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Modelling of Heavy Metal Pollution in an Unregulated Solid Waste Dumping Site with GIS

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Abstract: In this study, heavy metal pollution and distribution on leachate and soil have detected with the samples which were collected from the unregulated dumping site area in Eskisehir/Turkey. These samples were analyzed for pH, cadmium, copper, iron, lead, nickel and zinc in spring, summer and autumn seasons. The sampling points were marked on an air photograph by using GeoMedia Professional 6.0 software. Analysis results obtained from the sampling points were interpolated by using SURFER 7.0 software and distribution maps were performed. These maps were reregistered by using GeoMedia Professional 6.0 and compared with the air photograph and geological units. As a result, it was seen that heavy metal concentrations were increasing towards to agricultural areas in the northeast of the dumping site. When physical-chemical analysis results and findings obtained from GIS are evaluated with together, it is said that the Eskişehir dumping site is going to cause environmental and ecological problems in both short and long term and this site should be urgently rehabilitated.

Key words: Dumping site, geographic information systems, leachate, soil and Turkey

INTRODUCTION

Turkey has a unique geographic position at the crossroads between Europe and Asia. The country covers 779,452 km^2. According to TUIK (Turkish Statistical Institute, TURKSTAT), the population of Turkey is 67 million in 2000. Turkish Statistical Institute has been collecting data on waste by applying annual surveys to industrial establishments and municipalities. According to the results of Municipality Solid Waste Statistics Questionnaire of the year 2004 which was administered by TUIK, the amount of solid waste collected was 12.3 million tons in the summer of 2004 and 11.9 million tons in the winter of 2004, with an annual amount of 24.2 million tons. According to these results, the average daily solid waste quantity per capita was 1.34 kg in average. Among the total amount of 24.2 million tons of solid waste collected in 2004 from the municipalities which give solid waste service, 45% of the disposal was to the municipal dumping sites, 29% was to landfills, 15% was to metropolitan municipality dumping sites, 3% to other municipal dump sites, in addition, 1% was composted and 7% was other methods (Ministry of Environment and Forestry of Turkey, 2008).

The most used method to solve solid waste problem in Turkey is random storage of wastes on a suitable area. Landfilling, composting, incineration or recycling methods are not widespread. Site selection for landfill areas also proves to be one of the important problems. Therefore, it's focused on the rehabilitation of the unregulated dumping sites and construction of new landfills and then, composting, incinerating and recycling have discussed.

Thirty two engineered sanitary landfills with complete engineering controls, i.e. lining, leachate and gas collection and aftercare monitoring are under operation in Turkey. In this situation, pollution of present unregulated dumping sites should be determined in terms of the functionally of new systems which are going to be established. Also, unregulated solid waste dumping sites have played a part in the pollution of Turkey. The types of pollution originated from these sites are polluted water due to leachate; air pollution due to landfill gas; health effects

Leachate causes to the pollution of the soil, surface water and groundwater pollutions. Generally, leachate flows to base of landfill site and reaches to underground layer. Aquifer under the landfill site can be polluted depending on the structure of the layers and leachate collection system. Otherwise, the soil which is an important component of landfill site is a media where is deposited of polluted materials in nature. Because of being continuously transportation to other media (an air, ground and surface water) from this media by evaporation, erosion and infiltration, this component is a natural source which is needed to carefully monitor. In this content, soil characterization (properties of the soil bed, percent of the clay, mineral structure of the clays,

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structure of the soil, porosity, moisture content of the soil and pH of the soil etc.) is very important on the amount and distribution of pollution. Also, because of the solid waste characteristics (batteries, drugs, various dyes etc.), heavy metals can be passed through the soil. Then, these heavy metals can infiltrate to the ground and surface waters and therefore, heavy metals which go through the plants can reach to humans according to the food chain (Taşeli, 2007; El-Fadel *et al.*, 1997; Daskalopoulos *et al.*, 1997; Tchobanoglous *et al.*, 1993).

In this study, heavy metal pollution and distribution on leachate and soil have detected with the samples which were collected from the unregulated dumping site area in Eskisehir/Turkey. These samples were analyzed for pH, cadmium, copper, iron, lead, nickel and zinc in spring, summer and autumn seasons. The sampling points were marked on an air photograph by using GeoMedia Professional 6.0 software. Analysis results obtained from the sampling points were interpolated by using SURFER 7.0 software and distribution maps were formed. These maps were reregistered by using GeoMedia Professional 6.0 and compared with the air photograph and geological units.

Solid Waste Management in the City: The composition of solid wastes has varied according to socio-economic conditions, location, season, waste collection and disposal methods, sampling and sorting procedures, etc. Several distinct differences which are typical of wastes generated in the developed countries versus developing ones can be readily discerned. The solid waste composition in Eskisehir is 67.06% food wastes, 5.62% plastics, 10.07% paper-cardboards, 2.49% glasses, 1.26% metals, 3.86% ashes and 9.64% miscellaneous wastes and humidity is approximately 37%. Because of this humidity, water translates directly into a lower absorptive capacity and this causes a significant increase in the potential of leachate generation.

The dumping site investigated in this study is an unregulated dumping site that belongs to the Metropolitan Municipality of Eskisehir. The vehicles of the two private companies that belong to the two sub municipalities have worked for collecting municipal solid wastes. These are transported to the site and dumped there for 24 h every day in an unregulated way. This unregulated dumping site is an open area where the wastes are partially classified and recycled under unhygienic conditions.

Eskisehir solid waste dumping site, located in the south east of the city (Fig. 1), has an area of approximately 8 hectares, an average height of 50 m. This area is a natural valley shape and full of solid wastes since the middle of 1986. The dumping site has not been excavated or wastes have not been dumped in the natural depressions. The dumping site has received 750 tons/day of wastes generated in Eskisehir and 2.5 million m^3 municipal solid waste including household wastes, some industrial wastes and healthcare wastes so far. There is a small lake, a number of small wells and spring water flowing lowly in the close vicinity of the area. The leachate has been percolated into these groundwater sources.

Geological and Topological Characterization of Dumping Site: Geological structure of Eskisehir unregulated solid waste dumping site has formed from conglomera, tufa, marn-clay and limestone layers. The site is on the conglomera-sandstone (Mamuca Formation). Impermeability of these layers increases with depth of the layer. Also, limestone layers have been sloped down towards the direction of southeast. Therefore, direction of leachate movement in underground is towards to the southeast.

It was seen that the gradient of the region of solid waste dumping site usually lays on straight and the slope of this region has changed between 0-5° according to gradient map prepared by using MGE-SX (Modular GIS Environment) software on Digital Elevation Model for this area (Fig. 2a). However, the slope of the valley that wastes are unloaded is between 5-25°. As shown in the air photograph in Fig. 1, dumping site is on the side of the valley.

Eskisehir's topography is towards to the north and northeast (Fig. 2b). Topographical elevation of dumping site has decreased towards to the north side.

The elevation of the dumping site is between 950-1000 m. The difference of elevation between waste dumping site and Porsuk Basin is approximately 150 m. The Porsuk River, flows through the centre of Eskisehir dividing the city into two parts. For that reason, it is thought that the flow directions of ground and surface water are towards to the north in the direction of topography's slope. The surface flow of leachate, depending on topography's slope, is towards to the north of current area and Organized Industrial District that locates the east of the city.

The wind direction is very important parameter for the solid waste dumping site. The wind direction of Eskisehir is in the northeast. But, the wind which is blowing to the west from the east and southeast in winter and autumn seasons has caused to the movement of polluted air towards to the city center from the unregulated dumping site. In addition to, if the wind blows from northwest, inhabiting areas in east and southeast of city are negatively affected from this site.

MATERIALS AND METHODS

Sampling and analysis: In this study, pH, cadmium, copper, iron, lead, nickel and zinc analysis on leachate and soil collected from the surrounding of unregulated dumping site in Eskisehir/Turkey were realized in autumn, spring and summer months in 2002-2003 (Fig. 1).

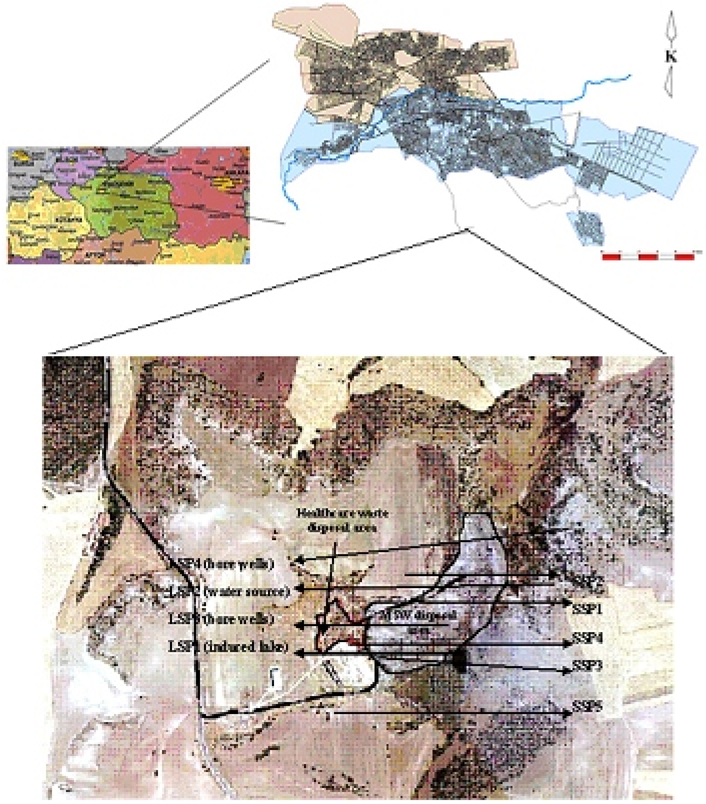
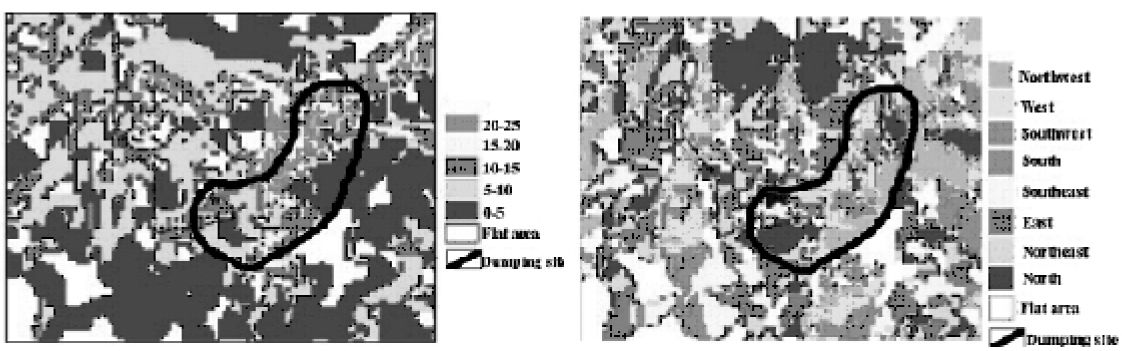


Fig 1: Location of unregulated dumping site in Eskisehir



(a) (b)

Fig. 2: (a) Slope map of Eskisehir unregulated dumping site , (b) Aspect map of Eskisehir unregulated dumping site

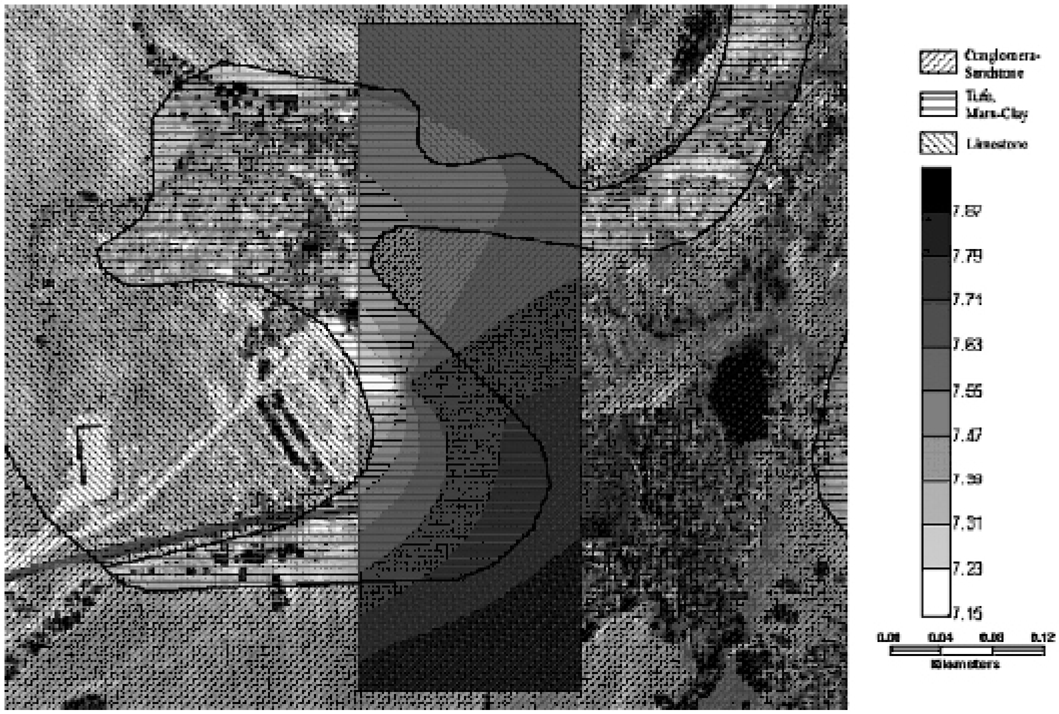
For leachate analysis, two of four points are drilling wells, one of these drilling well is in the site and the other is in the east of the site. Other two points are surface water.

For soil analysis, one of five points is in the site, other points are in the different places in its surroundings (Banar *et al*., 2006a, b).

All of these analyses were done monthly and arithmetic means of analysis results were taken into consideration in this paper. Unfortunately, the soil samples in winter season due to bad wheather conditions and the leachate samples in summer season due to water shortfall weren't taken.

GIS (Geographic Information Systems) studies: In this stage, according to UTM (Universal Transverse Mercator) WGS84 projection, coordinates of the sampling points were determined by GPS. These sampling points were marked on the air photograph using GeoMedia Professional 6.0 software.

Analysis results obtained from the sampling points were interpolated using SURFER 7.0 software and



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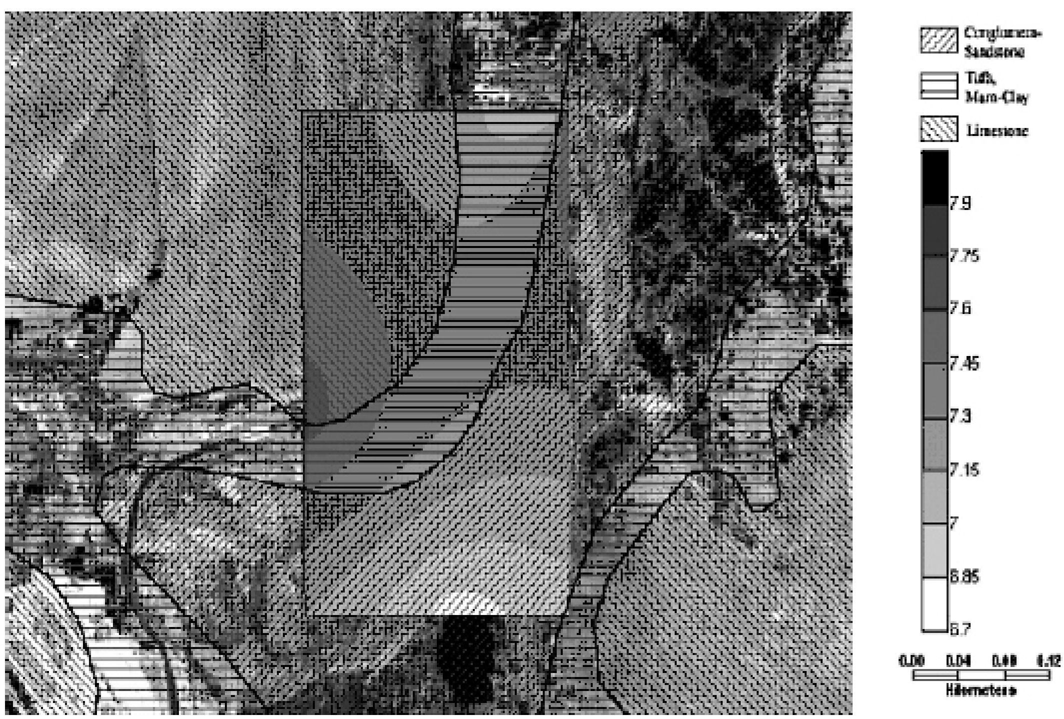
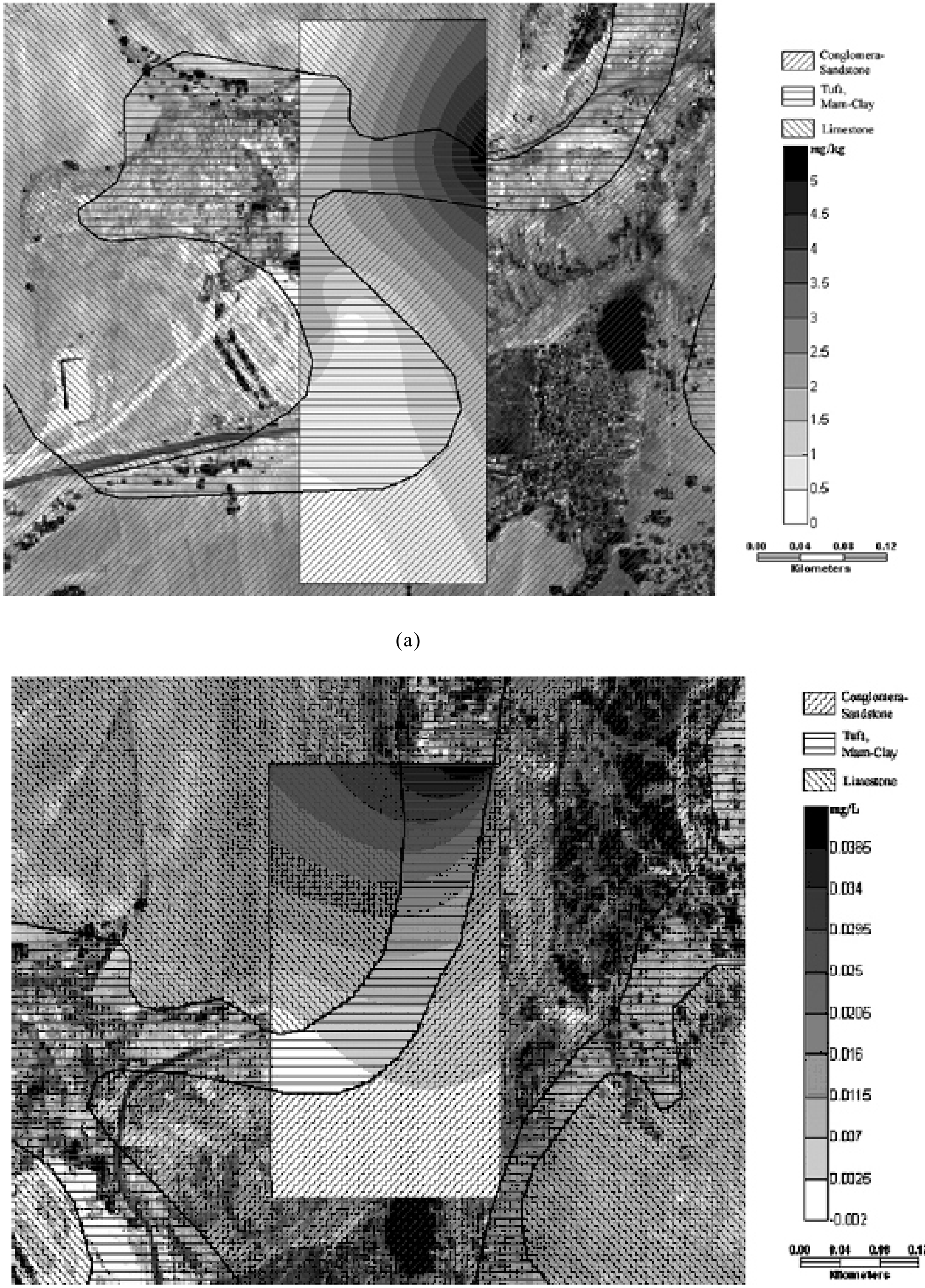


(b)

Fig. 3: (a) Distribution of pH value (soil), (b) Distribution of pH value (leachate)



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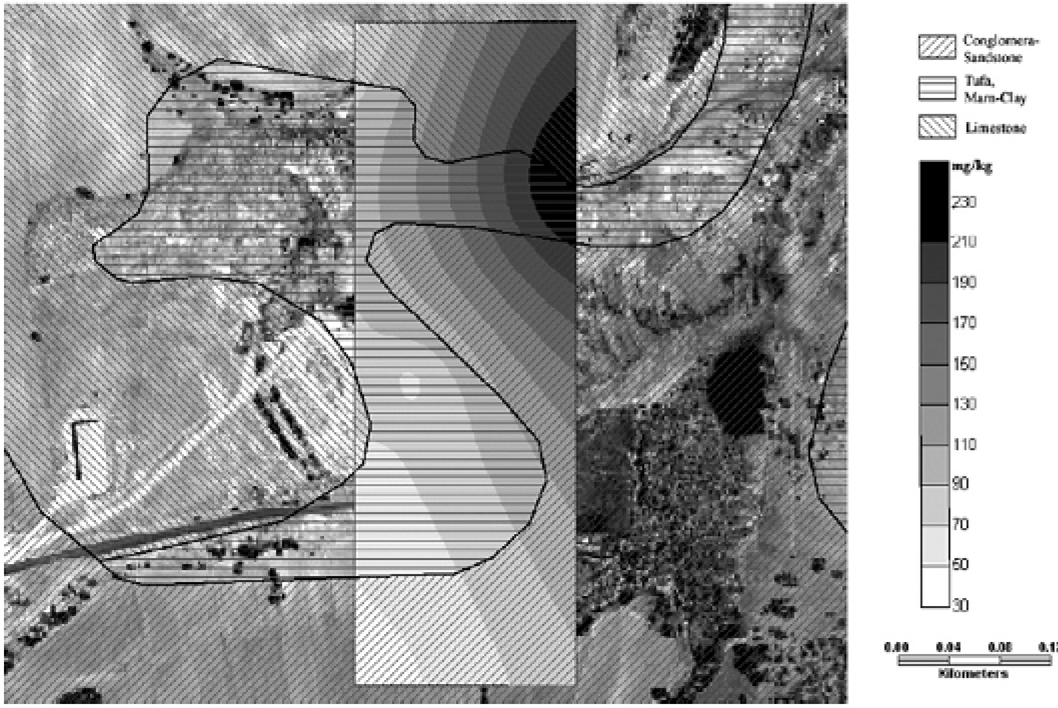
(b)

Fig. 4: (a) Distribution of cadmium concentration (soil), (b) Distribution of cadmium concentration (leachate)



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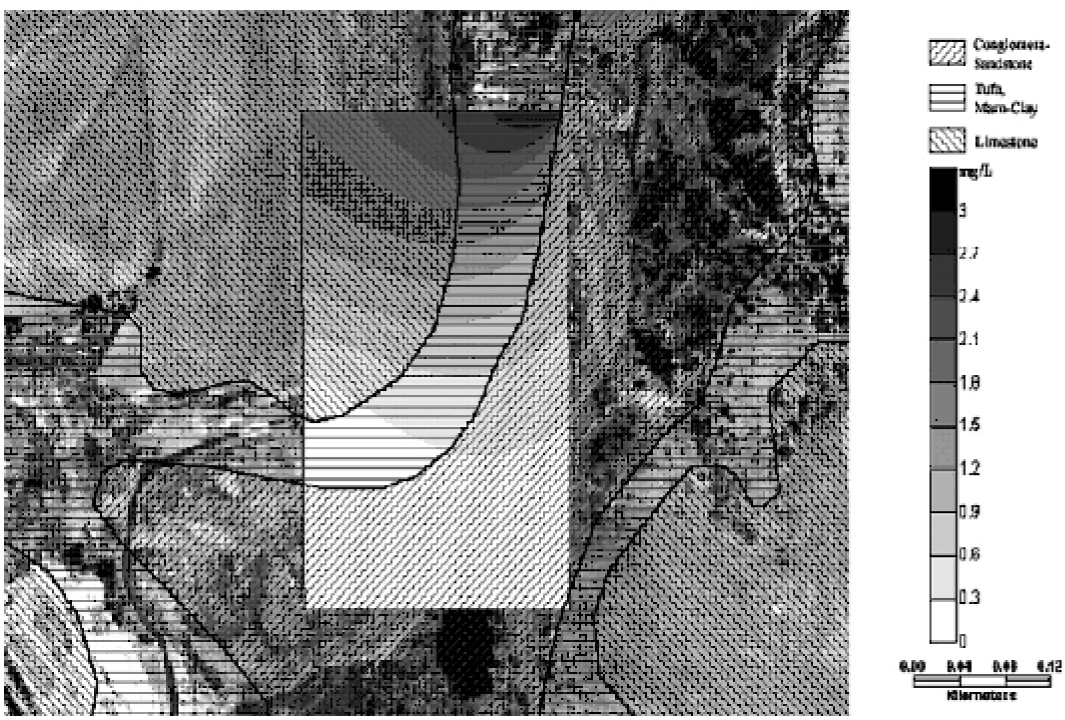
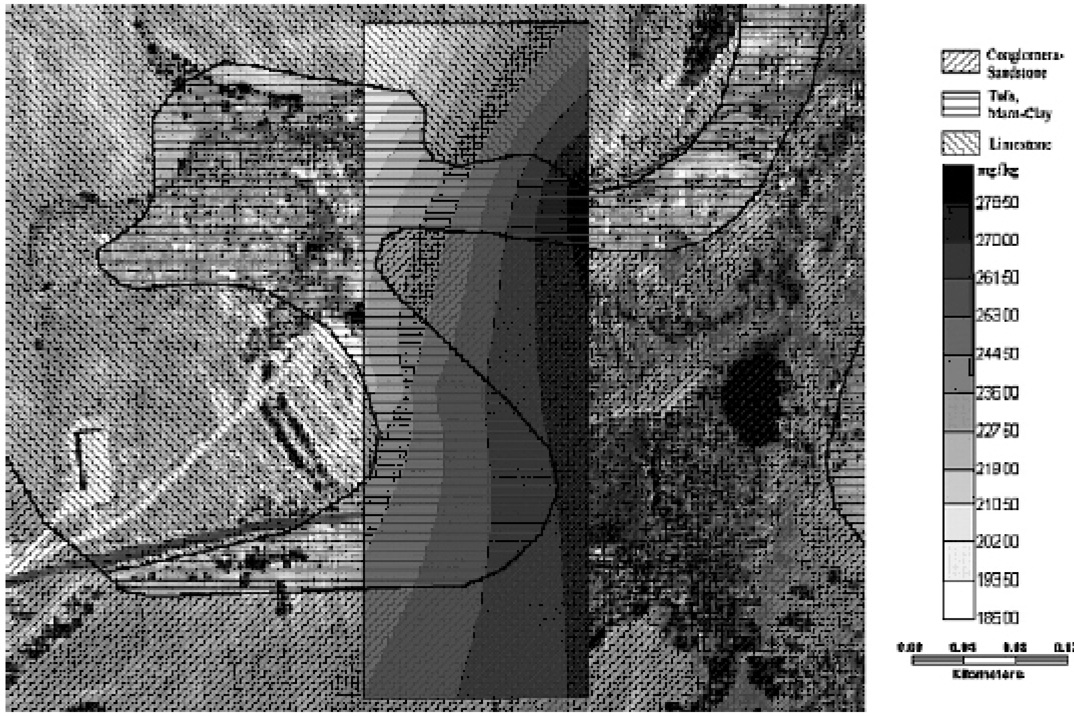


(b)

Fig 5: (a) Distribution of copper concentrations (soil), (b) Distribution of copper concentration (leachate)



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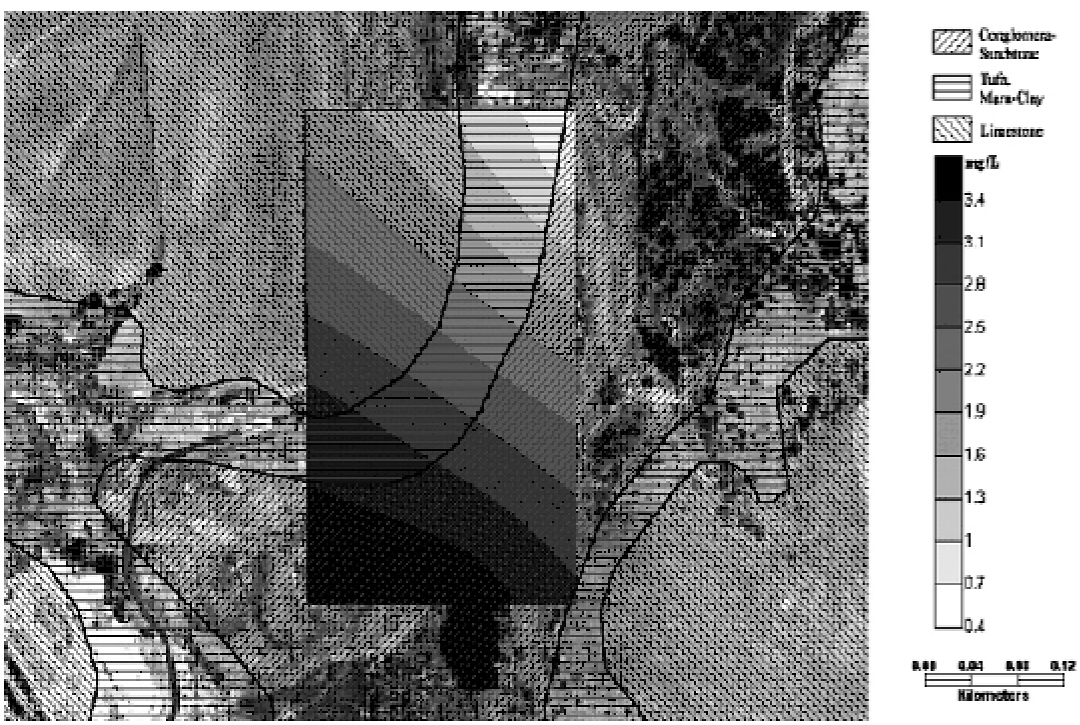
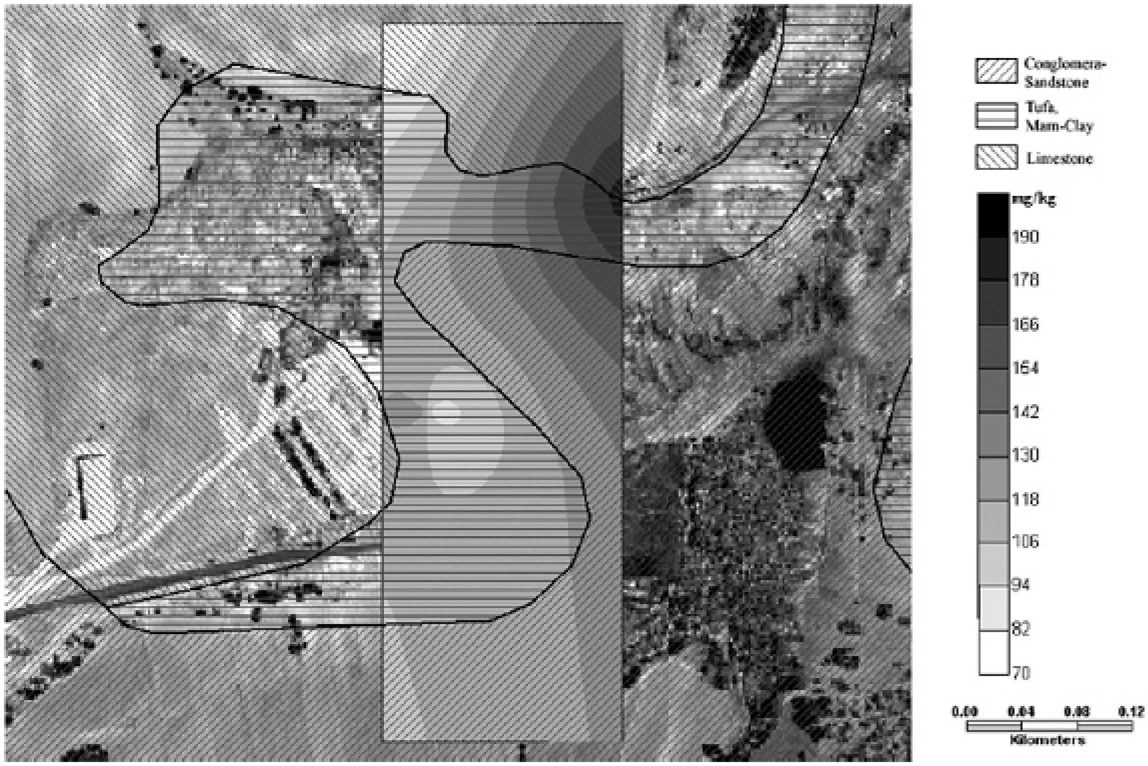


(b)

Fig 6: (a) Distribution of iron concentration (soil), (b) Distribution of iron concentration (leachate)



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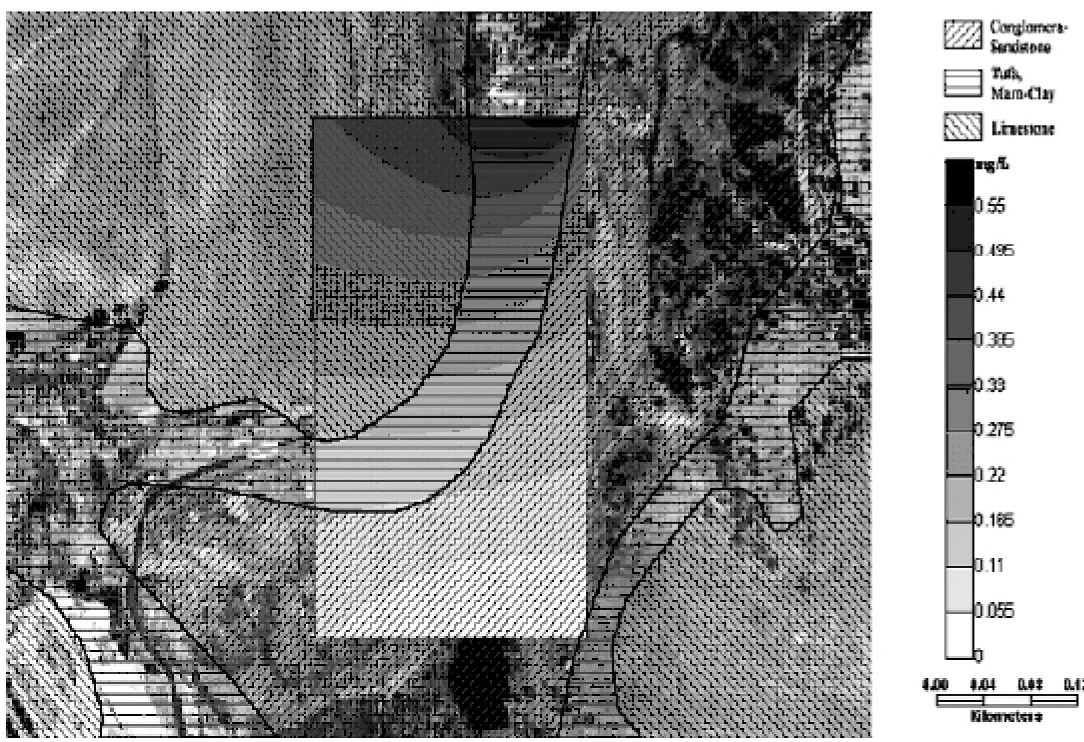

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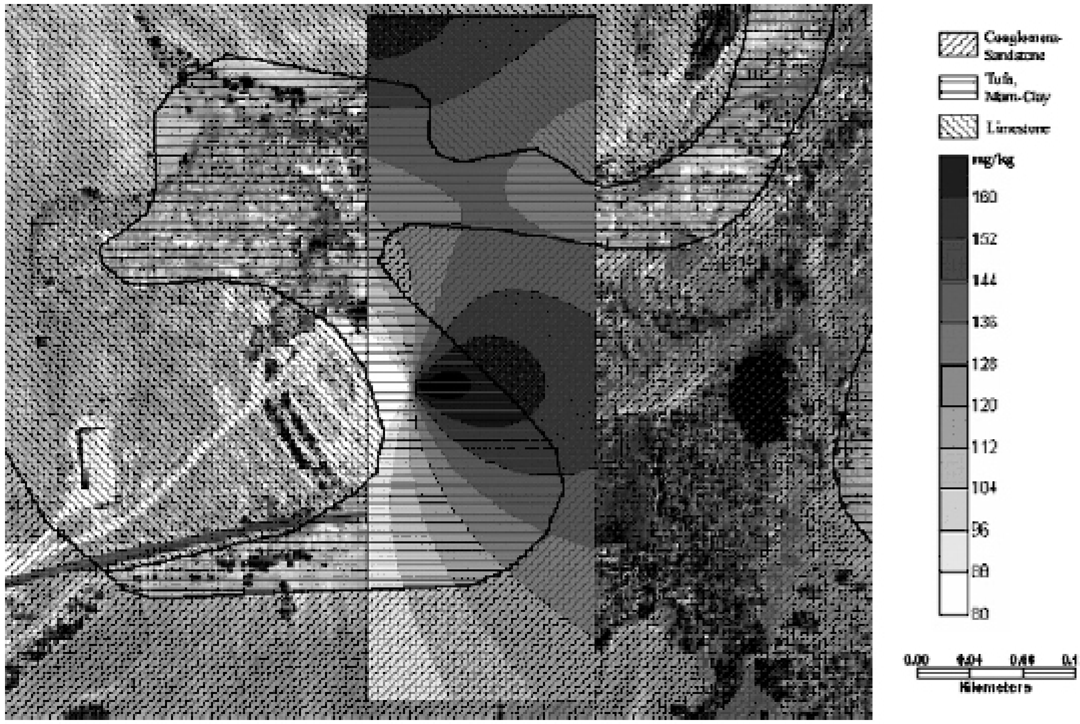
Fig. 7: (a) Distribution of lead concentrations (soil), (b) Distribution of lead concentrations (leachate)



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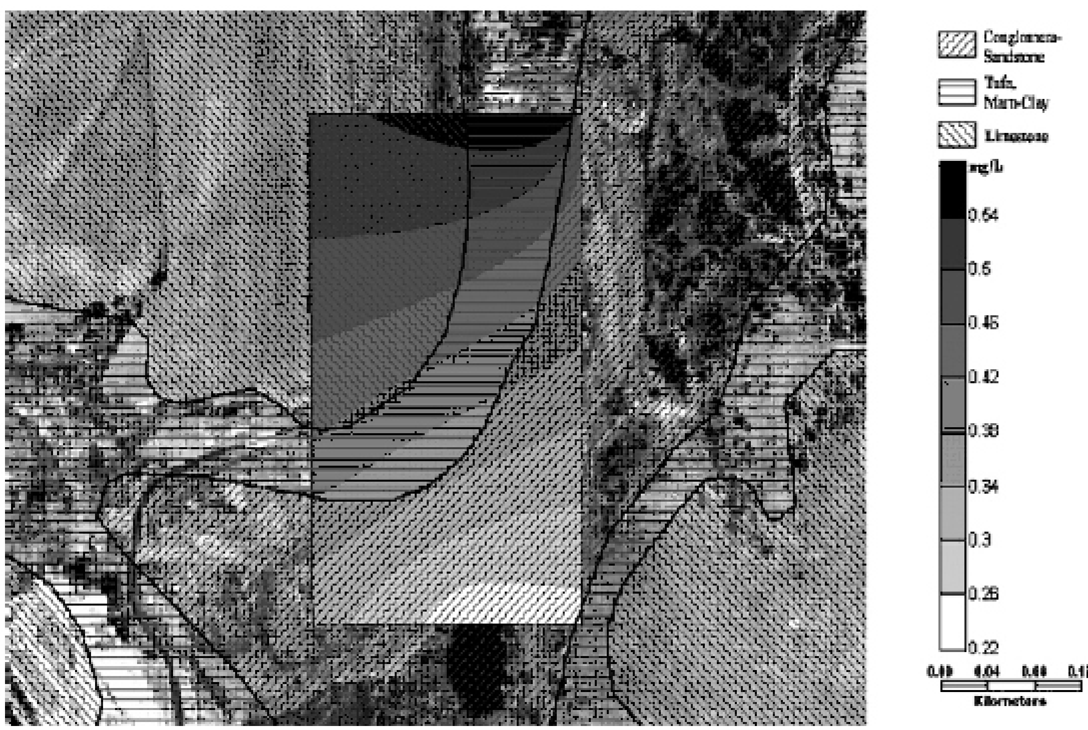
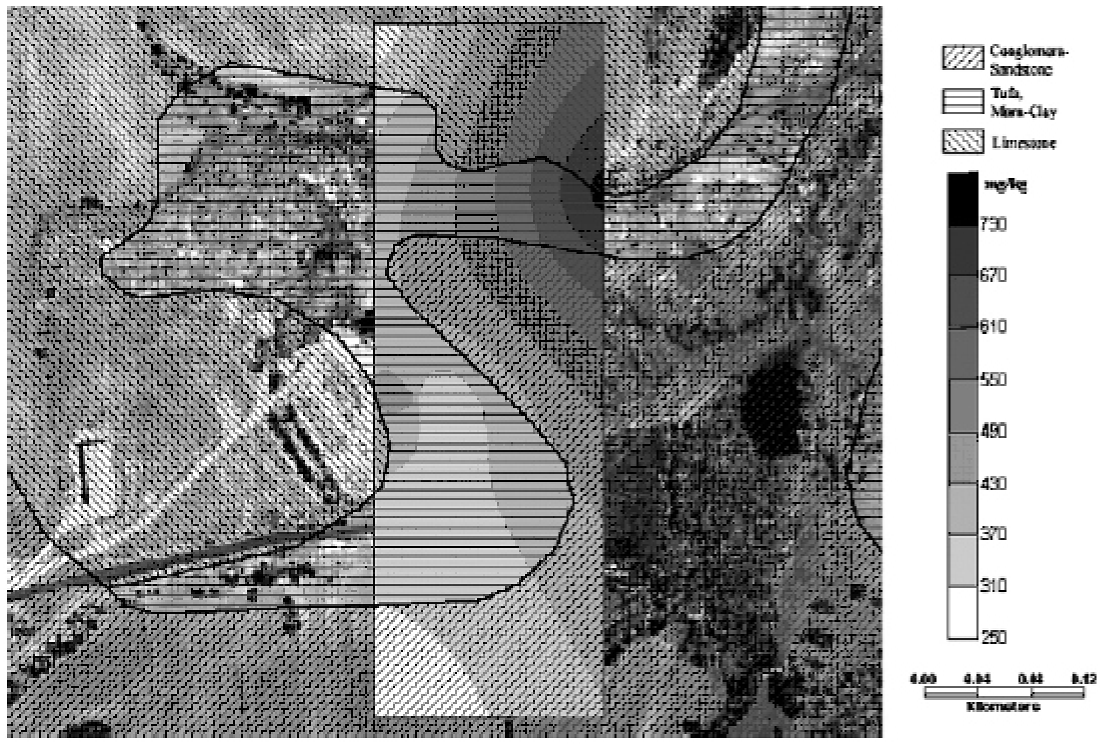


(b)

Fig 8: (a) Distribution of nickel concentrations (soil), (b) Distribution of nickel concentrations (leachate)



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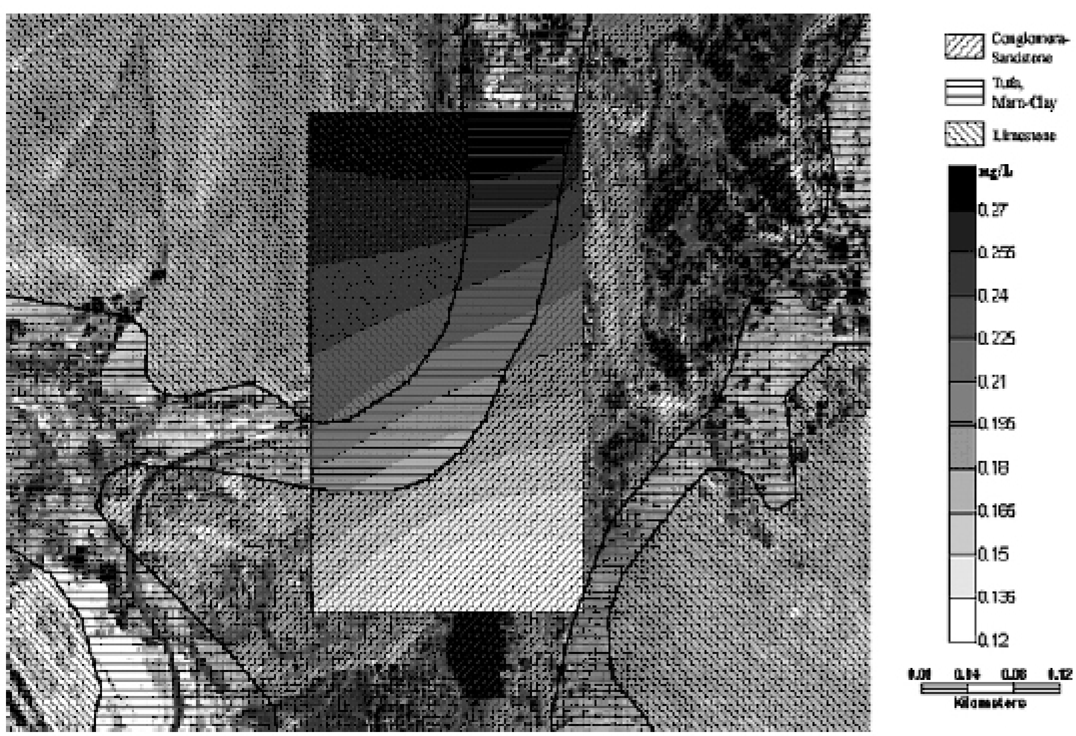

(b)

Fig. 9: (a) Distribution of zinc concentrations (soil), (b) Distribution of zinc concentrations (leachate)

Table 1: Comparison of soil and leachate analysis results in present study (range and mean of values) and limiting values in Turkish laws

Parameters	Analysis results for soil (mg/kg dried soil)	Limit value* (mg/kg dried soil)	Analysis results for leachate (mg/L)	Limit value ** (mg/L)
Cadmium	1.5	3	0.006	0.1
Copper	101.3	140	0.76	3
Iron	24132	-	2.6	10
Lead	124.3	300	0.13	2
Nickel	128.5	75	0.39	-
Zinc	410.1	300	0.21	5

* Ministry of Environment and Forestry of Turkey, 2005a, ** Ministry of Environment and Forestry of Turkey, 2005b.

RESULTS AND DISCUSSION

Detailed analysis results have been marked in the references of Banar et.al.2006a and 2006b. In this study, these results were evaluated using GIS and the images obtained from GeoMedia Professional 6.0 and SURFER 7.0 has shown in Fig. 3-9.

When pH values were examined, it was seen that these values are generally weak base properties and pH of the soil are higher towards to agricultural areas in the south of the unregulated dumping site depending on the soil structure.

When heavy metal concentrations were also examined, these parameters may be discussed in two parts. Because, in the northeast of this dumping site, while cadmium, copper, lead and zinc concentrations in the leachate and soil are higher, iron and nickel concentrations in the leachate and soil are lower. But, the highest concentrations for all of the parameters were seen in centre of the dumping site. Also, cadmium, copper, lead and zinc concentrations in the leachate and soil were changed as appropriate to the geological structure.

Heavy metals in soil migrates to plants, pollutes to groundwater (especially as ion), damages to microorganisms, humans and other livings by the way of food chain and this situation has created many risks. There is a water layer nearly 3-5 m below the surface of the ground. In this study, heavy metal concentrations in agricultural areas in the northeast of dumping site were determined higher than other sites and limiting values. Therefore, because of the agricultural activities and pastured animals, there are risks above mentioned with the respect to this subject in Eskisehir.

While the leachate passes into soil, polluted materials are adsorbed on the soil. The structure, pH, cation changeable capacity and organic matter of soil are important parameters for this mechanism. Especially, the soils which have clay and higher organic matter content have high cation changeable capacity and heavy metal and cations are adsorbed very much. Therefore, in this study, concentrations of pollution parameters on soil were detected higher than the leachate.

A comparison of the soil and leachate data obtained from this study, and legal status in Turkish Regulations of the Control of Soil Pollution (Annex-IA: Limiting Value of Heavy Metal in Soil) and Turkish Regulations of the Control of Water Pollution have shown in Table 1. As shown in Table 1, zinc and nickel concentrations (according to mean values) are higher than limiting values. Also, concentrations of other parameters except iron are higher than limiting value according to its maximum values. According to these results, it can be said that municipal solid wastes in Turkey have included hazardous wastes. Also, the results of leachate analysis are lower than limiting values, but only maximum concentration of copper in leachate are higher than limiting value.

CONCLUSIONS AND RECOMMENDATIONS

When physical-chemical analysis results and findings obtained from GIS are evaluated with together, it is claimed that Eskisehir dumping site is going to cause environmental problems in both short and long term and this site should be urgently rehabilitated. Co-disposal of municipal solid wastes with healthcare and industrial wastes creates a great concern for public health. Therefore, integrated solid waste management system in Eskisehir has to be established and new sanitary landfill site has to be constructed. The need to progressively reduce the proportion of biodegradable waste going to landfill will also have implications both for the generators (of biodegradable waste) and for the operators of other types of treatment/disposal facilities (including recycling, recovery, composting). All of these have implications for the planning of waste management at a regional and local level. For these purposes, GIS and various decision support systems should be used.

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