

Concentration of heavy metals beneath the Ampar Tenang municipal open-tipping site, Selangor, Malaysia

ABDUL RAHIM SAMSUDIN, BAHAA-ELDIN ELWALI A. RAHIM, WAN ZUHAIRI WAN YAACOB &
ABDUL GHANI RAFEK

Geology Program, School of Environment & Natural Resources Sciences,
Faculty of Science & Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

Abstract: Heavy metals namely Cu, Cr, Ni, Zn, Pb, and Co in soil horizons beneath the Ampar Tenang municipal open-tipping site have been extensively investigated through examination of twenty one representative triplicate soil samples that were collected from nine auger holes distributed in three locations within the study area. These include upstream (ATU), downstream (ATD), and soil-waste interface (ATI). Results obtained for ATI revealed considerably higher concentration levels of most of the elements analyzed compared to ATD and ATU. Moreover, Cr, Zn and Pb had shown higher levels of concentration amongst all examined metals. It was found that in most cases, the heavy metal concentration was generally high at the surface and downwards up to 60 cm depth, then decreased relatively with increasing depth. It was shown that, in addition to the vertical infiltration of leachate from the solid waste, the hydrological regime of groundwater has also a strong impact on the contaminants distribution in soils below the site.

INTRODUCTION

Landfilling which is still the most popular form of municipal solid waste treatment in many countries now, takes up lots of areas and leads to a serious pollution to its surroundings (Ding *et al.*, 2001). The most common heavy metals in the landfills are iron (Fe), cadmium (Cd), copper (Cu), zinc (Zn), and nickel (Ni) (Erses & Onay, 2003). In addition to the vertical infiltration of leachate from the solid waste, the hydrological regime of groundwater also has a strong impact on the contaminant distribution in soils below the landfill (Ahel *et al.*, 1998). The investigation of the chemical impacts on the soil in the vicinity of an uncontrolled combustion of municipal solid wastes in an open landfill in Crete area in Greece indicated that, high contaminants concentrations levels were found in the soil inside the landfill and in the immediate proximity (Martens *et al.*, 1998).

THE STUDY AREA

The study area is located in the Sepang district, some 3 km to the southwest of Dengkil town in Selangor state at coordinates N 02°48.925' and E 101°4.933' according to Trimble Global Positioning System (GPS) (Figure 1). This area lies within Langkat river basin, thus is characterized by flat lowlands where oil palm plantation and urban land uses are dominating over the tropical forests and the latter cover the south to southwestern part of the area. The site is an open tipping site, which receives 100 tons per day of mainly domestic waste. The thickness of the disposed waste ranges between 4.5 m to 9 m with average of 6.63 m.

The high ground rises between 30 m to 60 m. This is mainly covered by residual soils, derived from the weathering of foliated metasedimentary rocks, which are inferred to be the Kenny Hill Formation comprising essentially sandstone, shale, phyllite and quartzite (MGD, 2001; Omar *et al.*, 1999). In the low flatlands, thick Quaternary layers are deposited on the bedrock. It consists

of 0.5 to 5.5 m thick Beruas Formation with peat layer at the top, the clayey Gula Formation and the Kempadang Formation (MGD, 2001; Bosch, 1988). Immediately, below the peat there is a layer of very soft to soft compressible marine clay (Omar *et al.*, 1999). The residual soil is typically firm to stiff, becoming very stiff and hard sand silty clay with increasing depth (Omar *et al.*, 1999).

This study has been performed mainly to define the total content and migration of heavy metals in the soil beneath Ampar Tenang municipal open-tipping site. This because there is no liner to protect the very shallow groundwater zone (Figure 2) from the leachate seepage.

MATERIALS AND METHODS

Twenty one triplicate representative soil samples were collected from nine points using a hand auger according to the standard procedure described in USEPA (2000) (Figure 2). The auger holes were distributed among three locations within the study area. These include downstream (ATD), soil-waste interface (ATI), and upstream (ATU). The latter is considered as a control sample. Each auger hole was sampled at intervals of 25 cm from the ground



Figure 1. Location map of study area.

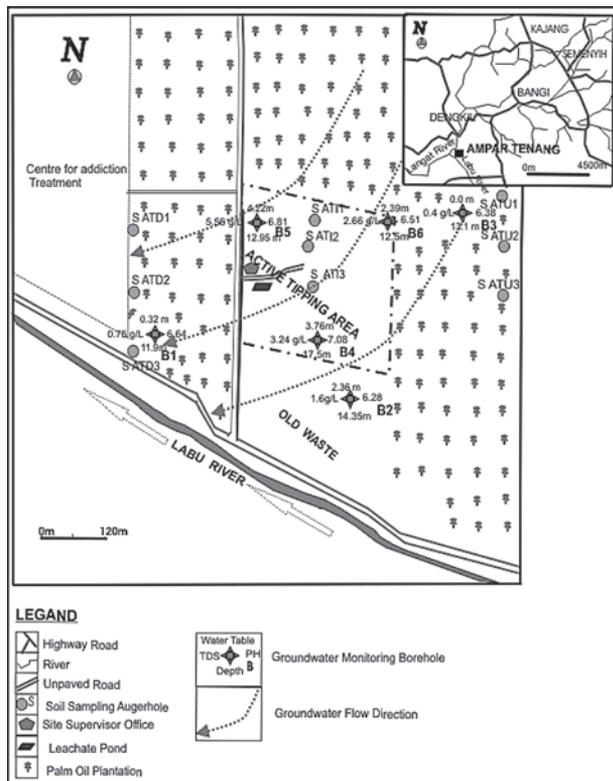


Figure 2. Layout of Ampar Tenang open-tipping site showing the locations of auger holes, groundwater monitoring boreholes, and general trend of groundwater flow direction.

surface downwards to depth of 150 cm. Samples were packed in plastic bags before sending to the laboratory. The soil samples were air-dried at room temperature for 2 weeks. Using a ceramic pestle and mortar, samples were gently ground and sieved through a No. 2 mm sieve. Then the soil samples of particles < 2 mm were preserved in sealed plastic bags before laboratory analysis. pH was measured using procedure described by ISO (1994). Microwave oven dissolution procedure described by Lamthothe *et al.* (1986) was used to determine the concentration of heavy metals in soil; in that 1.0 g sample, ground to pass 100 mesh, was placed in a 250 ml polycarbonate bottle. Then 2.0 ml of concentrated nitric acid (HNO_3) was added to the bottle, followed by 5.0 ml of 7:3 mixture of hydrochloric-hydrofluoric acid (HCL-HF). Samples were then placed into the microwave oven and heated with 650 W for 15 minutes. After cooling, 93.0 ml of 15% boric acid (H_3BO_3) solution was added to each bottle. Then the bottles were recapped and returned to the oven and heated again at 650 W for 15 minutes. After cooling to room temperature, the solutions were analyzed for heavy metals by spectrometry of atomic emission (ICP) using inductively coupled plasma of solid state (Perkin-Elmer model Optima 4300 Dual View). Concentrations obtained were expressed in mg/kg. The statistical analyses were performed using the SPSS for Windows statistical software package, Release 11.50 (6 Sep. 2002). Statistical differences between the means were compared using least

significant differences at probability $P \leq 0.05$ (significant) and $P \leq 0.01$ (very significant).

RESULTS

The study area is covered by a thin layer (50 cm) of dark brown spongy amorphous peat at the surface which, underlain by a very soft compressible clay. This clay is light grey in colour and is a very soft to very stiff sandy silty clay. Thus, all the soils in the vicinity of Ampar Tenang site were characterized by acidic pH of mean values ranging between 2.44 to 3.01. There was no change in pH with depth except for the ATD soil samples, which showed slightly decrease with depth of up to 70 cm and then remained unchanged (Figure 3).

Results of total concentrations and vertical migration of the analyzed heavy metals are illustrated in Table 1 and Figures 4 to 6. However, among all the analyzed heavy metals, only Cr, Zn, and Pb distributed considerably differently ($P \leq 0.01$) throughout the area, whereas Ni showed significant distribution difference at $P \leq 0.05$. However, Cu and Co were distributed insignificantly.

The vertical distribution of the most of the analyzed elements along the soil profiles (i.e. ATU, ATI, and ATD) exhibits notable decrease with increasing depth depending on the location of the profile. Nevertheless, some elements showed irregular migration patterns (e.g. Cu, Co, Cr). On the contrary, Zn and Pb concentration exhibits sharp increase at a depth below 40 cm before showing the usual behavior of the downward-decrease with increasing depth.

DISCUSSION

The most contaminated soil in the present study occurs in areas, where extensive wastes had been disposed (ATI) as shown in Table 1. Thus, the high concentrations of these metals especially, Zn, Pb and Cr at ATI locations were directly attributed to the release of contaminated leachate generated from decomposed garbage.

According to Elzahabi & Yong (2001), the solubility of heavy metals is highly pH dependent and increases with decrease in the soil pH. In the present work, the very acidic soil pH caused by solubility of the contaminants eased the mobility of heavy metals spatially and vertically. However, the contamination present in the solid waste exerted a significant impact on the underlying soil but it has to be stressed that different metals behaved differently. The first layer of the soil i.e. near the ground surface (Figures 4 to 6) efficiently retained some metals such Cr and Zn and to less extent Co and Ni. However, occurrence of the groundwater table very closed to the ground surface during the rainy season e.g. 0.0 and 0.32 m at BH3 and BH1 respectively as illustrated in Figure 2, supported the assumption of washing these metals into the groundwater. Furthermore, even during the dry season the insignificant drop of the groundwater table, which ranges between 0.37 m at BH3 to 0.48 m at BH1 (not shown in Figure 2), can highlight the short-distance pathway needed for these

Table 1: Mean values ± standard deviations for heavy metals in soil at Ampar Tenang open-tipping site. Number of samples = 21; ^b:upstream= ATU; interface= ATI; downstream= ATD; ** means very significant at $P \leq 0.01$; and * means significant at $P \leq 0.05$.

Metal ^b	Mean ± standard deviation (mg/kg)
Cu _{upstream}	0.28 ± 0.02
Cu _{interface}	2.21 ± 1.17
Cu _{downstream}	0.54 ± 0.36
Co _{upstream}	0.13 ± 0.20
Co _{interface}	0.79 ± 0.35
Co _{downstream}	0.14 ± 0.18
Cr _{upstream}	1.06 ± 0.40 **
Cr _{interface}	11.51 ± 2.12 **
Cr _{downstream}	2.59 ± 1.00 **
Ni _{upstream}	0.82 ± 0.18 *
Ni _{interface}	4.35 ± 0.97 *
Ni _{downstream}	1.81 ± 0.92 *
Zn _{upstream}	1.57 ± 0.33 **
Zn _{interface}	12.97 ± 5.28 **
Zn _{downstream}	5.41 ± 1.09 **
Pb _{upstream}	1.36 ± 0.58 **
Pb _{interface}	12.78 ± 1.48 **
Pb _{downstream}	3.38 ± 1.07 **

migrating elements to be released into the groundwater zone. In turn, this phenomenon can efficiently minimize the effect of natural attenuation of these elements by the soil material because even the partially attenuated elements near the ground surface can easily be washed during the periodical fluctuation of the groundwater table.

With exception of Pb in ATI soil and Zn in ATD soil, which exhibited lower concentration levels in the upper 30 cm, almost all of the examined metals site throughout the study area showed a notable decrease in the concentration below the depth 60 cm. The observed tendency to decrease with depth increase was related mainly to the flushing of these metals into the groundwater due to the mechanism of water table fluctuation. This mechanism was supposed to cause occasionally a considerable contaminants release into groundwater in the vicinity of Ampar Tenang open-tipping site. Furthermore, the acidic pH of soil could facilitate migration of these metals towards the groundwater zone. The preliminary results of groundwater analysis assert this interpretation. Apart from this, the elevated concentration of these metals in ATD can be attributed to the movement of leachate plume downward of the site toe; however, the possible contribution from the use of chemical fertilizers also needs to be considered.

In general, the concentration levels of the all analyzed heavy metals in the soil at the area of this site were found to be below the target limits determined by DoE (1997).

CONCLUSION

Soils of Ampar Tenang open-tipping site were investigated in terms of concentration and vertical migration of selected heavy metals. Since the waste was disposed directly onto an unlined natural formation, a

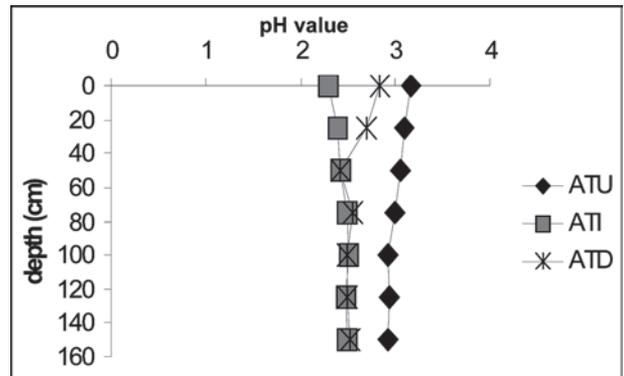


Figure 3. Variations of pH versus depth of different soil profiles at Ampar Tenang open-tipping site.

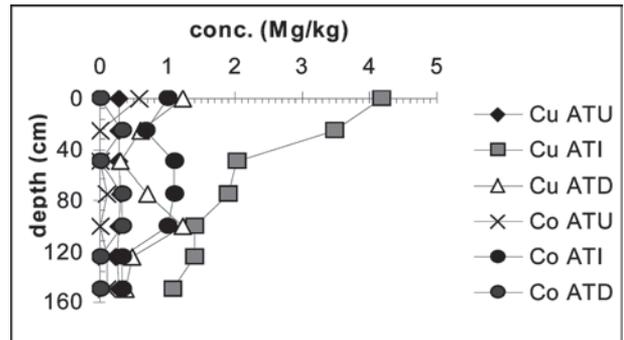


Figure 4. Behaviour of Cu and Co along different soil profiles of Ampar Tenang open-tipping site.

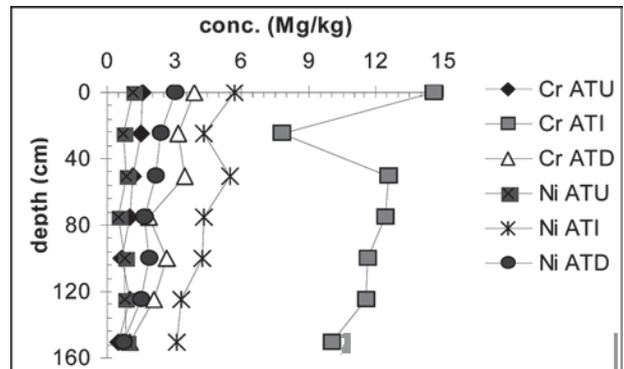


Figure 5. Behaviour of Cr and Ni along different soil profiles of Ampar Tenang open-tipping site.

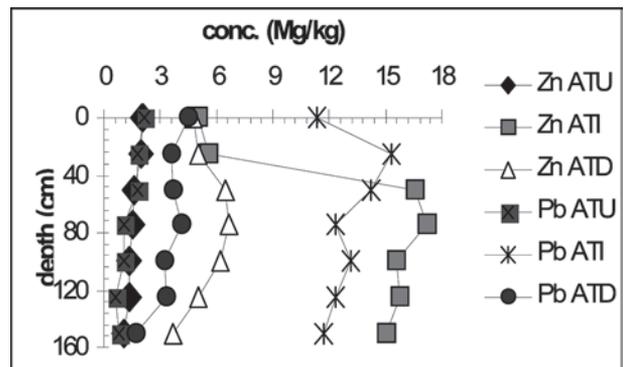


Figure 6. Behaviour of Zn and Pb along different soil profiles of Ampar Tenang open-tipping site.

number of contaminants including heavy metals readily penetrated efficiently through the soil and eventually reached the groundwater. The short pathway needed for these contaminants before releasing into the groundwater besides, the periodical water table fluctuations can possibly minimize the effect of natural attenuation of these heavy metals by the soil material.

It was found that soils from ATI locations were highly contaminated by heavy metals due to the impact of leachate seepage through the underlying soils. The acidic soil environment besides local groundwater flow directions availed the mobility of these metals spatially and vertically in the vicinity of the pollution source at Ampar Tenang site. In addition, the heavy metals present in the contaminated soils can be remobilized from the soil as a result of enhanced groundwater levels; therefore their replacement before constructing an impermeable barrier is highly recommended.

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