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2-D Electrical Resistivity Tomography Investigation in Landfill Site: A Case Study of Millar Road Landfill, Baldivis, Western Australia

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Abstract

Millar Road Landfill site was investigated using 2-D resistivity imaging techniques. The overall aim of the experiments was to evaluate the degree of contamination arising from the landfill. Resistivity data was collected from three profiles spread across the survey lines using the dipole-dipole based electrode configuration. Data was processed using RES2DIV inversion software which enables the apparent resistivity Pseudo-sections to be created. Analysis of the of Pseudo section results shows that profile one has a conductive path which penetrate to depth of 20m; profile two has very high conductive structure which extend diagonally across the study area and profile three showing a structure that is partly conductive and largely resistive as a result of closeness to fresh basement rocks. North-western boundaries of profile 2 and 3 indicated highly conductive area (HCA) and less conductive area (LCA are highly anomalous with very potential for association with leachate migration. These areas have shown various conducting path via cracks and veins so that the groundwater may have been contaminated. It is therefore suggested that geochemical analysis of the water in the identified areas be investigated to determine the extent of contamination. Also, the need to periodically monitor leachate migration process to safeguard the groundwater resources is very imperative hence it is recommended that a thorough study of any waste disposal site be carried out before the take-off operation.

Keywords: Electrical resistivity, landfill, contamination, leachate plume, aquifer, pseudo-section.

Introduction

Recent environmental studies have shown that in many industrialized world, landfill sites are very common and remains a major source of concern to geoscientists, environmentalist and the government at large if not properly managed[1]. Australia as a nation produces large quantities of waste per capita and this has progressively increased over recent time to reach an unprecedented level across all sectors of the community. This presents a significant management issue especially as Perth metropolitan area is susceptible to groundwater contamination due to a geological predominance of leached sand which has a high filtration rate. Chloride and ammoniacal-nitrogen are the most common contaminants. Also, several investigations into the Millar road landfill site have concluded that groundwater quality has been impacted by leachate from the wastes. Further, older waste sites often lack sufficient geological or artificial barriers hence the leaching of pollutants into the aquifer remain a source of concern.

Contamination problems are particularly severe for waste dumped in abandoned gravel pits, many of which extend to below the groundwater table. Being small and unregulated, the exact location, structure, and contents of such landfills are either unknown or poorly documented. Though, it may be difficult to obtain detailed information on the contents of a landfill; it is however useful in evaluating the level of risk associated with leaking pollutants. In such context, the integrated use of geophysical methods provides an essential tool in the characterization and evaluation of contaminants generated by urban residues domestic and/or industrial[2-6]. Among those geophysical methods, electrical resistivity tomography (ERT) is receiving greater attention especially for environmental and remedial studies as it produces electrical resistivity images of the subsurface[7-11]. The method is very cheap and non-invasive. Application of ERT has huge advantages especially for investigations involving contaminations where it is generally required to minimize ground noise. Results from the applications of ERT in environmental and engineering problems have been very encouraging especially in the investigation of landfill sites, where it has been used to map landfill geometry[12-16].

Site Description: The site comprises methane Gas Power Generation Facility to harvest methane produced during the decomposition process. The extraction and combustion of landfill gas prevents its escape into the atmosphere, reducing greenhouse emissions. Nine odour complaints were received in relation to the landfill in 2009. Two of these complaints were investigated by landfill staff and action to mitigate odour. In addition, in response to these complaints the city of Rockingham is now undertaking monthly Air Quality Monitory of the premises. Substantial part of the surrounding land which hosts the landfill site has not been used, while the other part was previously used for agriculture practices. The site consist mostly grassland and marsh, though areas of dense vegetation and woodland exist within the north dawn to the south-western side. In addition, an embankment which runs north-western within the site tend to be characterized by an abrupt change in slope and may be interpreted as an area of high ground to the northeast which could contain the landfill.

Study Area: The Millar road landfill (MRLF) is located on Lot 2170 Millar Road West, Baldivis which is some 12 kilometres southwest of Rockingham, the regional centre. The study area is about 46 kilometres of Perth's central business district (CBD). It is located on the Swan Coastal Plain within the Spear wood Dome System and largely comprises of siliceous sands. Baldivis is largely occupied by the existing landfill facility and cleared areas, with a small portion of the lot in the north-eastern corner comprising remnant native vegetation. Some part of the study area consists mainly of sand (yellowish brown, medium to coarse grained, sub-angular quartz and limestone soil unit, with an undulating landscape. The geology of the area can best be described as moderate-high permeability while Tamworth Hill serves as the major source of water reservoir in the area[17]. The western end of the study area has tuart trees with varying sizes and shapes (medium to tall) with a thick trunk and distinctive dichotomous branching forms some of which are found around the residential houses. Figure-2 shows map of Baldivis were the Millar road landfill is located.

Figure-1
Photo View of Millar Landfill Site

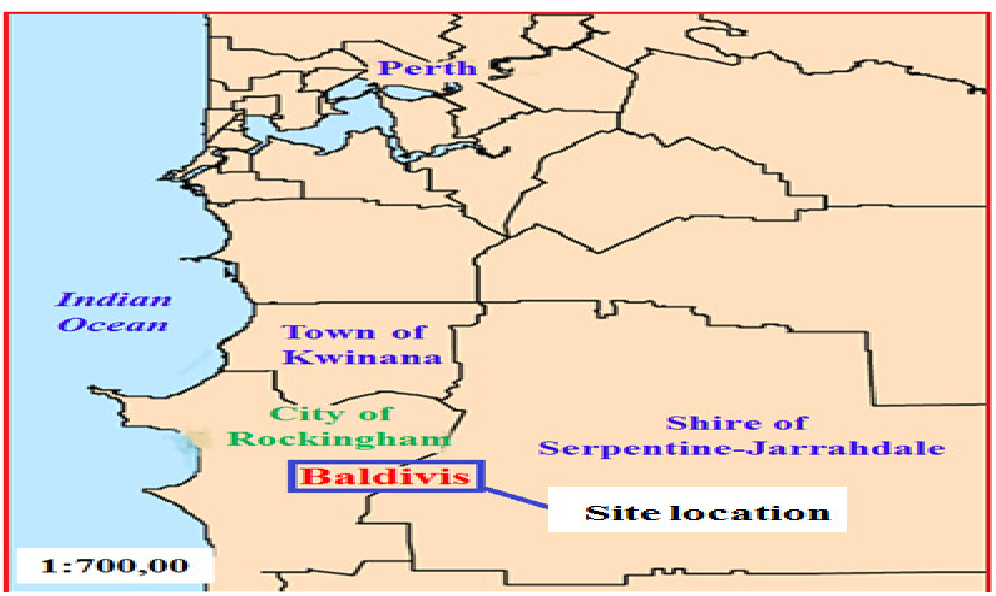

Figure-2
Map of Baldivis were the Millar Road Landfill is located

Material and Methods

For this geophysical investigation of delineating the extent of leachate plumes around the Millar landfill in Baldivis, Western Australia, an ABEM Terrameter SAS 1000, electrodes, reels of wire , cell, were used to collect the apparent resistvity data. In electrical resistivity method, the most common electrode configurations are the wenner, schlumberger, pole dipole and dipole-dipole. However, for the purpose of this investigation, the dipole-dipole electrode configuration was used (figure-3). A primary advantage of the dipole-dipole electrode array is the ease of deployment in the field due to shorter wire lengths.

Further, data collected with dipole-dipole configuration gave reasonable results that can be used to understand the subsurface layers as well as path way of the contaminant plumes. The spacing between the current electrodes pair, AB is given as "a" which is the same as the distance between the potential electrodes pair MN. The same process was repeated for measurements with different spacing ("$2a$" to "na") so that the apparent resistivity is calculated with

$k = ((n + 1)(n + 2)a$,where n is the level. It is worthy of mention here that the average depth of investigation using this electrode configuration depends largely on the "n" factor, as well as the value of "a"[18].

A total of three 2-D resistivity imaging surveying experiments were conducted across the area. The data was collected using dipole-dipole electrode configuration with 4m spacing between each stations numbered 1-20 spread across the landfill site bringing the total length of the survey area to 80m. The overall objective of using dense acquisition parameter was to map the possible conductive flow path via veins or opening through which the contaminant could be detected. The spacing of "a" was 4m so that it is feasible to detect the contaminant plumes up to 20m depth which is sufficient enough to provide the needed information about the pollution due to the waste disposal. Data was processed using RES2DIV inversion software[19].

Once the values of the apparent resistivities, electrode spacing and the distance locations in a text file is imported into the RES2DIV inversion software, apparent resistivity Pseudo-sections is created. The software uses the least square inversion by Quasi -Newton method to achieve the apparent resistivity Pseudosection[20]. The inversion process continues until the RMS error between the calculated and measured apparent resistivity is substantially reduced. The obtained Pseudosection sections of the apparent resistivity serve as a means of displaying the measured field values which will help to provide the information sought for. In each Pseudosection, the x axis represents distance (m) along the surface and also spacing between electrodes while the y axis represents depth (m). Colour legends at the bottom of the image indicate either apparent resistivity or subsurface resistivity values depending on the interpreter.

Results and Discussion

A total of three 2-D electrical resistivity tomography surveys (profile 1-3) were used in this investigation. The results from the interpretation of the 2D model are as presented below.

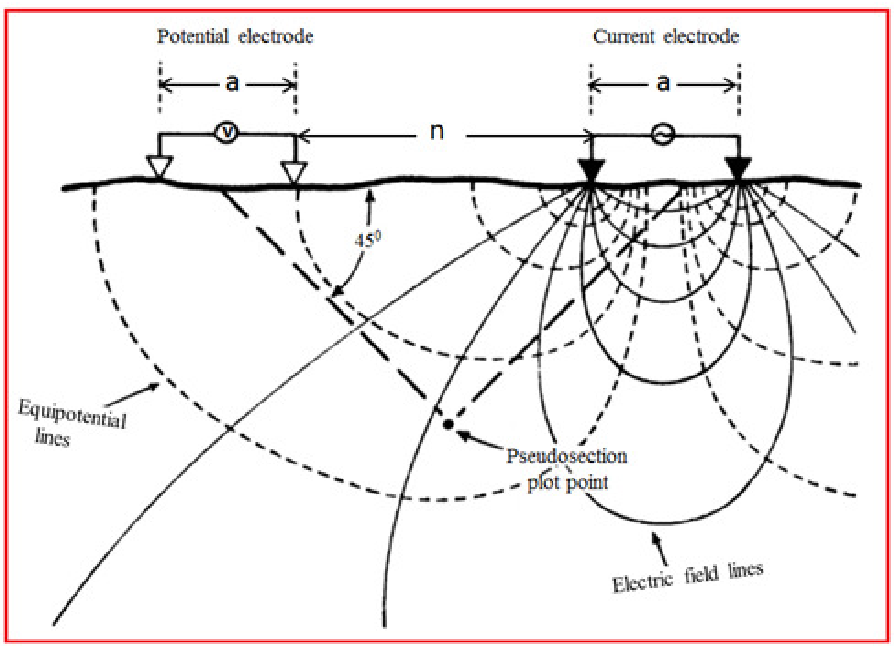

Figure-3
Dipole-dipole electrode configuration used for the survey. The electric field lines are indicated with solid lines while resultant equipotential surfaces is indicated with dashedn lines

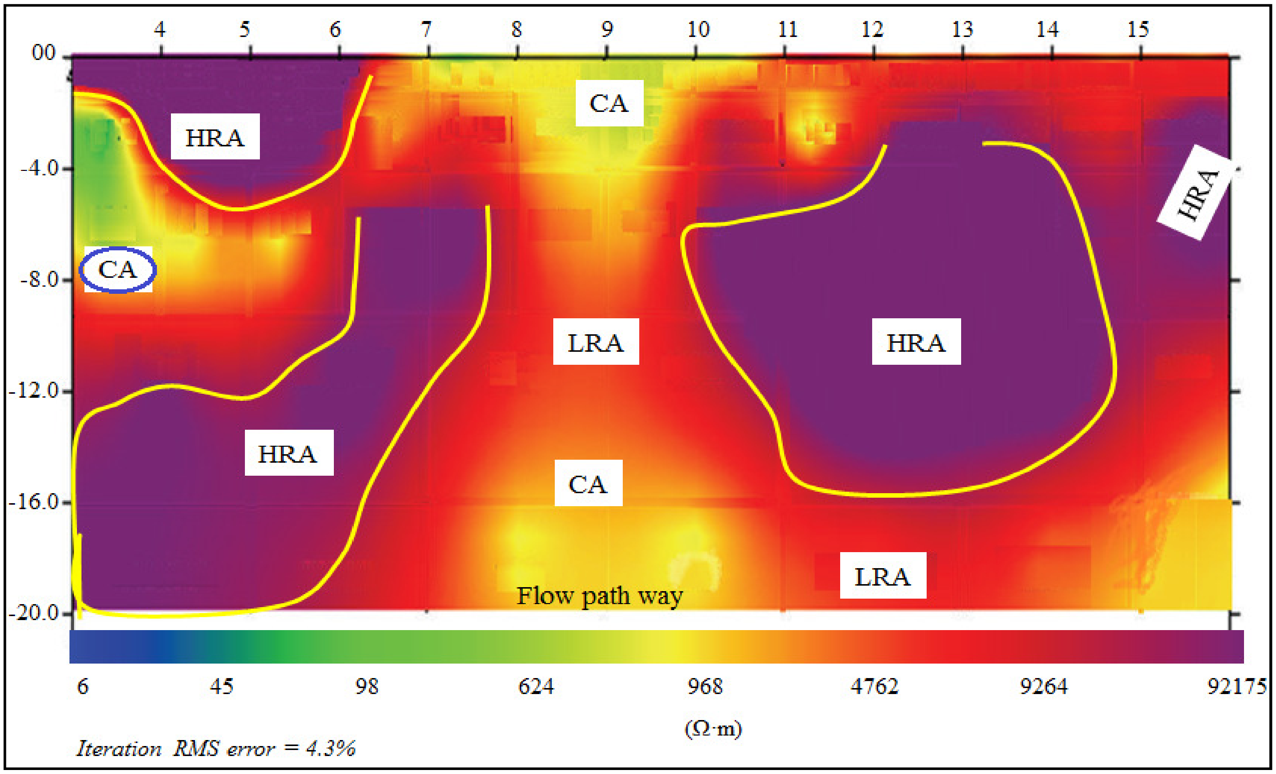

Figure-4
Calculated Apparent Resistivity Pseudosection of profile one. HRA - Highly resistive area, LRA-less resistive area, CA- conductive area

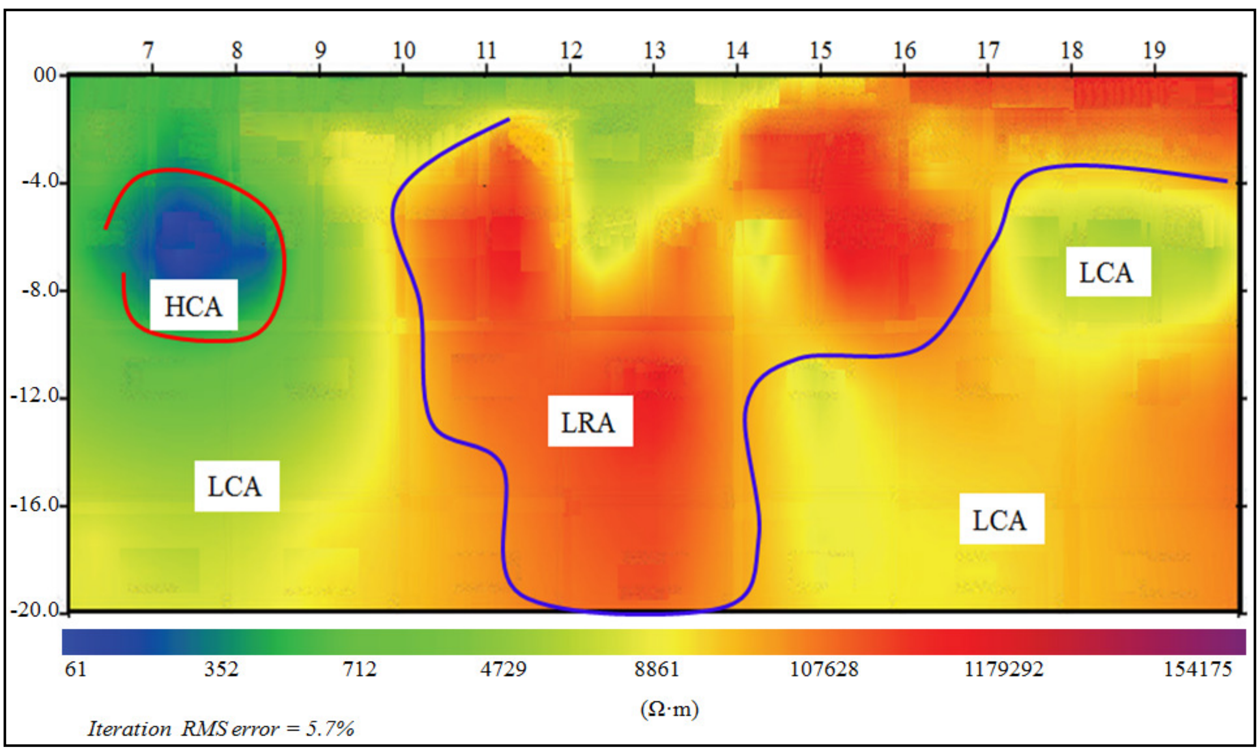

Figure-5
Calculated Apparent Resistivity Pseudosection of profile two. HRA - Highly resistive area, LRA-less resistive area, CA- conductive area, HCA- highly conductive area

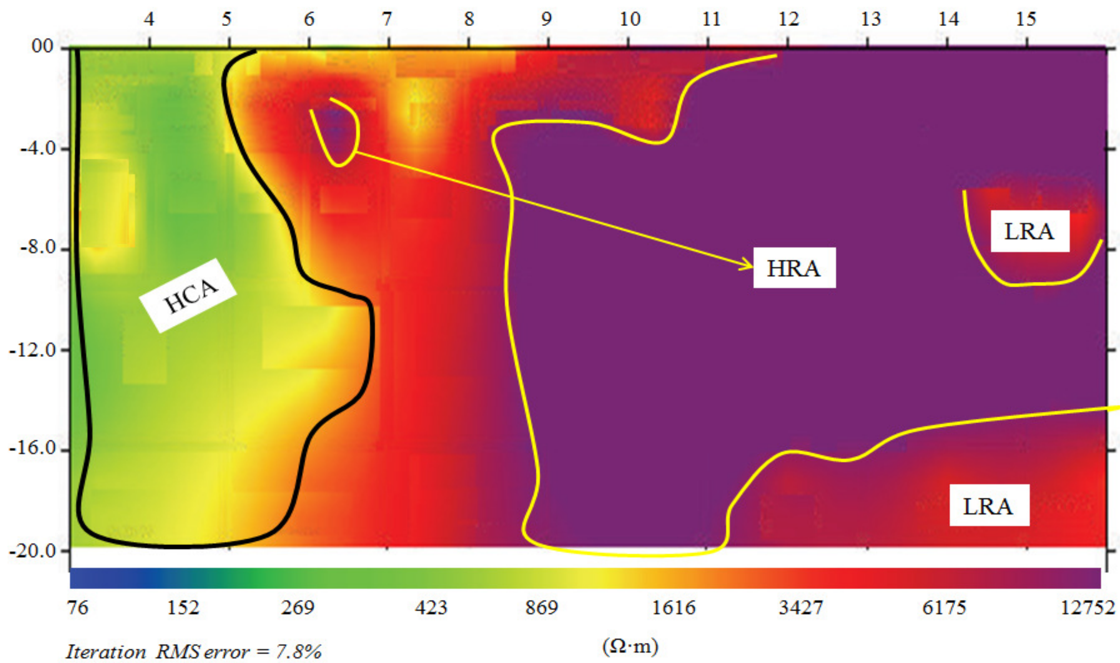

Figure-6
Calculated Apparent Resistivity Pseudosection of profile three. HRA - Highly resistive area, LRA-less resistive area, CA-conductive area, HCA- highly conductive area

In profile one figure-4, the low resistivity value of (132-305) ohms meter was interpreted as sandy clay. This follow by a layer of resistivity values ranging from 305-842 ohm meter which is also interpreted as lateritic clay/basement rocks. Results from this profile one is dominated by high resistivity marked high resistivity area (HRA) with handful conductive structures within the pseudo-sections. This pocket of conductive structures tends to extend beneath the surface to form conductive flow path which indicate an area of leachate migration to the north-west (CA) indicated with blue circle as a result of fracture or cracks. This conductive flow path may also serve as formal fluid conduit which enables the movement of contaminant into the fresh water area.

The Pseudosection of profile two indicates a block of resistive rock which was visible to a depth of 20m. Top layer along this profile has resistvity values of 278-714 ohms-meter which suggests typical sandy clay or lateritic clays. The 2D resistivity structure of this profile suggests a spurious conductive structure especially on the left flank in figure (5) with deep blue around 10m depth. This very conductive area with resistivity value ranging from 68-450 ohm-meter is surrounded by less conductive zone; which implies that the contaminants could have migrated into that area to form a block of plume. We also observed that the remaining Pseudosection is dominated with resistive structures with pockets of less resistive structures as indicated with purple circle.
The last profile has some unique results as the 2D resistivity structure indicates a partly resistive area and partly conductive area. This highly resistive area has some pockets and sheets of less resistive bodies being observed within. These zones of high resistivity in this profile are an indication that the zone is free or safe where there as little or no movement of contaminants. The remaining part has weak zones of high conductivity and low resistivity (78-255) ohms-meters. These areas may be susceptible to movement of contaminants coming from the dumpsite. It is very important that attention be paid to these weak/low resistivity zones as there are possibility of migration of leachates to the aquifer zone.

Overall, the presence of very conductive anomalies associated with the landfill to depths well below the landfill base is an indication of possible migration of leachate beneath the substructure. North-western boundaries of profile 2 and 3 indicated as highly conductive area (HCA) and less conductive area (LCA) respectively are highly anomalous with very potential for association with leachate migration.

Conclusion

Electrical resistivity tomography experiment has been carried out at a landfill site in Baldivis Perth, Western Australia. Data from these surveys have been modelled using RES2DIV inversion software which enables the apparent resistivity Pseudo-sections to be created. From the analysis of the results, a conductive zone has been identified, potentially indicating the surrounding groundwater around the landfill may have been contaminated. North-western boundaries of profile 2 and 3 indicated as highly conductive area (HCA) and less conductive area (LCA) respectively are highly anomalous with very potential for association with leachate migration.

The need to periodically monitor leachate migration process to safeguard the groundwater resources is very imperative hence it is recommended that a thorough study of any waste disposal site be carried out before the take-off operation. Such feasibility analysis will help determine whether the aquifer is naturally sealed or not as well help in determining the presence of impermeable layer above the aquifer.

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