JOURNAL OF
ENVIRONMENTAL HYDROLOGY

The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 8 2000

DETECTION OF GROUNDWATER POLLUTION USING RESISTIVITY IMAGING AT SERI PETALING LANDFILL, MALAYSIA

Abdel Latif Mukhtar[1]
Wan Norazmin Sulaiman[1]
Shaharin Ibrahim[2]
Pauziah Abdul Latif[1]
M.M. Hanafi[3]

[1] Department of Environment, Faculty of Science and Environmental Studies, UPM
[2] Department of Physics, Faculty of Science and Environmental Studies, UPM
[3] Department of Soil Science, Faculty of Agriculture, UPM

An electrical resistivity imaging survey, together with the results obtained from ground and surface water hydrochemistry and hydrogeological setting were used to detect pollution and subsurface flow of contaminants from the Seri Petaling Landfill, Selangor, Malaysia. Subsurface flow of leachate was east to west in the eastern sector of the landfill and north to south towards a downstream area. These flows were found to coincide with the general and local groundwater flow directions within the landfill area. A high concentration of contaminants exists in the downstream area coinciding with local groundwater flow. High concentrations of Cl, Na, and K were detected in the downstream area. Also, Ca and Mg are high compared to upstream areas and the river water, probably due to the release of contaminants from the waste body. Heavy metals concentrations are very low and do not show any sign of pollution in the area, although they are relatively high downstream. Leachate is also detected on the western side of the landfill, coinciding with the general eastward groundwater flow.

INTRODUCTION

The electrical resistivity method is the most commonly applied geophysical tool for groundwater exploration as it can determine aquifer thickness and depth to bedrock. It is also capable of determining the quality of groundwater i.e., whether the water is saline, brackish, fresh or contaminated (Zohdy, 1974; Stollar and Roux, 1975; Rogers and Kean, 1980; Urish, 1983). Rogers and Kean (1980) reported the successful monitoring of groundwater contamination at a fly ash disposal site using surface resistivity methods. The method is also capable of determining the subsurface flow of contaminated groundwater resulting from pollution if the polluted water has a distinctive resistivity. Resistivity imaging has been used to map groundwater contamination and for environmental surveys (Griffith and Barker, 1993).

LOCATION, GEOLOGY AND HYDROGEOLOGY

The Seri Petaling Landfill is located in Cheras, about 15 km south of the city center of Kuala Lumpur between latitudes 3º 3.2' and 3º 3.5' N and longitudes 101º 41.73' and 101º 42.6' E and it covers an area of 52 acres (Figure 1). The waste facility started operation in 1979 and was officially closed in 1991 with a total amount of waste of 7.1 million tons.

The maximum difference in elevation between the top of the landfill and the surrounding area was estimated to be 28.74 m, which creates a high groundwater head differential exerted by the leachate

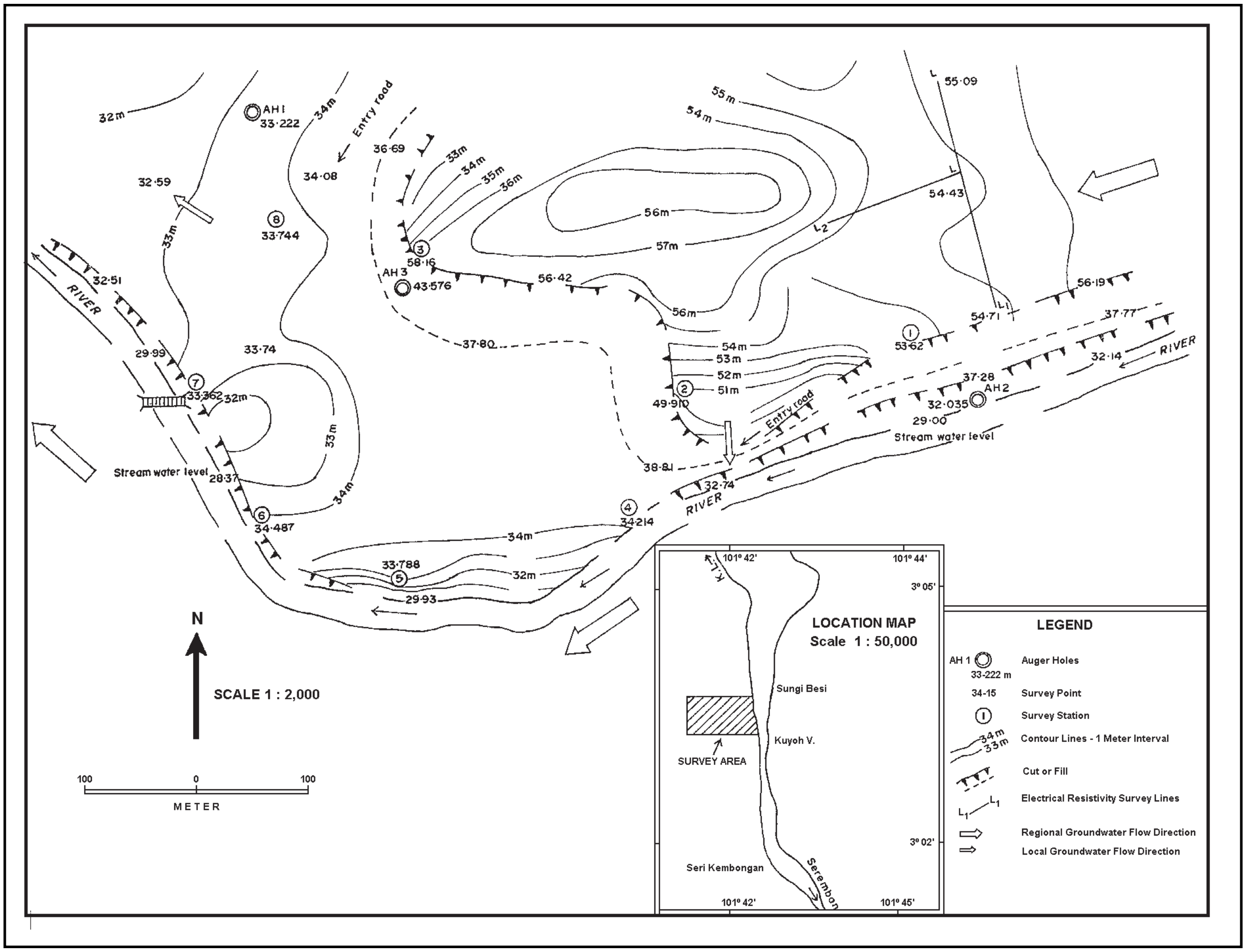


Figure 1. Location and topography of Seri Petaling landfill, auger holes, and Resistivity Survey Lines.

on surrounding groundwater and surface water bodies (Abdul Latif, 1998).

The climate of the area is tropical equatorial characterized by uniform temperature and high rainfall with mean maximum annual temperature varying from 32.3ºC to 24.2ºC and mean annual rainfall varying from 2137.9 to 2667.7 mm. Geologically the area lies entirely within the Kenny Hill Formation (Yin, 1961) believed to be deposited during the upper Paleozoic. Lithologically it consists of interbedded sandstones, shales, and mudstones which are thought to have been deposited in a moderately deep marine environment near a large supply of reworked sediments (Yeap, 1969). The formation is characterized by fracturing and foliation which facilitate groundwater movement. The landfill is located on a tin mine tailing area and, during the geological survey, fresh sandstone and phyllite of the Kenny Hill Formation were found outcropping northwest of the northern border of the landfill. Three boreholes AH1, AH2, and AH3 were drilled upgradient, downgradient, and within the landfill. Measured static water levels were 2.13, 2.10, and 6.18 m below ground surface, respectively.

METHODOLOGY

The method used to obtain a two-dimensional electrical resistivity image involved measuring the resistance of the ground using a McOhm OYO Resistivity Meter. A 250 m multicore cable with 5 m take-out intervals was laid in the ground and 50 electrodes (or less depending on the situation in the field) were connected at the take-outs. The electrodes were connected to a central switching system. Four electrodes were chosen at any one time for resistance measurements. Currents were injected into the ground via two current electrodes located to the exterior of the potential electrodes. The potential difference between the potential electrodes was measured and the resistance of the ground was calculated automatically by the meter. The measured resistances were recorded on a data entry sheet. The electrode configuration used in the survey is the Wenner Array (Figure 2). Resistance values were converted into apparent resistivity values ρ_a using the equation:

$$\rho_a = 2\pi a R$$

where (a) is the spacing used in the measurement and (R) is the resistance of the ground recorded by the McOhm OYO Resistivity Meter. The measurement position along the resistivity traverse, the electrode spacing and the calculated apparent resistivity values were entered into 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 input data file using a Jacobian Matrix Calculation and forward modeling procedures. The results of the interpretation are displayed as a 2-D electrical resistivity image of the subsurface along the line of the traverse. In this study two resistivity survey lines were located on the

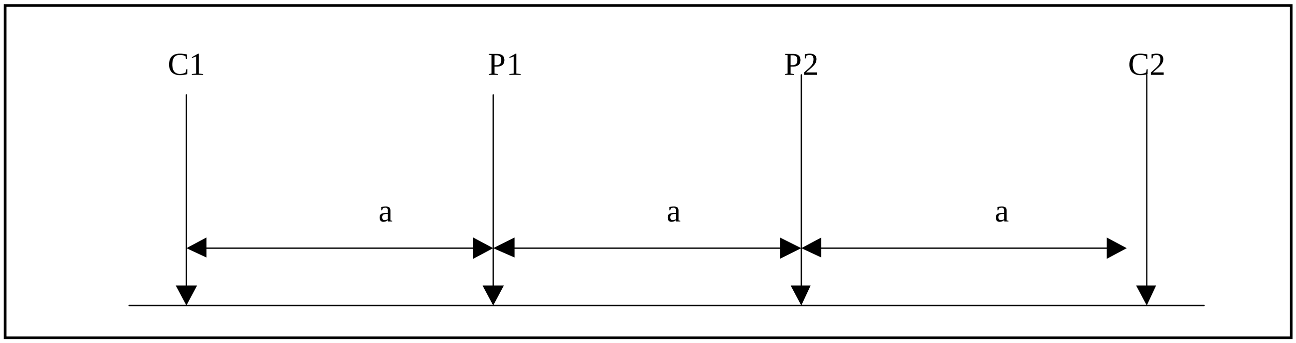


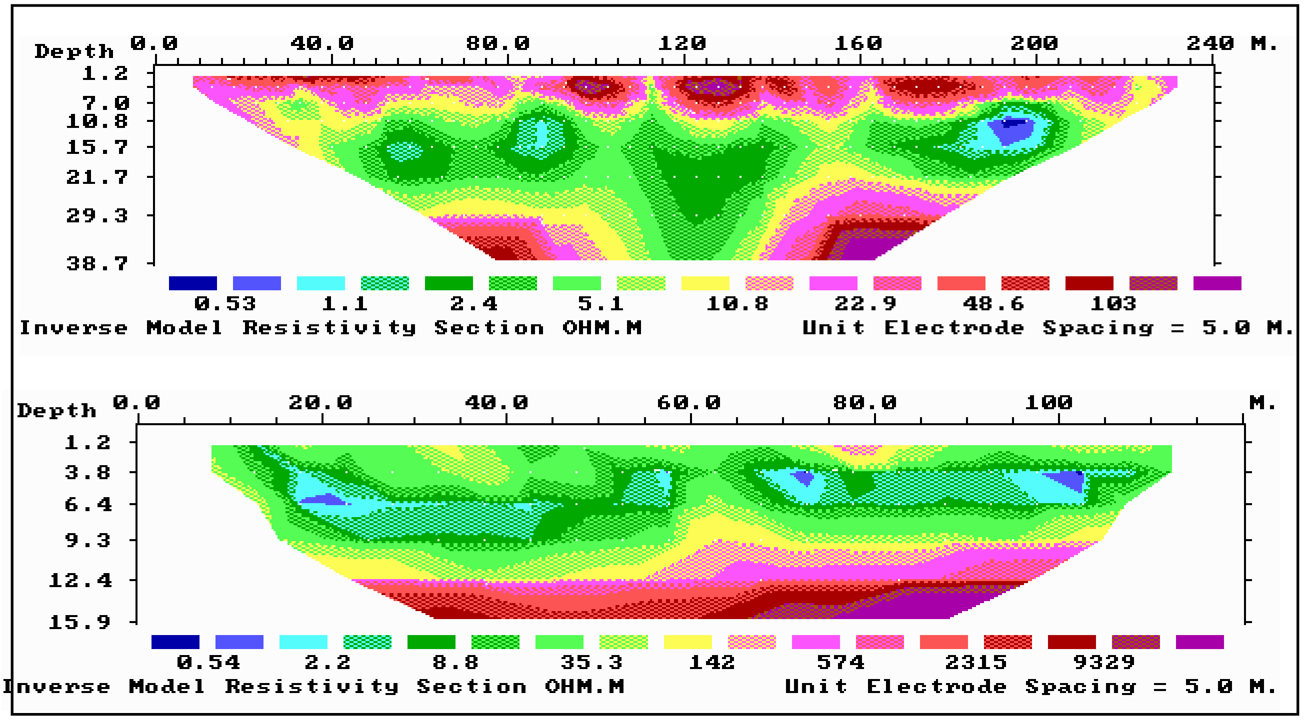
Figure 2. Electrode configuration (Wenner Array). (a, is the electrode spacing; C1, C2 current electrodes; P1, P2 potential electrodes).

top of the Seri Petaling Landfill, line L-L1 on the eastern side of the landfill running south to north with a length of 245 m, and line L-L2 approximately perpendicular to L-L1 with a length of 125 m. The electrical resistivity images of these two lines will be discussed and compared to resistivity values obtained from laboratory measurements for the landfill material and other earth materials as shown in Table 1.

RESULTS AND DISCUSSION

The inverse model for electrical resistivity data obtained along line L-L1 is shown in Figure 3. The base point (first electrode position) faces the Sungai Kuyoh river; the last electrode position faces Kesas Highway. The line has a length of 480 m and 376 data points. The inverse model shows that there is a large zone of decomposing waste saturated with highly conductive leachate with a resistivity less than 2.5 ohm-m. This zone is found at a depth of 7 m from the top of the landfill and occupies most of the area of the model section. It reflects varying degrees of waste decomposition. A zone of highly decomposing waste exists at about 185 m from the base point with a resistivity less than 1 ohm-m. The low resistive zone on the middle of the section can be interpreted as fresh waste, soil or sand saturated with leachate. Bedrock with resistivity of more than 100 ohm-m is found at a depth of approximately 35 m. The high resistivity layer on the top of the section (landfill surface) shows the placement of hard rocks and sand materials used for beautification of the landfill for the Commonwealth Games in September 1998. The model section also shows the possible movement of highly conductive leachate from north to south where a highly conductive zone on the northern side is located near the surface of the landfill. This zone is located deeper on the southern side following the general trend of regional groundwater flow. This leads to contamination of groundwater and nearby surface water in this direction (downgradient direction), which was supported by the results of chemical analysis carried out for the upgradient and downgradient boreholes and the river water as shown in Table 2.

Table 1 shows very high concentrations of chloride (Cl), sodium (Na), and potassium (K) ions in



Figures 3 and 4.

Table 1. Electrical Resistivity of Earth Materials *

Sampled Material	**Resistivity (Ωm)**
Leachate only	2.994
Sand saturated with leachate	4.97-5.04
Fresh waste (plant materials, rubber strands, sand) saturated with leachate	6.03-7.16
Soil saturated with leachate	3.15-4.00
Rain water only	73.88
Sand saturated with rain water	14.36-1750
Fresh waste (plant materials. rubber strands, sand) saturated with rain water	19.71-22.50
Soil saturateed with rainwater	9.30-10.57
Clay saturated with brackish water	0.12-0.20
Clean sand saturated with sea water	1.5-3.5
Fresh sandstone	600
Phyllite	300
Hard rock	>600

* After (Shaharin, 1998).

the downgradient area compared to surface water and the upgradient borehole. High pH values downgradient indicate that the landfill is now probably in its methanogenic phase and these inorganic pollutants were probably released from the landfill during its acidic phase of development. Heavy metals are found in very low concentrations and do not reflect pollution. They are more concentrated downgradient, coinciding with the general trend of the groundwater flow.

Line L-L2 (Figure 3) trends west to east approximately perpendicular to line L-L1, and it has a length of 125 m and a total of 92 data points on the top of the landfill. The first electrode is located at the western end. Compared to resistivity values shown in Table 1, the inverse model section shows that there are three distinctive zones of decomposing waste saturated with highly conductive leachate, and very low resistivity zones, with resistivity less than 1 ohm-m. These zones are surrounded with low resistive materials varying from 1 to 8 ohm-m, which can be interpreted as fresh waste materials together with sand and soil materials saturated with leachate.

There are two low resistive zones extending from the middle of the inverse model in the east and west directions. The one at the eastern side is found at a depth of 4 to 6 m from the top of the landfill, and the one at the western side is located at 5 to 8 m depth. This can be correlated to the general groundwater flow direction in the area from east to west (Figure 1), or it can be related to the structural and lithological conditions along this resistivity line. Bedrock with a resistivity greater than 100 ohm-m is located at a depth of 9 m at the eastern side and more than 10 m at the western side, probably controlled by the undulating topography of the bedrock. This prevailing situation shows the use of the resistivity imaging technique as a tool for lithological and structural interpretation.

Table 2. Chemical Composition of Groundwater and Surface Water

Parameter	**Upstream**	**Downstream**	**River water**
pH	5.66	7.87	7.36
Temp. (C^0)	29	33.1	32.7
Conduct. (μS/c)	0.096	7.52	0.38
Na (ppm)	8.25	380.9	16.72
K (ppm)	5.00	337.89	8.29
Ca (ppm)	3.27	73.04	24.05
Mg (ppm)	0.18	6.61	2.42
Zn (ppm)	0.02	0.03	0.01
Cu (ppm)	ND	0.02	0.0005
Cr (ppm)	ND	0.01	0.01
Cl (ppm)	10.95	838	21.28
F (ppm)	0.04	ND	0.17

ND, not detected.

CONCLUSION

It can be concluded from the resistivity images of lines L-L1 and L-L2 that there are two possible subsurface flow directions for the leachate, from east to west and from north to south. These leachate flow directions coincide with or run parallel with the general and local groundwater flow directions. Also the very high concentrations of Na, K, and Cl ions in the downstream area are possibly due to the effect of the leachate migrating from the waste body facilitated by high topography and its alteration of groundwater flow direction.

ACKNOWLEDGMENT

The authors wish to extend their thanks to three colleagues who kindly agreed to review this manuscript.

REFERENCES

Abdul Latif, P.; Investigation and Assessment of Municipal Landfill Sites in the Federal Territory of Kuala Lumpur, Malaysia (unpublished report), 1998.

Griffith, D. H. and R. D. Barker; Two-dimensional resistivity imaging and modelling in areas of complex geology: Journal of Applied Geophysics, 29, 211-226, 1993.

Rogers, R. B. and W. F. Kean; Monitoring groundwater contamination at a fly ash disposal site using surface electrical resistivity methods: Ground Water, 18, 472-478, 1980.

Shaharin, I.; Investigation and Assessment of Municipal Landfill Sites in the Federal Territory of Kuala Lumpur (unpublished report), 1998.

Stollar, R. and P. Roux; Earth resistivity surveys-a method for defining ground water contamination: Ground Water, 13, 145-150, 1975.

Urish, D. W.; The practical application of surface electrical resistivity to detection of ground water pollution:

Ground Water, 21, 144-152, 1983.

Zohdy, A. A. R.; Application of surface geophysics to groundwater investigations Chapter D1, electrical methods, techniques for water resource investigations of the U.S. Geol. Surv., 1974.

Yeap, E. B.; ‘Geology of Petaling jaya-Salak South area, Selangor, unpublished honour thesis, University of Malaya, 1969.

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

ADDRESS FOR CORRESPONDENCE
Abdel Latif Mukhtar Ahmed
Department of Environment
Faculty of Science and Environmental Studies
Universiti Putra Malaysia
43400 UPM Serdang
Selangor, D. E.
Malaysia

E-Mail: aaia38@hotmail.com