Journal of Applied Geophysics 138 (2017) 40–49

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

The examination of the spread of the leachates coming out of a solid waste disposal area on the ground with geophysical and geochemical methods (Sivas, Turkey)

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ARTICLE INFO

Article history:
Received 21 July 2016
Received in revised form 29 December 2016
Accepted 10 January 2017
Available online 12 January 2017

Keywords:
DCR
2D, 3D, inversion
Apparent electromagnetic conductivity
Disposal area
Leachate
Heavy metal
Pollution

ABSTRACT

This study has been conducted in the irregular solid waste disposal area in the city of Sivas. The pollution spread formed by the leachates coming out of the disposal area has been examined with geophysical and geochemical works in this study. For this reason, the spread of the leachate pollution expanding in different geological units at both sides of a creek on the ground has been examined. For this purpose, the pollution spread has been examined with the methods of Direct Current Resistivity (DCR) and Electromagnetic Conductivity (EMC) and soil analyses. In the DCR method, 2D inversion of each sounding-profile datum measured alongside the lines parallel to each other and 3D inversion of the data measured in all the lines have been used in the interpretations. Apparent conductivity map has been attained from EMC measurements. The results of heavy metal analyses in the soil samples taken alongside the Haçin Creek have been assessed with the Spider diagram method. It has been determined that the flow of the leachate from geophysical models is in a SE direction and towards Kızılırmak and it continues vertically deeper than 4 m. In addition, it has been understood that the flow direction of the leachate is inspected by the geological structures. It has been understood from the geochemical results that the pollution in the soil stems from the leachate. In this way, it has been observed that the underground and surface water resources in the territory are under the threat of the pollution occurring due to the leachate.

1. Introduction

The waste waters and rain waters coming out of irregular disposal areas distill the chemicals in the wastes and bear the polluters further. These waters that include chemical minerals pollute wide areas when they mix with surface or groundwaters. Therefore, these leachates stemming from the irregular disposal areas form an important environmental problem today. The studies of environment geophysics have an important place in the determination of these problems. The spread of the leachate on the ground is also examined with geophysical methods. Electrical methods are at first place and electromagnetic methods are at second place among these methods. The DCR method is a method that is sensible in determining the conductive zones in which there is the entrance of leachate to the groundwater or soil from the disposal areas; this is because, the ion concentration in the soil and groundwater on the soil grounds increases with the impact of the leachate. For this reason, the DCR method and EMC method are frequently used in the determination of the pollution spread in the shallow studies especially with the purpose of environmental monitoring (Nobes et al., 2000; Rucker and Sweeney, 2004; Rucker and Fink, 2007). One of the most important studies in the issue of leachate monitoring techniques belongs to Frangos (1994). Frangos has used the DCR method in the determination of leachate places. In this issue, successful studies have been conducted especially in open (irregular) solid waste disposal areas (Laine, 1991; Frohlich et al., 1994; Frangos, 1997; Petrovsky et al., 2001; Charlesworth and Lees, 2001; Rucker and Fink, 2007; Frohlich et al., 2008; Lopes et al., 2012). Afterwards, Aaltonen (1998), Aaltonen and Olofsson (2001) and Olofsson et al. (2006) have developed the monitoring systems for the leachates occurring in the disposal areas. In addition, Dahlin (1996) has attained very successful results in the determination of the old filling areas and possible leakage ways via the DCR method. Binley and Beven (2003) and Rubin and Hubbard (2005) have revealed the models regarding the monitoring of the hydrogeophysical properties in vadose zone, pollution or water flow. Karlık and Kaya (2001) and Kaya et al. (2007) have conducted studies regarding the mapping of the groundwater pollution by using the electrical-electromagnetic methods together in the open disposal areas and close surroundings. Rucker and Fink (2007) using these two methods together have examined the distribution of the liquid inorganic wastes via DCR and EMC methods. Rucker et al. (2009a, 2009b, 2009c, 2012) also have many similar 2D-3D studies regarding the distribution of different pollution types in disposal areas, leachate monitoring and displaying. It

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http://dx.doi.org/10.1016/j.jappgeo.2017.01.013
0926-9851/

has been shown with the use of different algorithms conducted by Neyamadpour et al. (2009) and with the technique developed by Dahlin et al. (2002) that 3D inversion is very beneficial in the environmental applications. In addition, according to Rucker et al. (2009c), pole-pole, pole-dipole and dipole-dipole arrays are more convenient in attaining a 3D model.

2D inversion of DCR data has been made and the results of the horizontal and vertical spread of leachate pollution have been discussed in most of these aforementioned studies. 3D studies are in majority of the studies in which DCR and EMC methods have been used together.

The examination area subjected to this study is the irregular solid waste disposal area and close surroundings in the city of Sivas taking place 15 km south of the Sivas-Erzincan highway (Fig. 1). The geophysical study area takes place in the north-western section of the creek drainage area. The disposal area in the city of Sivas in which unconscious (random) storage was made was used for 16 years. The majority of the rock types taking place in this area are aquifers or at least they have a limited quality of aquifers (Atmaca, 2004; Yılmaz and Atmaca, 2006). Groundwater level is 4 m in some places and it is close to the surface by as much as 2–3 m in the south of the waste area (EIA, 2005; Yılmaz and Atmaca, 2006). For this reason, the region is under a serious pollution threat continuing for years due to the leachates. The leachates get mixed with the creek in the waste area. This creek is connected to a bigger river, the Kizilirmak River, and it pollutes a wide area. Prior studies have been conducted for the purpose of examining this problem in the issues of environmental geology and environmental geotechnics (Atmaca, 2004; Yılmaz and Atmaca, 2004; Yılmaz and Atmaca, 2006). However, this study conducted with the use of DCR and EMC methods in the area is the first geophysical study. Such a study is also necessary in terms of monitoring the disposal area EIA (Environmental Impact Assessment) operation process and inspecting the occurring pollution on time.

2. Geology of study area

The disposal area and the dominant geological units in its surroundings are the Selimiye Formation (Ts), Hafik Formation (Th) and Quaternary (Qa) aged formations (Fig. 2).

The Selimiye Formation is the lowest level outcrop in the disposal area and it is predominantly represented with Oligocene-Miocene aged terrestrial fractured rocks (Kurtman, 1973; Yılmaz and Yılmaz, 2005). This unit generally consisting of violaceus, red or sometimes speckled gray pebble stone, sand stone, silt stone and mudstone intercalation (Ts, SW-ML) has been separated into various levels (Atmaca, 2004; Yılmaz and Atmaca, 2006). Tsa-e taking place at the bottom level consists of a level clay stone and sand stone intercalation and e level main pebble stone, sand stone, clay stone, mudstone and shale intercalation. Tsf consists of the intercalation of f level layered gypsum and fine grained fractured levels. Tsg being the g level taking place at the top consists of pebble stone and graveled sand stone. Sedimentary structures such as gradation and cross bedding are seen in the fractured levels. The rock types are mostly fractured and jointed and they reflect a porous and permeable structure. The disposal area dominantly takes place on e and f levels (Atmaca, 2004; Yılmaz and Atmaca, 2006).

The Hafik Formation (Th) is an Oligo-Miocene aged unit presenting a wide spread in the Sivas basin and mostly consisting of massive gypsums (Yılmaz, 1984; Yılmaz and Yılmaz, 2005; Aktimur et al., 1988). This unit mainly consisting of massive gypsum and gypsum interfingered fractured rocks (Th, ZK-OSK) is in a structure that is easily dissolved with the impact of the atmospheric processes. Anhydride ($CaSO_4$) and rock salt (NaCl) also take place as well as gypsum ($CaSO_4 2H_2O$) among the evaporate group minerals in the composite of the Hafik formation. These evaporate group minerals are easily dissolved when they come in contact with water. When water leaves the medium, these minerals could get crystallized again or new minerals may occur if the ions change their places or the minerals may transform into each other. Therefore, the water quality in the basins in which the rock types formed by these minerals are dominant in the medium gets distorted easily and the surface and groundwaters in which the evaporate group minerals dissolve are naturally polluted (Atmaca, 2004; Yılmaz and Atmaca, 2006).

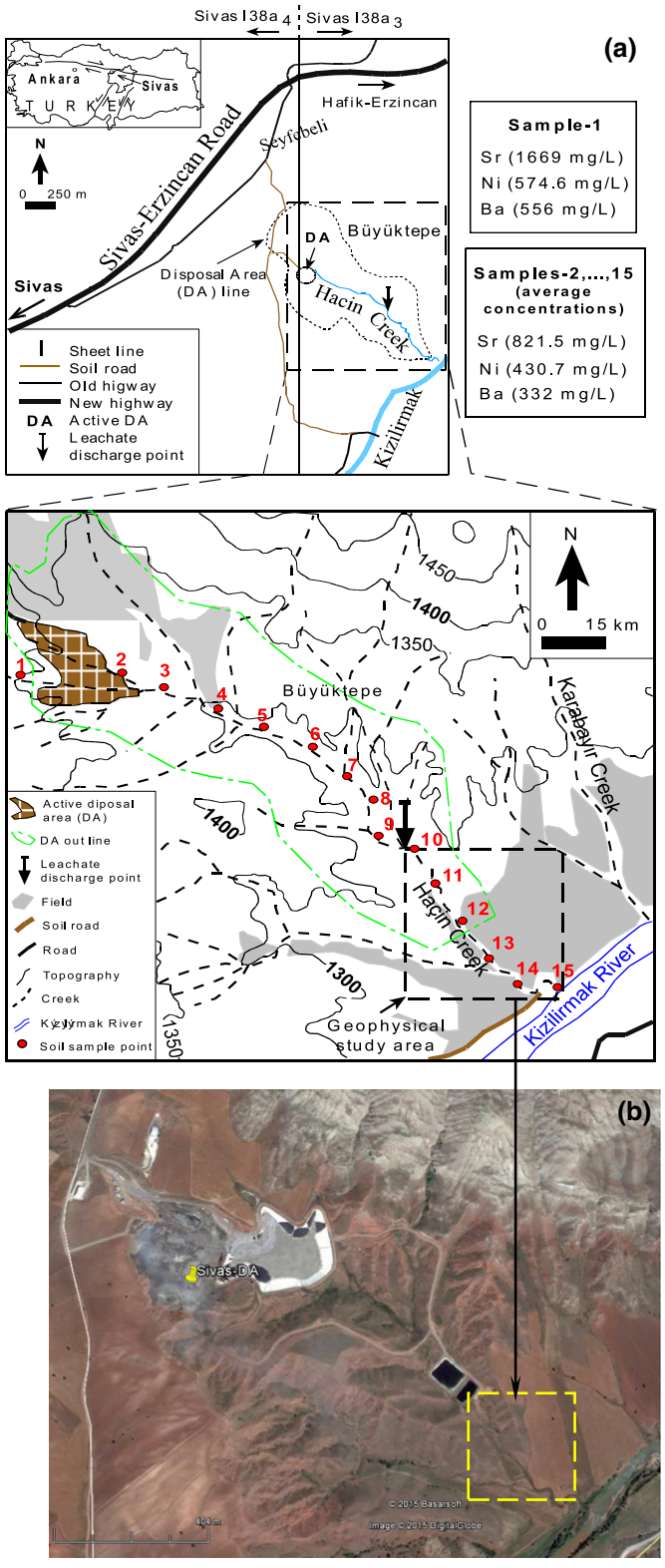

Fig. 1. a) The study area and the soil sample points on the topographic maps. b) The satelitte photo of the study area. (www.googleearth, 15.04.2015).

Quaternary aged alluviums and soil cover are observed in the river valleys and in some plains as a thicker level (Qa, CL-ML-GW-SW). The