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Delineation of leachate plumes at two waste disposal sites, Selangor

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Abstract: This paper discusses the results of two-dimensional (2D) direct current resistivity imaging surveys, which were conducted to identify and delineate the extent of contaminated land and leachate plumes as well as to assess the capability of the 2D resistivity as a pre-characterization tool for tracing the properties of disposed waste and its severity underneath capped landfill sites. The study was confined to two different municipal waste disposal sites, namely Ampar Tenang open-tipping site and Bukit Kemuning capped landfill. There are a total of eleven 2D- resistivity survey lines. Depending on site specification, the lines were distributed as 2 and 9 lines at the Bukit Kemuning and Ampar Tenang sites, respectively. In this study, the 2D resistivity imaging was carried out using SAS1000 & SAS4000 resistivity meters and ABEM LUND automatic electrode selector system. The objectives of the study were to delineate the locations of the contaminated subsoil and groundwater in terms of leachate plumes. Generally, the results of measured resistivity values obtained from the two sites defined the contaminated leachate plumes as electrically conductive anomalies of relatively low resistivity value of less than 10 Ωm. In addition, the observed resistivity values of 2D image profile, which were measured at the top of an excavated part of the Bukit Kemuning landfill, were found to be in a good agreement with the actual profile as regards to characteristics, degree of decomposition, depth and thickness of the disposed wastes, as well as thicknesses of both the cap and liner of the landfill. This proves the efficiency of using the 2D direct current resistivity technique in waste disposal site investigations.

Abstrak: Kertas kerja ini membincangkan keputusan survei keberintangan geoelektrik dua dimensa yang dijalankan untuk mengenal pasti and menentukan tahap pencemaran tanah serta larut lesap disamping menilai keberkesanan kaedah keberintangan 2-D sebagai alat pencirian awal untuk mengkaji sifat sisa buangan serta tahap pencemarannya dibawah permukaan tapak buangan tertutup. Kajian ini tertumpu hanya kepada dua tapak buangan iaitu Tapak buangan sampah terbuka Ampar Tenang dan tapak buangan sampah tertutup Bukit Kemuning. Sebanyak 12 garis survei keberintangan telah dibuat iaitu dua di Bukit Kemuning dan 9 garis di Ampar Tenang. Dalam kajian ini, survei keberintangan telah dilakukan dengan menggunakan meter keberintangan SAS1000 dan SAS4000 dan sistem pemilih elektrod LUND ABEM. Matlamat kajian telah dapat dicapai dalam menentukan kedudukan tanah dan air bawah tanah yang tercemar. Secara umumnya daripada pengukuran keberintangan didua tapak pembuangan sampah, di dapati nilai keberintangan larut lesap menunjukan anomali kekonduksian elektrik dengan nilai keberintangan yang relatif rendah daripada 10 Ωm. Selain itu profil imej keberintangan geoelektrik 2-D yang diukur di tapak pembuangan sisa Bukit Kemuning didapati bersesuaian dengan profil sebenar dari aspek pencirian, darjah penguraian, kedalaman dan ketebalan sisa buangan serta ketebalan tanah penutup dan lain-lain maklumat operasi lampau tapak tersebut. In dengan sendirinya telah memboktikan keberkesanan teknik keberintangan geoelektrik 2-D untuk penyiasatan tapak pembuangan sampah.

INTRODUCTION

Electrical resistivity surveys are commonly used for geotechnical investigations and environmental surveys (Loke, 1999). Due to its efficiency and effectiveness in producing images of the subsurface, resistivity-imaging methods have now becomes more popular in electrical exploration (Dahlin and Zhou, 2002). The two dimensional (2D) direct current (DC) electrical resistivity methods measure the apparent resistivity of the subsurface, which can be inverted to develop a model of the subsurface structure and stratigraphy in terms of its electrical properties (Loke, 2003). The resistivity of the subsurface is affected by porosity, amount of water in the subsurface, ionic concentration of the pore fluid and composition of the subsurface materials. However, the resistivity data can be used to identify, delineate and map subsurface features such as electrically conductive contamination plumes, the vadose zone, and electrically conductive lithologic units such as clay (Dawson *et al.,* 2002).

In this study, two different municipal solid waste disposal sites have been surveyed i.e. Bukit Kemuning covered landfill and Ampar Tenang open-tipping site, which are located in Selangor State (Figure 1).

The overall goals of this study were identification and delineation of the extent of the contaminated leachate plumes as well as testing of the efficiency of 2D DC-resistivity as a pre-characterization tool for tracing the properties of disposed waste and severity of the contamination underneath capped landfill sites.

DATA ACQUISITION

The data acquisition was done as two-dimensional (2D) resistivity imaging, using SAS1000, SAS4000 and SAS 300C connected to an ABEM LUND automatic electrode selector system and a laptop microcomputer to select the relevant electrodes for each measurement. This measuring system was connected to a total of 61 steel electrodes, which were laid out in a straight line with constant spacing via a multicore cable. The resistivity unit automatically selects the four active electrodes used for each measurement. The Wenner equal spacing electrode array was used for this survey. The measured resistivity data was interpreted using the RES2DINV inversion software (Loke and Barker, 1996).

INTERPRETATION OF RESULTS

Ampar Tenang Open-Tipping Site

A total of nine lines of 2D-resistivity images were established with four of them located on the waste pile. One more line of 400 m in length, partially covered the eastern edge of the site at a distance of 153 m from the northeastern corner of the site. The other four lines were distributed up- and downstream of the site (Figure 2). Figure 3 shows the inversed resistivity models of the three resistivity lines (Profiles 5, 6 & 7) measured on the top of the waste pile. The electrically conductive anomaly on the dumping site was interpreted as leachate plumes, which appears to have seeped through the underground soil at depths of as far as 20 m below surface (Profile 5). The 2-D image of the resistivity also shows that the thickness of the decomposing waste is slightly more than 10 m (Profile 6) and this agrees well with the actual thickness of the waste pile observed in the field. Past re-excavation and re-filling operations of the waste have created some isolated low resistivity zones which were interpreted as being related to fringing of contaminated leachate water mixed with existing decomposed wastes.

Bukit Kemuning Capped Landfill

Location of resistivity lines is shown in Figure 4. At this site, the resistivity imaging results outline a large variation in the properties of disposed waste. In Profile 1 (Figure 5), the high resistivity parts near the surface are interpreted as non-degradable wastes which agree with the picture of the excavated part where Profile 1 has been conducted (Figure 6). However, the low resistivity zone at depths of 6-13 m below ground surface may be interpreted as decomposed wastes together with leachate-saturated soil in both the unsaturated zone as well as in the groundwater zone. Generally the distribution of resistivity values in Profile 1, draws a typical picture of the actual excavated part (Figure 6) in terms of the thicknesses of cap, disposed waste, and clay liner. The sharp variation in resistivity distribution between the upper and lower parts of the measured section (Figure 5) is strongly attributed to the degree of waste decomposition i.e. degradable (leachate) and non-degradable.

Profile 2, which covered the entire width of the landfill, was conducted after the site was converted to a development site, which in turn can explain the unconformity of resistivity measurements. The development work involved excavation, removing and re-disposing of disposed wastes, which exposed some decomposed wastes on the surface producing a very low resistivity zone of highly contaminated leachate-saturated wastes (Figure 7). At depths of 6 – 16 m below ground

Figure 1: Location map of study area.

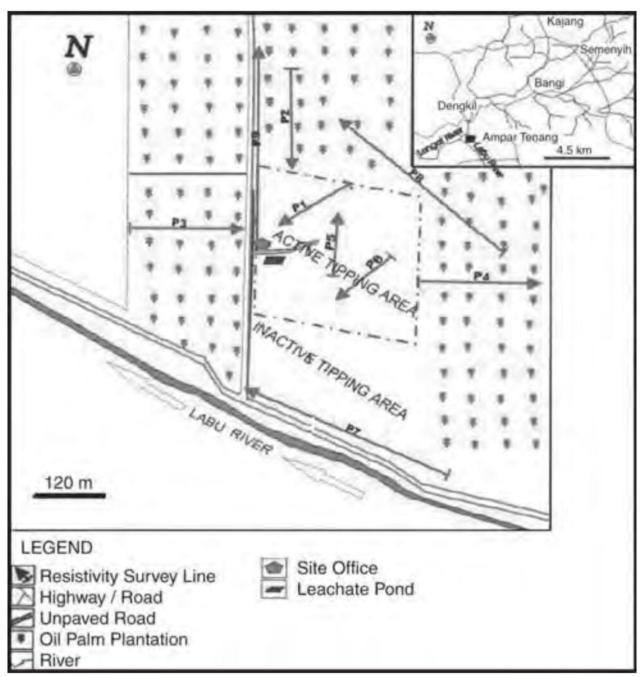

Figure 2 : Resistivity lines at Ampar Tenang waste disposal site.

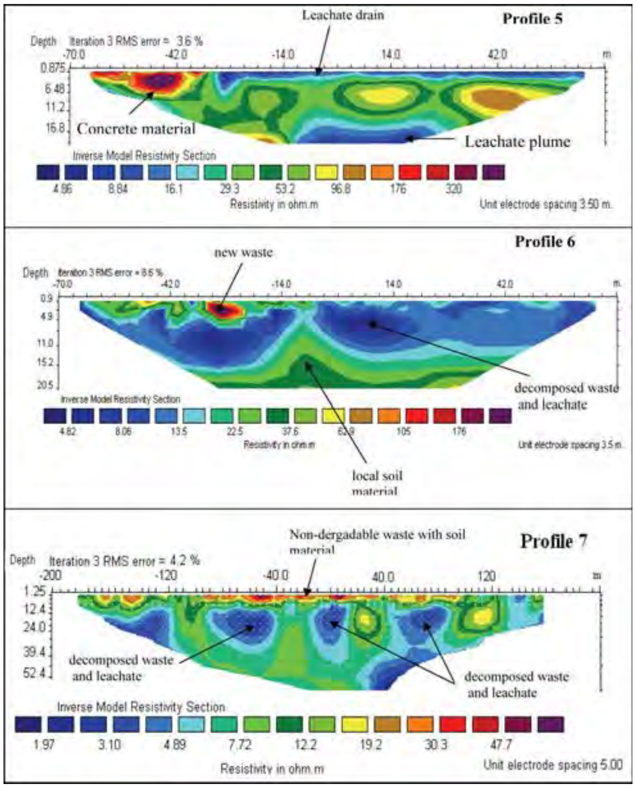

Figure 3: Profiles conducted on top of the wastes at Ampar Tenang.

Figure 4 : Resistivity lines at Bukit Kemuning capped landfill site.

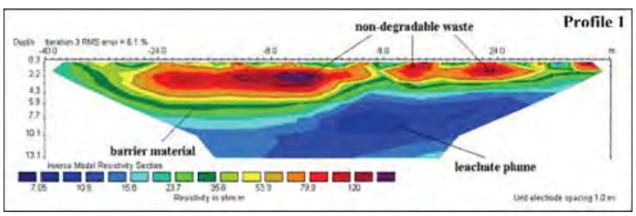

Figure 5: DC-resistivity imaging Profile 1 (Bukit Kemuning Landfill).

Figure 6: Photograph of the excavated part of Bukit Kemuning Landfill.

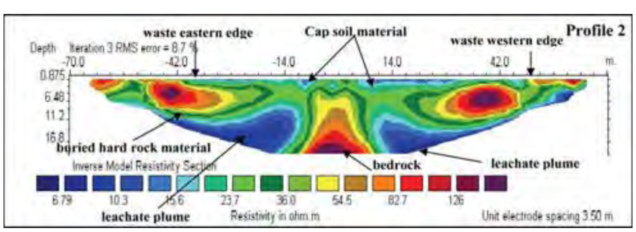

Figure 6 : DC-resistivity imaging Profile 2 (Bukit Kemuning Landfill).

surface, the highly contaminated leachate (0.73 Ωm) formed two leachate plumes of locally different flow directions. The left plume in Profile 2 was considered the same leachate plume traced in Profile 1. However, the variation in resistivity values was strongly attributed to dilution of the contamination load of leachate by accumulation of rainwater in the deep excavated part for quite a long time.

CONCLUSION

By applying 2D DC-resistivity imaging technique, the impacts of the surveyed sites have been successfully characterized in terms of resistivity distribution underneath the vicinity of each site. The migration of Ampar Tenang leachate was traced in the form of low resistivity zones (with resistivity less than 2.0 Ωm) of decomposing waste bodies saturated with highly conductive leachate.

At Bukit Kemuning two plumes of a very highly conductive leachate have been traced. The result of Profile 1 at Bukit Kemuning, proves the potential of 2D DC-resistivity imaging technique as a pre-characterization tool which can be used to map subsurface contamination (soil and groundwater) in the vicinity of waste disposal sites.

The complexity of subsurface conditions beneath contaminated land requires a multidisciplinary approach combining systematic and careful application of hydrogeological, chemical and environmental geophysical techniques.

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