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Soil contamination by heavy metals: Measurements from a closed unlined landfill

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ABSTRACT

The aim of the present study was the characterization of soil samples of a closed unlined landfill located northwest of Thessaloniki, North Greece, in relation to heavy metals values. Samples were obtained by drilling in different depths (2.5–17.5 m). Then they were analyzed by atomic absorption spectrophotometry for Cd, Cr, Cu, Ni, Pb and Zn investigation. The chemical analysis showed that the metal values varied over a wide range: from 0.50 to 18.75 mg/kg for Cd, 3.88–171.88 mg/kg for Cr, 8.13–356.25 mg/kg for Cu, 5.63–63.75 mg/kg for Ni, 2.50–92.50 mg/kg for Pb and 6.38–343.75 mg/kg for Zn. The highest values found in three of the six drillings, in depths over 2.5 m. Although the area is heavily industrialized, the presented results indicated that local industries have not constituted an extensive metal pollution source for the site. Finally, after all necessary preparatory operations of site cleaning and flattening, surface planting selected and applied as a phytoremediation rehabilitation method of the site.

1. Introduction

Modern civilization is completely dependent on a large range of metals for all aspects of daily life. There is a long history of association between metals and human development. However, due to mining, mineral, smelting and tannery industry, heavy metal pollution has become serious. Heavy metal pollution not only affects the production and quality of crops, but also influences the quality of the atmosphere and water bodies, and threatens the health and life of animals and human being (Kumar, 2008). Several researchers have clearly identified the influence of human activity as a major cause for metal contamination of the ecosystem (Charlesworth et al., 2003; Tüzen, 2003; Al-Khashman, 2004; Banat et al., 2005; Chen et al., 2005).

Metals are considering among the most dangerous environmental pollutants, because they do not disintegrate with physical processes and therefore remain for longtime period. They affect biogeochemical cycles and accumulate within living organisms, eventually making their way to humans through the food chain, where they can cause perturbation to biological reactions, long-lasting harm to vital organs or even death (Tiller, 1989). Ingestion, inhalation and skin contact are the main routes of human exposure to soil metals. Since soil is the major sink for airborne metals, the measurement of their levels in this media is useful to establish trends in abundance and their consequences because of natural and anthropogenic changes (Nadal et al., 2004). Hazardous metals like Pb, Zn and Cd take part in the biogeochemical cycles and their mobility depends strongly on their chemical forms rather than total element concentration (Garcia et al., 2005). Metal speciation can help to assess how strongly they are retained in soil and how easily they may be released into soil solution (Kaasalainen and Yli-Halla, 2003).

The main objective of this study was the characterization of soil samples issued from a closed unlined landfill located near Thessaloniki, in northern Greece, in relation to their content of heavy metals. The soil samples collected from the under study area, one of the largest industrial areas where metal-processing, chemical, cement, food and wood industries are located. In the studied disposal site, during the period 1990–1997, both industries and the community dumped their wastes. In order to assess the situation of the site and to decide for its rehabilitation for both esthetic and ecological purposes, a wide survey performed, focusing on the evaluation of heavy metal pollution and their associated risk. This risk assessed by comparing results to guidelines developed in Europe for heavy metals in soils.

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Nomenclature

D	drilling
L/S	liquid/solid

Table 1
Characteristics of the soil samples

Samples	Drilling	Mean sample depth (m)	Description
4	D1	0.45	Brown-reddish sandy potter's clay earth
		1.00	
		1.55	Green schist vitiated with calcite concretions
		2.25	
5	D2	0.25	Grit, clays
		0.75	
		1.75	
		3.00	Grit, timbers, braces, bricks
		3.75	
2	D3	0.90	Grit, clays
		3.50	Peridotites, green schist
4	D4	1.10	
		2.00	Grit, pieces of schist
		2.75	
		5.15	Peridotites, green schist
10	D5	1.00	Grit, clays
		4.50	
		5.75	Waste
		6.25	
		6.75	
		7.70	
		8.65	
		9.95	
		12.75	
		14.4	Peridotites, green schist
15	D6	0.90	Grit, clays
		2.60	
		5.75	Waste
		6.20	
		7.90	
		9.25	
		10.50	
		11.50	
		12.85	
		13.25	
		13.75	
		14.75	
		15.15	
		15.45	
		15.80	Peridotites, green schist
40			Total

2. Methods

2.1. Site description

The closed unlined landfill of Efkarpia, is located in the north-western part of Thessaloniki (longitude: 22°97′, latitude: 40°50′). The community of Efkarpia is the second largest industrial area in the greater Thessaloniki area, after Sindos. Its population according to inventory of 2001 is 6.645. A large number of metal-processing, furniture and wood, textiles and clothing, food, chemical and cement industries are located there. The related produced wastes are 240, 220, 200, 150, 110 and 40 t/y, respectively. The closed landfill site located in a gully, covers 3 hectares and it is 5 km far from the nearest residential area of the village of Efkarpia. Nearby, there are also many sheepfold units, the nearest of which is 200 m far from the site. Local industries and the community of Efkarpia have dumped their waste in this disposal site during the period 1990–1997. The most intensive deposition of urban waste took place between 1993 and 1995, while between 1995 and 1997 the landfill received mainly waste from local industries. An average of amount of 16 t of waste was estimated as the daily dumped quantity during 1990–1997.

For the purpose of the present investigation, six wells (termed D1–D6) were drilled at the disposal site for sampling purposes, in December 2003. Drilling depth was extended up to finding the maternal rock and wells depth varied between 2.5 and 17.5 m, because the thickness of waste in the old landfill varied. Soil sampling was performed on a dry basis via a barrier sampler. In this way, 40 soil samples collected from the six drillings. Initially, all samples were stored in a covered place and left to dry out. Then, they were pulverized and sorted with a 2-mm sieve (Nastis et al., 2005) and analyzed for the estimation of Cd, Cr, Cu, Ni, Pb and Zn values. A short description of the samples is given in Table 1. The physical properties (soil profile) of the *in situ* soil for each of the six drillings (D1–D6) are as follows:

D1: Only natural ground was found, since this drilling was relatively near the "official" landfill border. Down to 1 m, brown-reddish sandy potter's clay earth was found and, then, down to the final depth of 2.5 m, green schist vitiated with calcite concretions.

D2: It reached a final depth of 4.5 m, after which natural ground was found; disposed excavation wastes (consisting primarily of rubble grit and clays) were found down to a depth of 2.5 m, followed by disposed wood, bricks and generally inert construction wastes which were found next and until the final drilling depth.

D3: With a final depth of 4 m, disposed excavation wastes (i.e. rubble, grit and clays) were (again) found down to 2.5 m, whereas natural soil (consisting of peridotites and smashed green schist) was located next and down to the final drilling depth.

D4: With a total depth of 6 m, primarily excavation waste (grit, pieces of limestone, etc) and secondarily industrial wastes (mainly rugs) were found down to a 4 m-depth. Then (and down to the final drilling depth), natural soil was found, consisting of peridotites and schist.

D5: It had a final depth of 14.8 m. Excavation waste was found here also and down to the first 5 m, whereas then and down to a 14 m-depth, mainly municipal and industrial wastes of miscellaneous nature were observed. Finally, down to the final depth of 14.8 m, the above-mentioned peridotites and green schist were found again.

D6: This was the deepest drilling, as it reached 17.5 m down. Rubbles from the landfill were found again down to 4 m and, further down, wastes were found up to a depth of 16 m. Then, natural soil was found consisting of peridotites and smashed green schist.

In general, the type of discovered waste was related mainly to the type of region's industries, as it consisted mainly of by-products from cement, metal-processing and clothing industries. However, a relatively high amount of plastic bags was also found, these were probably used for packing the waste. At the same time, significant quantities of debris and timber by-products were dug out.

2.2. Sample processing

Several chemical and fractionation methods for heavy metal analysis in soils and sediments have been and are still being