2D depth models of the Lines 1 EW (A), 2 EW (B) and 3 EW (C) (see location in Figura 2).

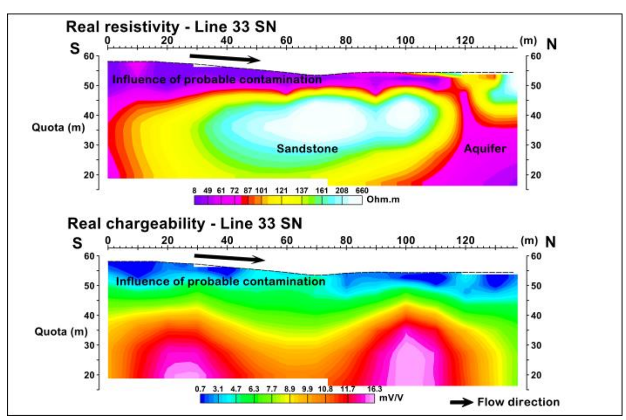

Figure 4 - Resistivity and chargeability 2D depth models of the Line 33 SN (see location in Fig. 2)

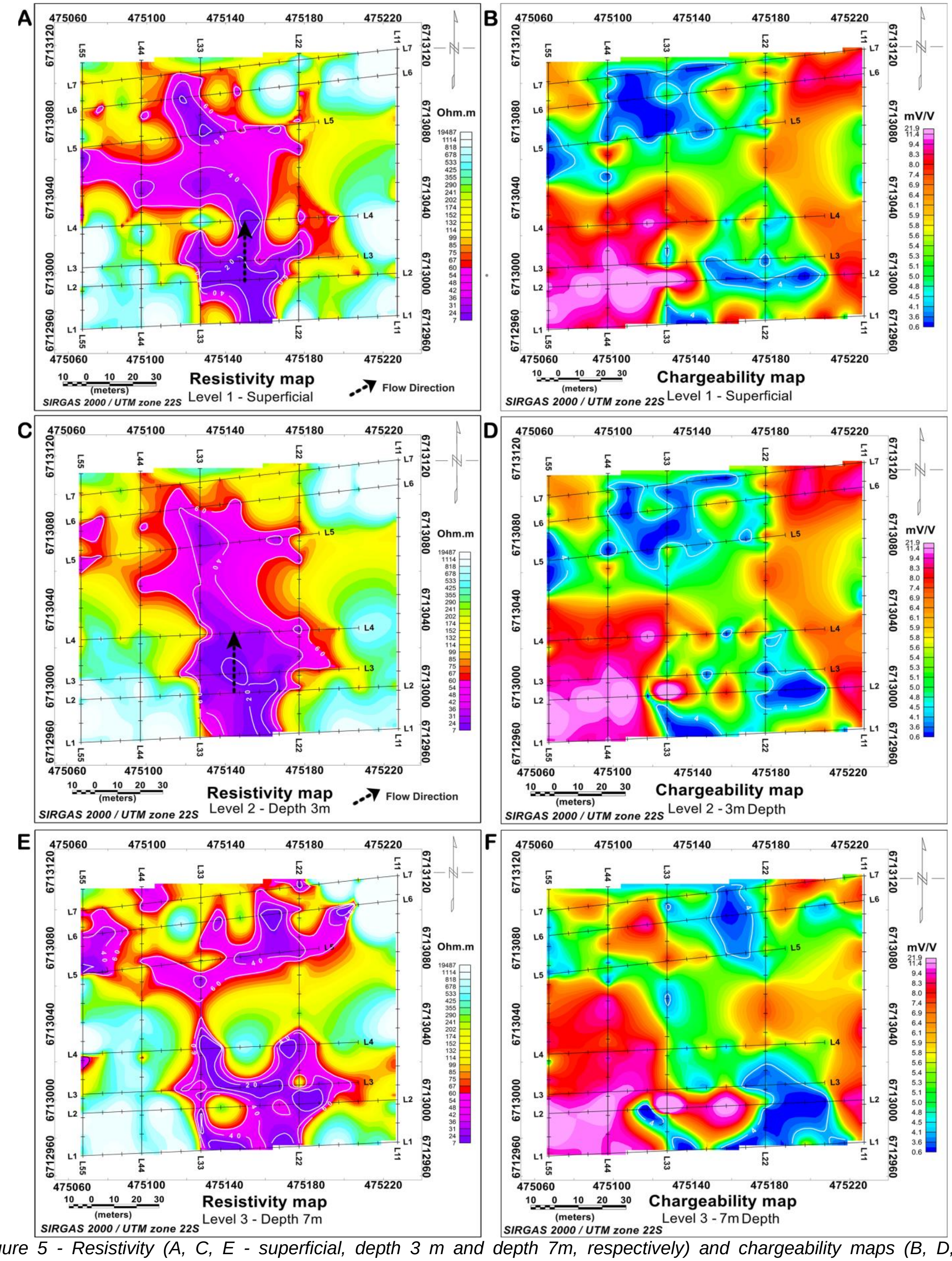

Figure 5 - Resistivity (A, C, E - superficial, depth 3 m and depth 7m, respectively) and chargeability maps (B, D, F - superficial, depth 3 m and depth 7m, respectively).

Conclusions

Electrical resistivity and induced polarization applied using dipole-dipole array (AB=MN=10m), were efficient to outline the plume boundary horizontally and vertically. Electrical resistivity was the most effective technique. The geophysical results allow us to characterize the plume by its low resistivity values (<60 ohm.m), that mainly corresponds with low chargeability values (< 3 mV/V). Contrasting with higher values (> 60 Ohm.m and > 3 mV/V) of the no contaminated residual soil and sandstone. Concerning the geoelectric methods resolution, until the depth of 7m, the plume can be better outlined. The depth models allowed to estimate the lateral (50x 60 m) and vertical (7m) dimensions of the contaminant plume, determining its preferential flow direction to the north, matching the terrain topography. The results suggest that the contaminated area is restrict to the source surrounding. The use of more than one geophysical method in environmental studies permits to generate reliable data for contaminant remediation and management.

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