# EVALUATION OF GROUNDWATER QUALITY IN A LANDFILL USING RESIST-IVITY SURVEY

**By**

**Abdelatif Mokhtar Ahmed[1] and Wan Norazmin Sulaiman[2]**

1- College of Water Science and Technology, Sudan University of Science and Technology, P.O.Box 352, Khartoum North, Sudan. 2- Department of Environmental Sciences, Faculty of Science and Environmental Studies, University Putra Malaysia, 43400, UPM, Serdang, Selangor, DE, Malaysia.

## ABSTRACT

This paper describes the groundwater quality at Seri Petaling Landfill located in the state of Selangor, Malaysia. Electrical resistivity imaging survey line was conducted on the top of the landfill. Hydrogeological and hydrochemical studies were also carried out at the site. Three boreholes drilled in the upstream, down stream, and within the landfill itself represent-ed the groundwater. They are AH1, AH2, and AH3 respectively. Total dissolved solids distribution were estimated and conducted on the same resistivity line. The groundwater aquifer was determined to be unconfined. The top of the aquifer is covered with dry superficial layer and underlined with the bedrock of Kenny Hill Formation. The total dissolved solids (TDS) represented by $Na^+$, $K^+$, $Ca^{++}$, $Mg^{++}$, $Cl^-$, $SO_4^{--}$, and $NO^-_3$ ions were estimated to be more than 4000 $\mu$S/cm at a depth of about 16 m and a distance of 190 m along the resistivity survey line. The groundwater was determined as unfit for domestic purposes.

**الملخص:**

هذه الورقة تناقش نوعية المياه الجوفية في مكب الأوساخ الكائن في منطقة سري بتالينغ في ولاية سلانغور (ماليزيا). لقد استعملت طريقة المقاومية الأرضية للدراسة. أيضاً هنالك دراسات هيدروجيولوجية وهيدروكيميائية استعملت لمعرفة نوعية المياه. لقد تم معرفة الأمـلاح الذائبـة الكليـة بمسـاعدة المقاومية الأرضية. كما أنه تم التعرف على الخزان الجوفي وهو شبه محصور تغطيه طبقة جافة غير حاملـة للميـاه على سطحه ويرقد من فوق سخور غير مسامية تعرف بتكوينات كيني. تم تقدير الأملاح الذائبة الكلية بـأكثر من 4000 ميكروسلمن/سم وعليه تم التوصل إلى أن المياه الجوفية في هذه المنطقة غير صالحة للاستعمالات المنزلية.

## INTRODUCTION

One of the adverse impacts of land filling of municipal and industrial solid wastes is the production of leachate (garbage juice) which can cause significant impairment of groundwater use for domestic water supply as well as surface waters that receive leachate Lee and Jones (1996). The most widely used geophysical methods in hydrogeology are the electrical techniques. The resistivity method is the most popular of all electrical techniques and can determine the aquifer thickness and depth to bed rock. The electrical imaging survey is a relatively new geophysical technique used for environmental surveys and groundwater exploration. Olayink and Barker (1990) and Acworth and Griffith (1985) have demonstrated that resistivity imaging has applications in hydrogeology in basement areas and mapping of strongly faulted areas. One of the more recent developments is the application of practical field equipment and interpretation software for two-dimensional (2D) electrical imaging surveys (Griffith *et al*, 1990); Loke and Barker (1996), which made it possible for such surveys to be carried out routinely on commercial basis. This study was conducted to provide information about the hydrogeology of the area and the groundwater quality in the landfill.

## LOCATION AND GEOLOGY

The Landfill of Seri Petaling is located in Cheras, lying 15 km South of the city centre of Kuala Lumpur (Capital of Malaysia) between latitudes $3^0$ $3.2^{'}$ and $3^0$ $3.5^{'}$ N and longitudes $101^0$ $41.73^{'}$ and $101^0$ $42.6^{'}$ E, covering an area of 21.1 ha. This waste facility started operation in 1979 and was officially closed in 1991 with total amount of waste 7.1 million ton receiving 1500 ton/day. The maximum difference in elevation between the top of the landfill and the surrounding area was estimated to be 28.74 m, which indicate a maximum pressure exerted by the leachate onto the surrounding groundwater and surface water bodies (DOE, 1999). (Fig. 1) shows the location and topography of the site. The climate of the area is tropical equatorial characterized by uniform temperature and high rainfall with mean max. Annual temperature varying from 32.3 to $24.20^0$ C and mean annual rainfall varying from 2137.9 to 2667.7 mm. geologically the area entirely lies within the Kenny Hill Formation, which were investigated by Yin (1961), and believed to be deposited during upper Palaeozoic. Lithologically it consists of interbedded sandstones, shale’s, and mudstones, which are thought to have been deposited in a moderately deep marine environment situated near a large supply of reworked sediments. This landfill is located on tin tailing area, and during the geological survey around the landfill fresh sandstone and phyllite of the Kenny Hill Formation were outcropping to the North West direction of the northern boarder of the landfill.

## MATERIALS AND METHODS

A resistivity imaging survey line ($L$-$L_1$) was conducted to the Eastern side of the landfill on its top (Figure 1). The method used for obtaining a 2 dimensional electrical resistivity image involves measur-ing of the resistance of the ground using OYO McOhm Resistivity Meter. Currents were injected into the ground via two current electrodes located to the exterior of the potential electrodes. The potential differences between the potential electrodes were measured and the resistance of the ground was calculated automatically by the meter. The measured resistances were recorded into a pre-prepared data entry sheet. The electrode configuration used was that of Wenner Array.

Resistance values were converted into apparent resistivity values $\rho_a$ using an equation: $\rho_a = 2\pi$ a R, where a, is the spacing used in the measurement, R, is the resistance of the ground recorded by McOhm OYO Resistivity Meter. The x position of measurement along the resistivity traverse, the electrode spacing and the calculated apparent resistivity values were entered into the data files, which were subsequently used by the RES2DINV (2 Dimensional Resistivity Imaging Interpretation Software). The interpretation program essentially calculates the true resistivity and true depth of the ground from the inputted data file using Jacobian Matrix Calculation and Forward Modelling procedures. The results of the interpretation are displayed as the 2-D electrical resistivity image of the subsurface along the line of survey. The electrical resistivity image of this line will be discussed and compared to those resistivity values obtained from the laboratory measurements for the landfill materials and other earth materials as shown in (Table 1).

The groundwater elevations from the three bore holes at the landfill were determined to be 30.72, 41.58 and 24.04 m for the upstream (AH1), bore hole within the landfill (AH3), and the downstream (AH2) respectively (Fig. 1). These bore holes were drilled to the bedrock (Kenny Hill Formation). Following Todd’s procedure

(1980) the groundwater flow direction was estimated to be towards the downstream bore hole.

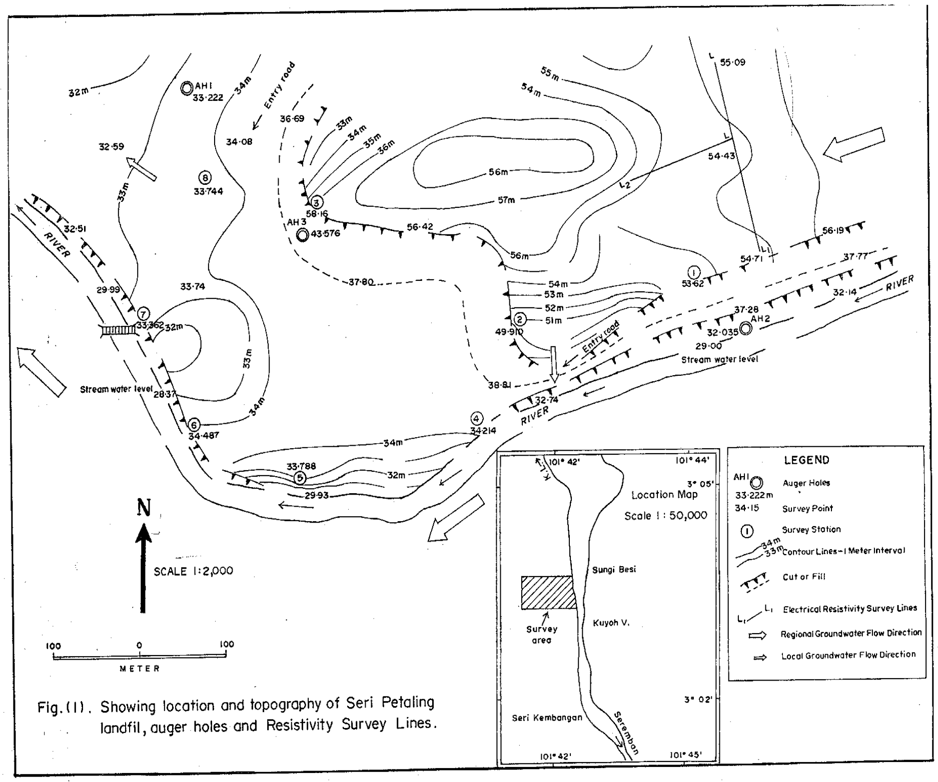


**Fig (1): Location, Topography of Seri Petaling Landfill and Resistivity Survey line L-$L_1$**

The groundwater chemistry was determined by sampling the bore holes located in the upstream and downstream areas of the landfill. The sampling was carried out over a period of six months from August 1998 to January 1999 using an electric pump. Groundwater samples were collected from the boreholes and stored in 1-liter polyethylene plastic bottle containers. The collected samples were then kept in an icebox and sent to the laboratory for preservation and chemical analysis. The samples were preserved under the temperature of 4 $^{0}$ C and acidified with concentrated hydrochloric acid to a pH below 2.0 to minimize precipitation and adsorption on the walls of the container (APHA-AWWA-WEF 1985).

**Table (1): Electrical Resistivity of Earth Materials (Mean ± Standard Deviation)**

| Sampled Materials | Resistivity (Ohm-m) |
|---|---|
| Leachate only collected from the landfill | 2.99 ± 0.002 |
| Sand saturated with leachate from the landfill area | 5 ± 0.04 |
| Fresh waste (plant materials, rubber strands, sand) saturated with leachate | 3.51-4. ± 0.6 |
| Soil saturated with leachate | 3.74 ± 0.25 |
| Rain water only | 73.82 ± 0.13 |
| Sand saturated with rain water | 15.93 ± 1.57 |
| Fresh waste (plant materials, rubber strands, sand) saturated with rain water | 20.92 ± 1.43 |
| Soil saturated with rain water | 9.98 ± 0.64 |
| Clay saturated with brackish water (Pulau Burung, Nibong Tebal, Southern | 0.16 ± 0.04 |

| | |
|---|---|
| Seberang Perai) | |
| Clay saturated with brackish water (Lukut) | 0.143 ± 0.11 |
| Clean sand saturated with sea water (Tioman) | 2.33 ± 1.04 |
| Fresh sandstone | 610 ± 36.1 |
| Phyllite | 304.33 ± 17.89 |
| Hard rock (Sandstone of Kenny Hill Formation) | 651 ± 49.12 |

The groundwater investigation and analysis were carried out for in-situ parameters examined in the field and laboratory chemical analysis. In-situ parameters include pH, temperature, dissolved oxygen and electrical conductivity. These parameters were determined using pH meter with glass electrode, Thermister probe (YSI 58), dissolved oxygen meter, and digital T-LC meter respectively. The laboratory parameters include the major actions, namely $Na^+$, $K^+$, $Ca^{++}$, and $Mg^{++}$ and was determined by Atomic Optical Emission Spectroscopy using induced couple plasma (ICP-2000) spectrometer. Majoranions namely, $Cl^-$, $SO_4^{--}$, and $NO^-{}_3$ were determined using ion chromatographic technique, and chromatography was performed on Alltech chromatograph.

The total dissolved solids (TDS) were represented by $Na^+$, $K^+$, $Ca^{++}$, $Mg^{++}$, $Cl^-$, $SO_4^{--}$, and $NO^-_3$. They calculated over the sampling period (August 1999 to January 2000) for the upstream and downstream bore holes. The corresponding electrical conductivity values were also measured. A relation-ship between total dissolved solids and electrical conductivity was establish-ed using the curve fit statistical program. There was a significant ($P \le 0.01$) positive relationship ($Y = + 256.17\ X + 11.01$, $R^2 = 0.988$) between the TDS and EC (Fig. 2). The established relationship between conductivity and total dissolved solids was then applied to the field data to calculate the TDS distribution along the resistivity survey line. Surfer computer software (Golden Software Inc., 1987) was used to plot and contour the TDS values of the formation.

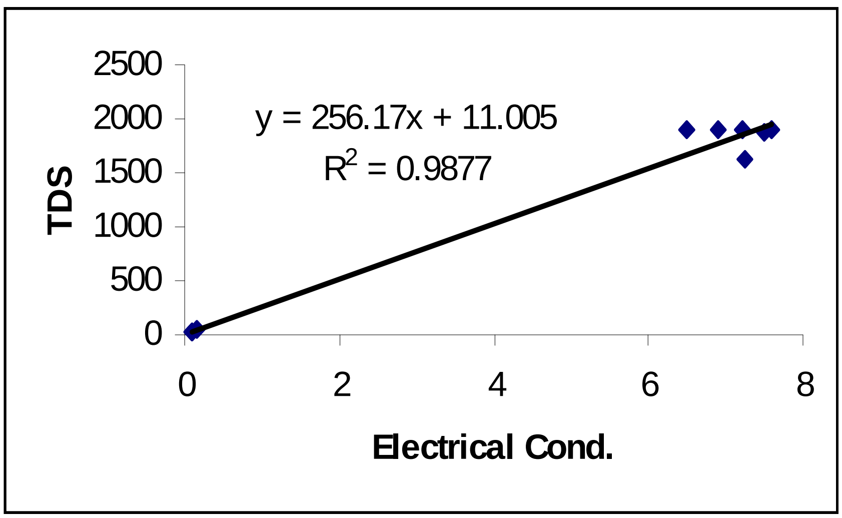


**Figure (2): Relationship between Total Dissolved Solids (TDS) and Electrical Conductivity (EC)**

## RESULTS AND DISCUSSION

The resistivity line ($L\text{-}L_1$) is located on the Eastern direction of the landfill on its top, running South – North direction. The resistivity image of this line is shown in

(Fig. 3). The base point (first electrode position) facing Sungai Kuyoh river where the last electrode position facing Kesas Highway, the line had a length of 240 m and 376 total number of datum points. The resistivity image shows that there is a large zone of decomposing waste saturated with highly conductive leachate with resistivity less than 2.5 ohm m. This zone is found at a depth of 7 m from the top of the landfill and occupying most of the area of the resistivity image. The zone reflects varying degree of waste decomposition where there is a zone of highly decomposing waste at about 185 m from the base point with resistivity less than one-ohm m. The low resistive zone on the middle of the image was interpreted as fresh waste, soil or sand saturated with leachate. The bedrock with resistivity more than 100 ohm m was found at a depth of approximately 35 m. The high resistivity layer on the top of the image (landfill surface) shows the placement of hard rocks and sand materials used for the process of beautification of the landfill for the Commonwealth Games held at Bukit Jalil in September 1998, or can be described as top dry layer of superficial deposits. The resistivity image also shows the possible movement of highly conductive leachate from north to south direction in agreement of the estimated groundwater flow direction.

TDS along the same resistivity survey line vary between 200 to 4000 µS/cm (Fig. 4). By comparing this section to the resistivity distribution along the same line (Fig. 3), high TDS (> 4000 (µS/cm) was observed at a depth of about 7 m and a distance of 205 m along the profile. This area represents the decomposing waste zones with low resistivity values (< 0.5 Ωm). Low TDS was observed in the top layer (dry layer) and at the bed rock (Kenny Hill Formation). The high amount of TDS (> 4000 (µS/cm) along this profile verify the fact of groundwater pollution in this area due to the waste dumping and leachate production. The groundwater in this area is unfit for human consumption due to the existence of high TDS, which is far higher than the amount of 500 µS/cm set by the WHO (1984) guidelines for drinking water.

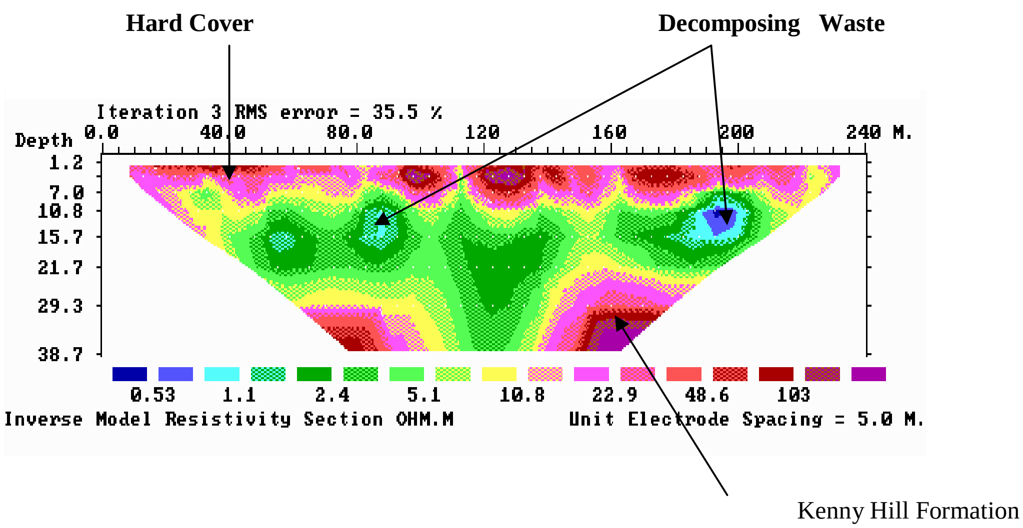


**Figure (3): Resistivity Image along Line L-$L_1$**

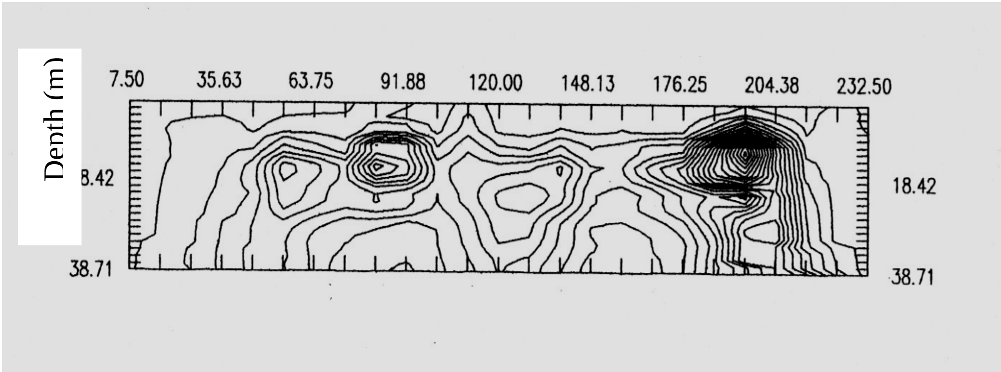


**Figure (4): Total Dissolved Solids Distribution along Line L-L$_1$ (Contours in**

## CONCLUSION

It can be concluded that the groundwater in this landfill is unfit for domestic consumption because of the presence of high total dissolved solids along the survey line. In addition to the resistivity imaging survey is a useful technique for the evaluation of the groundwater quality in waste disposal areas. And it is more useful when combined with the groundwater chemistry and hydrogeology of the area.

## REFERENCES


1- **Acworth, R. I. and Griffith, D. H.,** (1985). Simple data processing of tripotential apparent resistivity measurements as an aid to the interpret-ation of subsurface structure. Geophysical Prospecting, **33**, 861-887.

2- **APHA-AWWA-WEF**, (1985). Standard methods for the examination of water and waste water. 19th ed. Washington D.C.

3- **DOE.,** (1999). Department of Environment. Investigation and assess-ment of municipal landfill sites in the federal territory of Kuala Lumpur. (Unpublished Report).

4- **Golden Software Inc**. (1987). Surfer access system version 3.00

5- **Griffith, D. H., Turnbull, J. and Olayinka, A. I**., 1990. Two-dimensional resistivity mapping with a computer controlled array. First Break, **8**, 121-129.

6- **Lee, G. F., and Jones-Lee, A.,** (1996). Landfill leachate manage-ment: overview of issues. MSW Management, **6** 18-23. Report of G. Fred Lee and Associates, El Macero, California.

7- **Loke, M. H. and Barker, R. D.,** (1996). Rapid least-squares inversion of apparent resistivity pseudosections by a Quasi-Newton method. Geophysical Prospecting, **44**, 131-152.

8- **Olayinka, A. I. and Barker, R. D.,** (1990). Borehole siting crystaline basements area of Nigeria with a microprocessor controlled resistivity traversing system: Ground Water, **28**,178-183.

9- **Todd, D. K.,** (1980). Groundwater Hydrology., Wiley and Sons Inc., New York, USA.

10- **WHO.,** (1984). World Health Organization. Guidelines for Drinking Water Quality, **Vol. 1**, Recommendations, Geneva: WHO.

11- **Yin, E. H.,** (1961). Geology and Mineral Resources of the Kuala Lumpur area (unpublished work), Malaya Geological Survey Department.