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Resistivity Imaging for Mapping of Groundwater Contamination at the Municipal Landfill La Chureca, Managua, Nicaragua

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SUMMARY

The purpose of this study was to map and describe groundwater contaminations at the La Chureca landfill. The groundwater level in the landfill is higher than in the surrounding area creating a local deviation from the regional groundwater flow. Due to this the contaminated groundwater from the landfill spreads out in the nearby soil and groundwater. The resistivity imaging results clearly show a top layer of around 10 metres thickness with low resistivity, where the resistivity has an inverse correlation with distance to the landfill. The soil samples show that the upper 10 m of the soil consists of loose permeable volcanic ashes with high water content, which are followed by a compact impermeable layer of tuff. The correlation between low resistivity and contaminated groundwater is confirmed by chemical analyses of groundwater samples. The compact layer of tuff appears impermeable enough to stop the contamination from penetrating deeper than approximately 10 m, which is supported by the resistivity imaging that show no traces of low resistivity below the top layer. Based on the combined results the contamination plume seems to stretch around 400 m in the southern direction and not more than 1000 m in the western direction.

Introduction

Emissions from landfills can be divided into three different physical phases; particles, gases and contaminated waters (leachates). The major local environmental problem is discharge of leachates into surrounding ground and surface waters (Christensen et al., 1992).

In developing countries the lack of resources are the key issue for waste and landfill management. Disposal of waste in to landfills is a cheap method and in developing countries it will continue to be the dominant method of waste disposal for the foreseeable future. The most common way of waste disposal in developing countries is open dumping (Rushbrook, 1997; Visanathan et al., 2003). The characterization of waste is usually poor and hazardous waste may be co-disposed with non-hazardous wastes. Dump sites are usually uncontrolled, creating considerable health, safety and environmental problems (Pugh, 1999). However, in developing countries, disposal in to landfills is considered to be the most important method of waste disposal and the closure or upgrading of existing sites is therefore one of the most important steps towards sustainable waste disposal (Visvanathan et al., 2003).

In Managua, the capital of Nicaragua, most of the solid waste is disposed in to an open dump, the La Chureca Landfill. Only a few percent of the solid waste generated in Managua is recycled by waste collection crews and scavengers living at the landfill. The operation of the landfill started in 1967 and today it is the largest in Central America. Six days a week it receives waste from the whole city of Managua (approximately 1200 tons each day). The plan is to close the landfill in 2013 (Pomares and Flyhammar, 2006). The landfill is located at the shore of Lake Managua and contaminations of surrounding ground and surface waters have been reported by Miranda (1995).

The purpose of this study was to map and describe groundwater contaminations at the La Chureca landfill. A Minor Field Study (MFS) was carried out at the Department of Engineering Geology, Lund University, Sweden in cooperation with Centro de Investigaciones Geocientificas, Universidad Nacional Autónoma de Nicaragua during the interface of the rain and the dry season (October to December) in 2005. Resistivity surveys together with analysis of soil and water samples were used to map and characterize ground water contaminations at the landfill.

Site description

The investigation site is located in the grasslands SW-W of the La Chureca landfill (Figure 1). The landfill covers an area of approximately 40 ha and is delimited by Lake Managua to N and NE, which is situated 40 m.a.s.l.. The climate is tropic (Kogyo, 1995).

The geology is characterised by several periods of extremely intense volcanic activity. In the vicinity of Managua the first 8-10 meter of the geological sequence (the Managua sequence) consists of poorly consolidated volcanic deposits from volcanic eruptions in the area during the last 25 000 to 35 000 years. The Managua sequence is followed by the Las Sierras group consisting of Tertiary and Quaternary basaltic tuffs and mudflows (Bice, 1985).

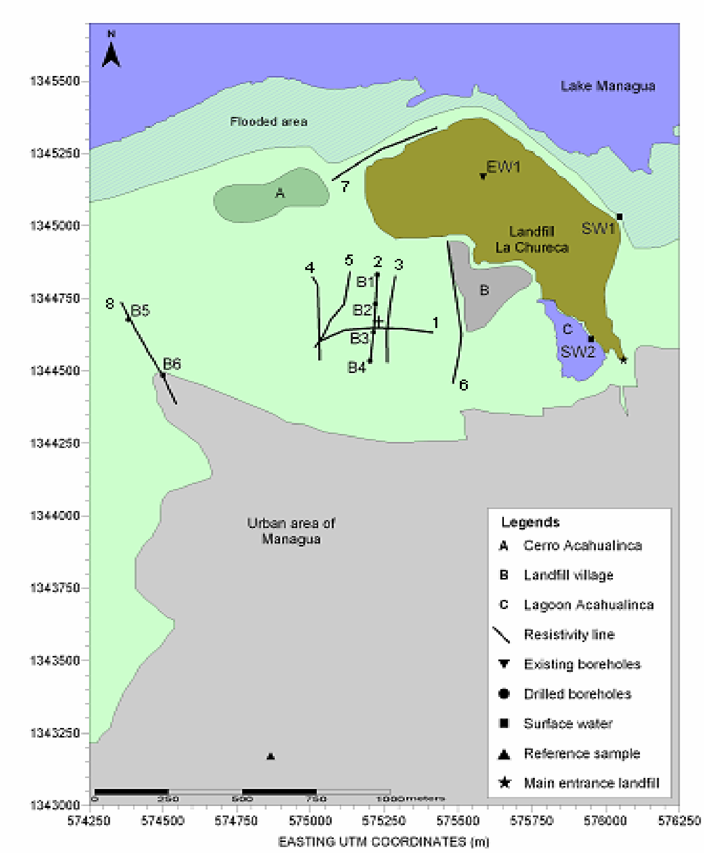

Figure 1 Map of the investigation site at the La Chureca. Landfill. The position of resistivity lines (1-8), soil samples and ground water samples (B1-B6), reference ground water sample (RS), leachate water sample (EW1) and surface water samples (SW1 and SW2) are marked.

The regional ground water flow in the so called Managua aquifer is from the volcanoes in the south towards the lake in the north. Hence, the investigation site is placed in a discharge area. The hydraulic conductivity of the aquifer varies between 3-33 m/day (Norman, 1991).

Methods

Resistivity surveys were performed with the multi channel data acquisition system ABEM Lund Imaging System. Eight lines (Figure 1), each between 300-500 m long and with a maximum investigation depth of 70 m, were measured. The inverted models were created using Res2dinv, and the results presented as 2D resistivity cross sections.

The resistivity sections were used as a base for selecting locations for drilling and sampling. Geology samples were collected during drilling along resistivity line 2 and 8 (Figure 1) to characterize different layers in the geological sequence The drilling was preformed with a geotechnical drilling track vehicle and a hand drill at 6 different locations (B1-B6), to depths between 3 and 11 meters.

Water samples were collected from existing wells situated upon the landfill (EW1) and a few kilometres south of the investigation site (RS), observation pipes close to the landfill (B1-B3 and B5), Lake Managua (SW1) and Acahualinca Lagoon (SW2). The water quality was determined by analyzing parameters such as temperature (T), pH, redox potential (ORP), chemical oxygen demand (COD), electrical conductivity (EC) and chloride (Cl^-).

Results and discussion

The ground water level within the landfill was higher than the ground water level in the surrounding grass lands and the water level in Lake Managua and the Acahualinca Lagoon, indicating a local ground water flow from the landfill towards the surroundings.

The resistivity survey identified a general pattern of the electrical properties of the geological sequence within the investigation site, showing a zone with lower resistivity roughly within the top 10 meters (Figure 2). However, within this zone there is also a positive correlation between the resistivity and the distance to the landfill. The resistivity values are generally higher with less spatial variations along line 6 and 8 compared to line 1-5. Line 6 is located W of the oldest parts of the landfill, while line 8 is located 1000 m WSW of the landfill.

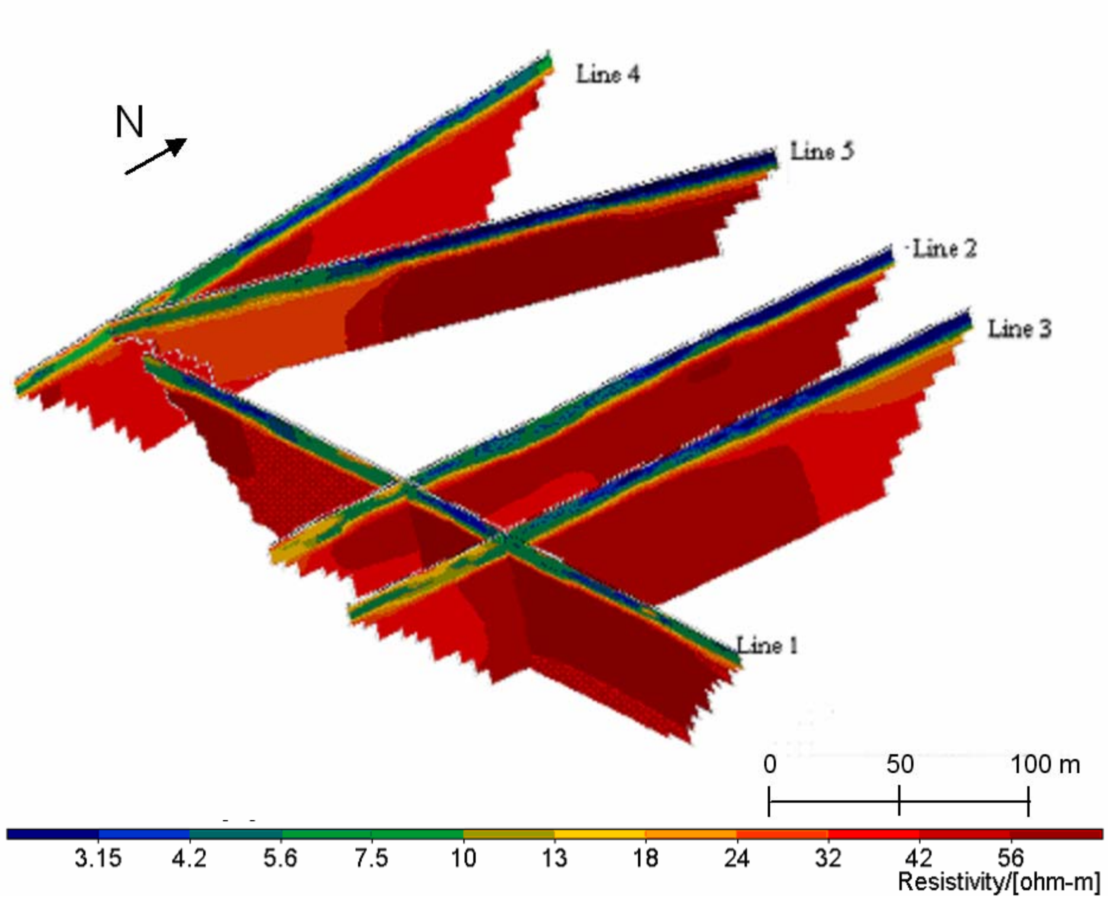

Figure 2. Fence diagram showing the inverted model sections from resistivity line 1-5.

Soil samples from resistivity line 2 showed a geological sequence starting with a layer of organic soil, followed by different layers of permeable volcanic sediments of scoria and pumice. In one of the boreholes (B1), a compact layer of tuff was found at 10.4 meters. This correlates well with the increase in resistivity at that depth.

The composition of water samples at different distance from the landfill showed decreasing concentrations of dissolved ions, exemplified by the electrical conductivity (EC) and Cl in Table 1, with increasing distance from the landfill. Many of the analysed parameters in the ground water collected at line 8 (B5) are within the same range as the reference sample (RS) indicating a low degree of contamination. However, the results in table 1 indicate that even ground water close to the landfill seem to be oxidized with low concentrations of dissolved COD and a high ORP in contrast to the COD concentration and ORP in leachate (EW1).

Table 1: Water sample analysis results.

Parameter	Unit	EW1	B1	B2	B3	B5	SW1	SW2	RS
Temp.	**°C**	33	31	33	31	29	30	29	30
pH	**-**	6.6	7.6	8.1	7.5	6.0	7.4	7.8	7.3
ORP	**mV**	-110	250	230	205	250	190	180	280
COD	**mg/l**	442	55	52	40	66	52	32	0
EC	**mS/cm**	5.6	13	5.5	2.8	0.71	1.4	0.31	0.54
Cl^-	**mg/l**	1400	2800	640	150	120	50	7	75

Conclusions

The groundwater level in the landfill is higher than in the surrounding area creating a local deviation from the regional groundwater flow. Due to this the contaminated groundwater from the landfill spreads out in the nearby soil and groundwater. The resistivity imaging results clearly show a top layer of around 10 metres thickness with low resistivity, where the resistivity has an inverse correlation with distance to the landfill. The soil samples show that the upper 10 m of the soil consists of loose permeable volcanic ashes with high water content, which are followed by a compact impermeable layer of tuff. The correlation between low resistivity and contaminated groundwater is confirmed by the chemical analyses of groundwater samples. The compact layer of tuff appears impermeable enough to stop the contamination from penetrating deeper than approximately 10 m, which is supported by the resistivity imaging that show no traces of low resistivity below the top layer. Based on the combined results the contamination plume seems to stretch around 400 m in the southern direction and not more than 1000 m in the western direction.

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