

LEACHATE MOBILITY AT CHETTICHAVADI MUNICIPAL SOLIDWASTE DUMPSITE, SALEM USING GEOPHYSICAL AND GEOCHEMICAL METHODS

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Abstract : Leachate originating from open refuse dumpsite systems can be delineated through an integration of qualitative and quantitative methods. This study was designed to examine extent of leachate and pollution from one of the numerous open refuse dumpsites in Tamil Nadu. Qualitative assessment was determined using Vertical Electrical Sounding (VES) geophysical methods. The methods were projected to produce 2-D view of the site which shows a NW-SE flow pattern of the leachate and possibly, the groundwater. Quantitative assessment was achieved by analysis of geochemical substances in the water samples taken from wells and boreholes in the precinct of the dumpsite. Here, we examine the macro elements, salts (sulphates, nitrates and chlorides), heavy metals contents and physical parameters of the water samples. The analysis reveal the presence of these substances in the water and their strong correlations justified the provenance as the same. As part of the quantitative evaluation, physical parameters (pH, TDS, total hardness and electrical conductivity) of the water samples were also determined. The samples pH plotted in the alkaline domain unsuitable for human consumption. Leachate flow direction was generated from the decreasing concentration of measured parameters (geochemical elements and physical properties) in NW-SE direction which agrees with similar flow pattern deduced from VES results.

Keywords: Integration, Vertical Electrical Sounding, Qualitative, Quantitative

I. INTRODUCTION

This research work aims to showcase the effectiveness of integrating non-invasive geophysical methods with widely employed geochemical approach in environmental assessment of waste disposal site [1]. While the latter is a quantitative phenomenon, the former elaborately displays qualitative conditions of the site. Both can map the contaminant plume and groundwater flow direction. The geophysical methods we introduced are electrical resistivity tomography ERT, vertical electrical sounding VES and induced polarization IP methods.

Electrical Resistivity Tomography (ERT) is a technique for imaging the subsurface electrical structure using electrical currents. From a series of electrodes, low frequency electrical current is injected into the subsurface, and the resulting potential distribution is measured. Early development of ERT in geophysics was confined to imaging rock core samples in the laboratory [2], but prototype data-collection hardware and research-grade inverse codes suitable for field scale applications soon followed [3]. The method has been developed to detect leaks from large storage tanks[3], monitor underground air sparging [4] and mapping movement of contaminant plumes [5]. More recently, ERT has been used for locating shallow cavities, fractures, fissures and mapping groundwater flow, identification of geological structures [6], engineering and environmental surveys [7], and in agriculture [8].

II. STUDY AREA

The study dumpsite is an open dumping system in Chettichavadi, Salem district which began in recent years. Dumping at the site is indiscriminate and unsorted. Wastes types dumped on the site are mainly domestic and non-hazardous wastes. Some components of these wastes including food, papers etc, oxidize thereby changing the redox potential of the water in the dump. Percolating groundwater provides a medium through which the wastes particularly organics can undergo degradation into simpler substances through biochemical reactions involving dissolution, hydrolysis, oxidation and reduction processes. The percolating liquid dissolves different compositions of waste to form a complex mixture called leachate. This leachate mainly organic carbon largely in the form of fulvic acids migrate downward and contaminate the groundwater. Thus, shallow sources of groundwater, hand-dug wells, which constitute about 85% of sources for domestic and irrigation water systems, are at high risk of contamination from the dumpsite.

III. MATERIALS AND METHODS

Five vertical electrical resistivity survey locations were grouped into 2 profiles study, covering the entire study area. The orientations of VES survey along with NE-SW and E-W. The traversing made it over in same geological formations to project a two dimensional subsurface lithology. All these geoelectrical resistivity profiles generated through IPI2WIN software package.

The geoelectric resistivity profiles are nothing but the geoelectrical section of each VES location united into one profile with a definite orientation of the direction. Each geoelectrical resistivity profile has one profile, namely pseudo section displaying the apparent resistivity at different depths below the ground level from the surface to 50 m depth.

The leachate used in this study was collected from the dumpsite. Two samples were collected. One from the seepage from the dumpsite and the other from the leachate collection well. The leachate samples were collected using precleaned glass bottles then tightly sealed and kept in an icebox. The samples were then transported to the laboratory and kept in the refrigerator at 4°C prior to using in the study.

The chemical properties of the leachate analyzed in this study are: pH, total dissolved solids (TDS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total organic carbon (TOC), electrical conductivity (EC), chloride content (Cl⁻), alkalinity content and heavy metals. The American Public Health Association (APHA) standard was followed for analysis of leachate samples in the study area.

IV. RESULTS AND DISCUSSION

4.1 GEOELECTRICAL PROFILES STUDY

VES-1 is studied in northern part of the study area. The resistivity pseudo VES 2D section represents the field along with Northwest to Southeast direction. The locations falls in this vertical section are Chettichavadi (Salem Municipality Solid Waste Disposal Area) of the upper part of study area. The traverse of the profile is from Northwest to Southeast direction of the study area as pictures in Fig.1. This 2D resistivity section reveals that (VES-1) with a structural ridge on two sides is lowland.

The upper layer having a resistivity of 150 to 190 ohm m indicates the presence of sub-surface soil in moist nature. The layer thickness is about 1.2 m. The second layer having thickness up to 2.37 m and resistivity of 250 ohm m represents the presence of weathered zone with small amount of water. The resistivity of the third layer decreases to less than 150 ohm m which is attributed to the presence of groundwater and it is the aquifer with 2.6 to 4 m thickness. Light green batches are indicated that Magnesite vein deposits and alternate light blue colour portions may be weathered zone with water. So that this location leachate is not influenced for groundwater, because this location is upland and deep slope for all sides

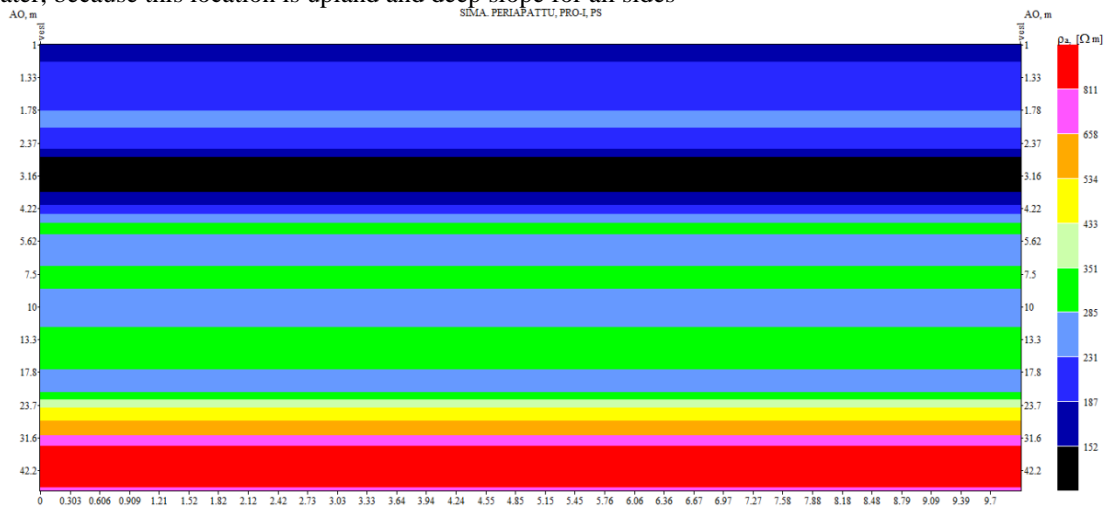


Fig. 1. VES No. 1 Pseudo-Vertical Cross-Section with Resistivity Section

Top soil thickness is about 1.2 m. The second layer having thickness up to 5 m and resistivity of 82 ohm m represents the presence of weathered zone with water (Fig. 2). The resistivity of the third layer increased to more than 100 ohm m which is attributed to the presence of groundwater and adjoining the Magnesitedeposits thickness ranging from 5.1 to 11 m thickness. Leachate is not influenced for groundwater, because this location is deeper slope area.

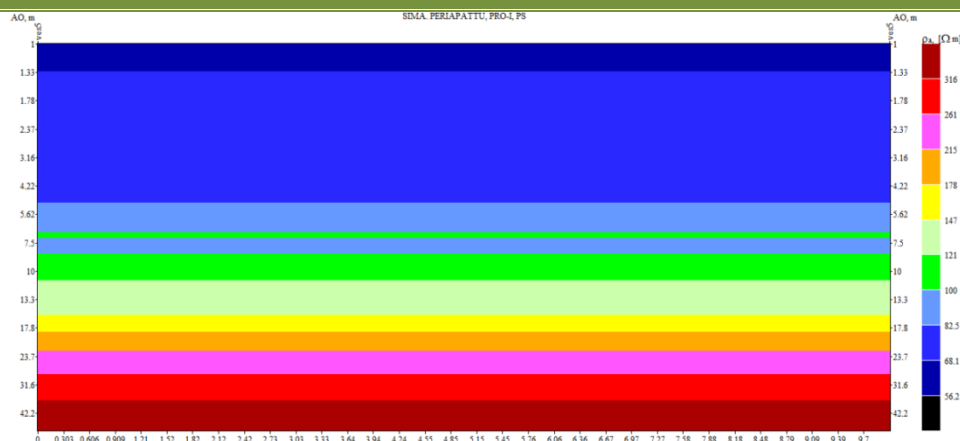


Fig. 2. VES No. 2 Pseudo-Vertical Cross-Section with Resistivity Section

Further, VES-3 (Fig. 3) shows the top soil layer thickness is 1 m. Second layer resistivity is less than 20 ohm m, which suggests the presence of leachate. The thickness of this layer is found up to 0.6 m. The third layer having a resistivity varies from 42.8 to 69.5 ohm m and extending up to a depth of about 23.7 m indicates the presence of surface mono-mineralic rock (pyroxene and peridotite) nature.

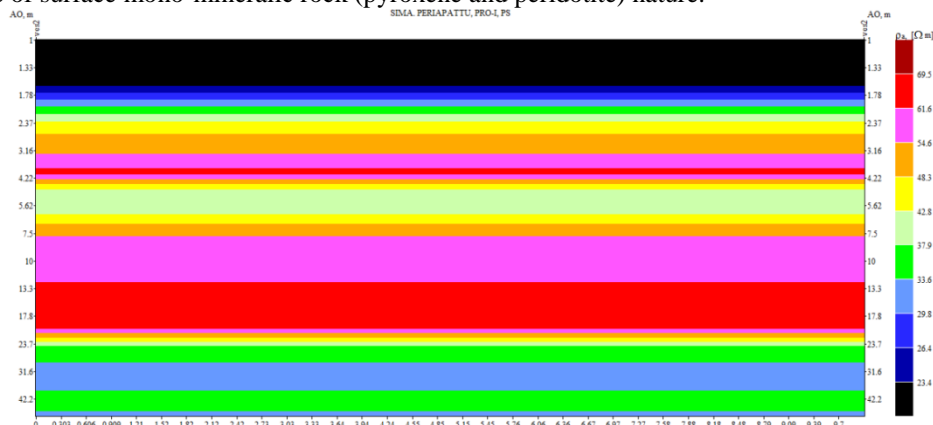


Fig. 3. VES No. 3 Pseudo-Vertical Cross-Section with Resistivity Section

The interpreted result of geoelectrical sounding at VES-4 location (Fig. 4) shows that top soil thickness is 1 m. the second layer having a resistivity ranging from 170 to 225 ohm m and extending up to a depth of about 2 m indicates the presence of Magnesite deposits. The second layer has thickness of 4 m and resistivity of the order of 170 ohm m is due to the presence of weathered zone with water (Shallow aquifer). The next 10 m thick layer has resistivity of more than 250 ohm m may be interpreted as moist semi-compact peridotite rock. The next layer resistivity of less than 100 ohm m. sudden decrease in the resistivity indicates the presence of leachate companied with groundwater.

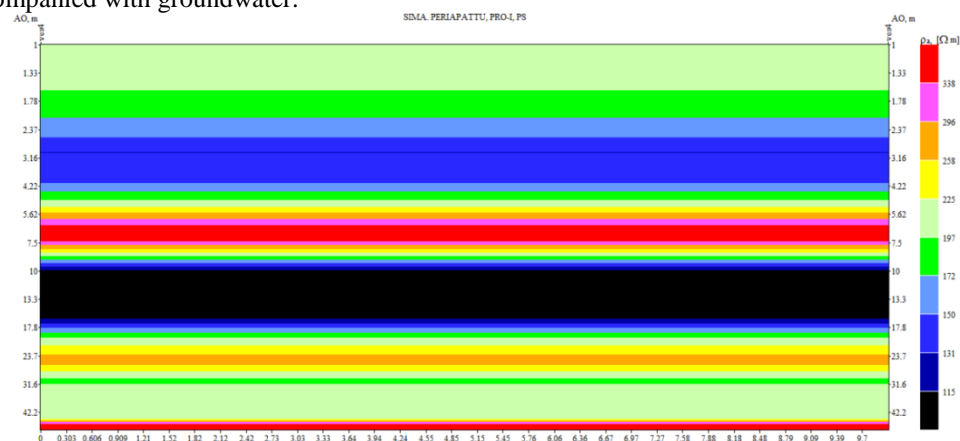


Fig. 4. VES No. 4 Pseudo-Vertical Cross-Section with Resistivity Section

The interpreted result at VES-5 (Fig. 5) location shows the presence of multilayer layers. The upper layer having a resistivity of 30 ohm m indicates the presence of sub-surface soil moist nature. The layer thickness is about 1 m. The second layer having thickness of 5.6 m and resistivity of less than 20 ohm m represents the presence of leachate with shallow water in weathered zone. The resistivity of the third layer decreases to 50 ohm m which is attributed to the presence of Magnesite with polluted water in 7.5 m thickness. The resistivity of the fourth layer increases to less than 10 ohm m indicative of the presence of leachate with a thickness of about 2m. The fifth layer extending up to a depth of about 50 m has resistivity of more than 100 ohm m indicative of the presence of fine grained pyroxene with Magnesite vein. This VES location groundwater is heavily affected by leachate.

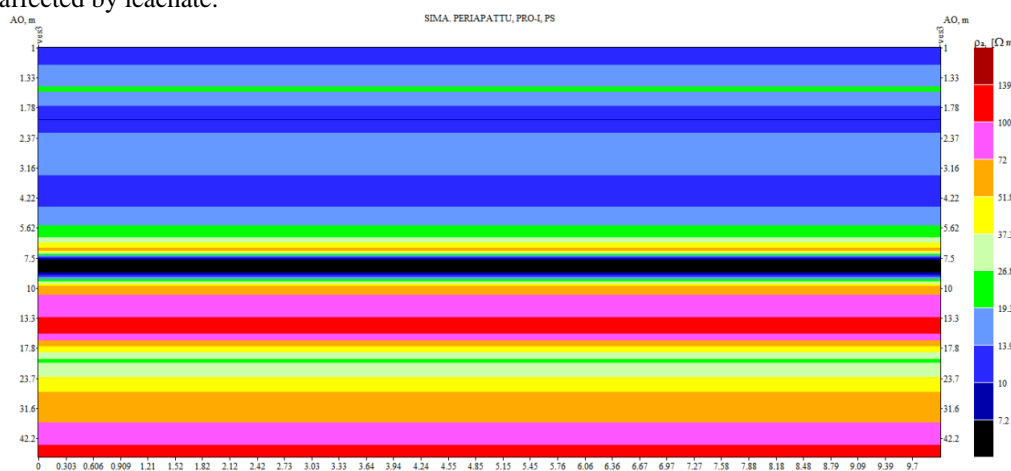


Fig. 5. VES No. 5 Pseudo-Vertical Cross-Section with Resistivity Section

4.2 CHEMICAL CHARACTERIZATION OF THE LEACHATE USED

The landfill leachate is generated as a consequence of water percolation through solid waste, as well as oxidation and corrosion of the waste discarded in poorly designed landfill sites, which allow the leachate to easily pass through the soil strata and cause severe risk to the surrounding soil, the groundwater and the health of the local community.

Many authors have noted that, besides the vertical in- filtration of leachate from the solid waste, the hydro- logical groundwater flow also play a prominent role in contaminant distributions beneath the subsurface of a landfill or dumpsite. This accounts for the contamination of groundwater aquifer not directly or vertical located on dumpsite or landfills across the globe.

The results of the chemical analysis of the leachate obtained from landfill site which was used in this study, is listed in Table 1.

Table 1 Chemical characteristics of the leachate obtained from landfill

Sl.No	PARAMETERS	SAMPLE 1	SAMPLE 2
01	pH at 25°C	11.40	11.05
02	Conductivity @25°C	24800 μ mhos/cm	16380 μ mhos/cm
03	Total Dissolved Solids	16542 mg/l	12757 mg/l
04	BOD @ 27°C for 3 days	3800 mg/l	340 mg/l
05	COD	15732 mg/l	1192 mg/l
06	Chloride as Cl	6262 mg/l	4990 mg/l
07	Sulphate as SO ₄	195 mg/l	225 mg/l
08	Oil & Grease	108 mg/l	69 mg/l
09	Total Phosphate as P	4.73 mg/l	4.68 mg/l
10	Zinc as Zn	0.33 mg/l	0.09 mg/l
11	Total Chromium as Cr	0.50 mg/l	0.44 mg/l
12	Copper as Cu	BDL (DL:0.01 mg/l)	BDL (DL:0.01 mg/l)
13	Iron as Fe	BDL (DL:0.005 mg/l)	BDL (DL:0.005 mg/l)
14	Nickel as Ni	0.71 mg/l	0.69 mg/l
15	Total Kjeldahl Nitrogen as N	1354 mg/l	116 mg/l

The pH of the Leachate depend not only the concentration of the acids that are present but also in the partial pressure of the CO₂ in the landfill gas that is in contact with the leachate. These results indicate that the leachates are at the later stage of methanogenic phase. This means that the age of landfill, rainfall and kind of waste are the most important factors which affect the composition of leachate. Table 5.1 shows that the pH value of the leachate is 11.40 and 11.05, which is alkalinity and can reduce the mobility of the heavy metals.

Electrical conductivity is used an indicator of the abundance of dissolved inorganic species or total concentration of ion. Electrical conductivity values show variety result between that Leachate. The value is 16380 μ mhos/cm and 24800 μ mhos/cm. However the EC value which are obtained for the leachate are not within the standard range required for treated waste water discharge determined by local standards. When considering the average value of conductivity leachate samples were conclude that leachate was high amount of mineral salt. Total Dissolved Solids values in the leachate are 16542 mg/l and 12757 mg/l. The BOD @ 27°C for 3 days values are 3800 mg/l and 340 mg/l. The one which is having higher values is due to the raw leachate and the one with lower values is due to the complete digestion of the leachate.

The concentration of sulphate at the Leachate showed different values. The values are 195 mg/l and 225 mg/l. The treatment plant receives massive quantities of human excreta and other biological waste matter that can be the reason high value of sulphate concentration. The concentration of nitrate for the leachate is range between 1354 mg/l and 116 mg/l. The nitrate of the leachate is chiefly from biological sources, human and animal excreta accounting for a large percentage of the total nitrogen load. The concentration of nitrogenous compound indicates the occurrence of extensive anaerobic bacterial activities. Nitrite oxidized in to the nitrate, which can be quickly assimilated by plant or otherwise reduced again to nitrite and NH₃. Therefore, the concentrations of nitrate for the leachate are higher than the nitrite. The concentration of phosphate of the Leachate showed different values. The value obtained are 4.73 mg/l and 4.68 mg/l.

The concentrations of chromium (Cr), copper (Cu), Nickel (Ni) and iron (Fe) are significant indicating the severity of toxic metals in the leachate. This aspects forms the main issue of the investigation. The distribution of Fe at the Leachate indicates that Fe and steel scrap are also dumped in the landfill. The dark brown color of the leachate is mainly attributing to the oxidation of ferrous to ferric from and the formation of ferric hydroxide colloids and complexes with fulvic/humic substances.

The presence of Zn in the leachate shows that the landfill receives waste from batteries and fluorescent lamps. The distribution of Cu at the leachates are below the detectable limits. On the other hand most of these results are not within the standard acceptable level of treated wastewater discharge determined by international standards. Cr (0.44-0.50 mg/l) and Ni (0.69-0.71) were also present in the leachate samples. A variety of waste is dumped at landfill site which likely indicate the origin of Zn, Cr, Cu and Ni in leachate.

V. CONCLUSION

Integration of electrical and geochemical methods has been used to assess the subsurface conditions under a municipal dumpsite system in the study area. Our geophysical method was able to map and delineate the contaminant plume (leachate) beneath the aged open dumping system being recently cleared in preparation for its possible con- version into shopping complex. The integrated methods has proven to be tools for environmental assessment of waste dumpsite.

The interpreted result of geoelectrical sounding at VES-4 location shows that top soil thickness is 1 m. the second layer having a resistivity ranging from 170 to 225 ohm m and extending up to a depth of about 2 m indicates the presence of Magnesite deposits. The second layer has thickness of 4 m and resistivity of the order of 170 ohm m is due to the presence of weathered zone with water (Shallow aquifer). The next 10 m thick layer has resistivity of more than 250 ohm m may be interpreted as moist semi-compact peridotite rock. The next layer resistivity of less than 100 ohm m. Sudden decrease in the resistivity indicates the presence of leachate companied with groundwater.

The interpreted result at VES-5 location shows the presence of multilayer layers. The upper layer having a resistivity of 30 ohm m indicates the presence of sub-surface soil moist nature. The layer thickness is about 1 m. The second layer having thickness of 5.6 m and resistivity of less than 20 ohm m represents the presence of leachate with shallow water in weathered zone. The resistivity of the third layer decreases to 50 ohm m which is attributed to the presence of Magnesite with polluted water in 7.5 m thickness. The resistivity of the fourth layer increases to less than 10 ohm m indicative of the presence of leachate with a thickness of about 2m. The fifth layer extending up to a depth of about 50 m has resistivity of more than 100 ohm indicative of the presence of fine grained pyroxene with Magnesite vein. This indicates that this location is heavily affected by leachate.

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Whilst this investigation was instigated as a mapping project to give a "snapshot" of landfill behavior, longer term monitoring, particularly of water levels, is recommended.

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