Study of metals in leached soils of a municipal dumpsite in Tampico, Tamaulipas, Mexico: preliminary results

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Abstract

The Zapote dumpsite measures 420000 m^2 and is 28 years old; an estimated 2.5 millions tons of waste have accumulated on the site (household waste, clinical waste, commercial waste). The thickness of the waste is 3 to 9 meters. Since operations began, no control regulations have existed on the residues received. The Zapote dumpsite is located within a salt-marsh between a system of channels and river lagoons of brackish water, located in a tropical sedimentary environment in the urban zone of Tampico, Tamaulipas, Mexico. Recently, the Zapote has been closed and work is presently underway in its rehabilitation since a geo-environmental perspective. The present investigation integrates information of preliminary results of metals (Pb, Ni, Cd, Cu, Mg, Fe and Al) contained in sediments that underlie the Zapote dumpsite. In laboratory research the metals of the sediment were correlated with the metals contained in samples of leachate from the Zapote dumpsite. The concentration of metals Pb, Ni, Cd, Cu, Mg, Fe and Al were analyzed in samples of sediments that underlie the body of the dumpsite in layers of 10 cm, reaching a depth of 1.5 m under the interface waste-soil. The results denote high concentrations of metals in layers that are in contact with waste that decreased until reaching 60 to 80 cm of depth. The proportions of the concentrations of metals studied in the soil are comparable with that leached, until layers of 60 to 80 cm of depth are reached, and are then lost in the deepest layers. The high plastic characteristics of clay layers have stood in the way of metallic contaminants in sub layers of the Zapote dumpsite. The results were correlated with metal concentrations of natural and anthropogenic sediments of the region.
Keywords: metals in soils, sediments in a dumpsite, metal concentration.

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1 Introduction

The dumpsite of approximately 42 ha was in use from 1978 to 2003. An estimated 2.5 millions tons of waste accumulated on the site, mostly household waste, but clinical and commercial waste are also probable. At the time of the dumpsite opening no regulations existed in this matter and it was operated without a management plan. The object of this contribution is to prospectively assess the downward migration of waste originated metals through leachate.

2 Study area

The dumpsite is situated on a peninsula called "El Zapote", formed by the conjunction of Panuco and Tamesí river estuaries. The Zapote dumpsite is located in the Municipality of Tampico in Tamaulipas state, Northeastern Mexico, fig. 1, between 614481 N latitude, 2458816 W longitude to 615011 N latitude, 2458580 W longitude (UTM 12 Region, WGS84).

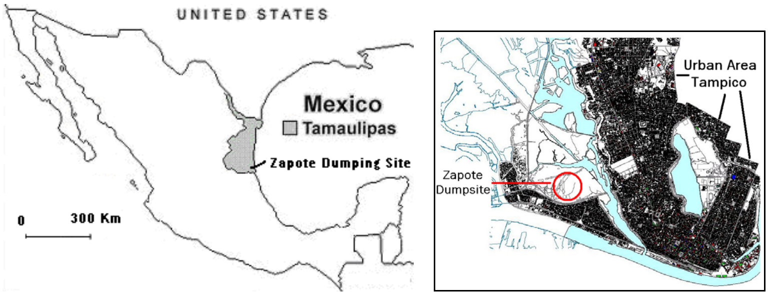

Figure 1: Location of Zapote dumpsite in Tampico, Tamaulipas, Mexico.

The regime of rain and temperature corresponds to Aw Koeppen, which is tropical with rain in summer, like Tamayo [1]. Figure 2 shows a typical year.

The estuary has no dikes in this area, so it is influenced by floods and tides. The site is in a low, flat area with no geological deformations, dating from the mid or superior Eocene period. The wastes have been dumped over a layer of natural occurring clay, which is two to seven meters thick. This has been verified by three deep drillings of about 12 m. An additional 14 bore-holes of 1 m depth around the site indicate with fair confidence that the clay is ubiquitous beneath the dumpsite. The clay layer of high plasticity is believed to have its origins from sediment deposition of an ancient lake (low energy water dynamics allowing fine particles deposition). The permeability of this clay can generally be regarded as very low with a permeability coefficient ranging between 10^{-9} and 10^{-11}, UAT-DEP-FI-, DM-MT and CICATA-UA-IPN SES [2].

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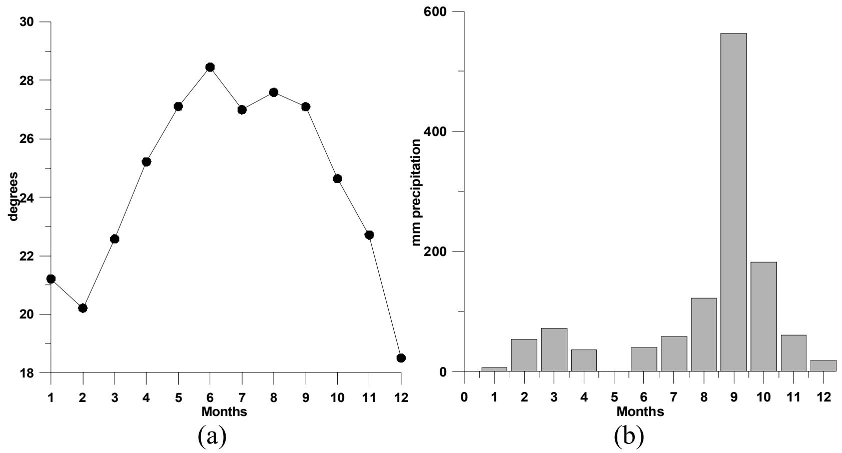

Figure 2: Monthly mean temperature (a) and rain (b) for Tampico in 1998. (Source Secretaria de Agricultura and Recursos Hidraulicos, Mexico.)

3 Method

3.1 Leachate sampling

In 2004, samples of leachate were collected with a small electric pump in May (dry season) from venting wells, and in October (rainy season) from small ponds where leachate accumulates on the edges of the dumpsite. Samples were collected after a clay cover was completed in April 2004. After collection, samples were conserved, EPA 3051 [3], and cooled for their transportation to the laboratory.

3.2 Soil sampling

Fifteen samples of soil beneath the dumpsite were collected in October 2004, from a hole opened by an excavator machine after the removal of the waste layer, in the southeast part of the dumpsite, considered the most active zone. Samples were collected on the wall of the hole every 10 cm to a depth of 1,5 m., using small sections of PVC pipe (3.5cm diameter) drilled in horizontally.

3.3 Samples analysis

Metal content of leachate and soil was determined by Atomic Absorption spectrometry, after acid digestion, EPA 3051 [3]. Results correspond to analyzed metals and tracers with certified reference material in samples of leachate and to results of the prospecting laboratory curve of for soil samples. Determinations in soil and leachate were carried out with standards of primary type (CENAM) and standards of international secondary type (High Purity).

4 Results

4.1 Leached

Leachate content of Pb, Ni, Cd and Cu are reported for dry and rainy seasons in 2004. Metal contents for the dry season are consistently of higher than those measured in the rainy season, fig. 3. The proportional concentration of metals is Ni> Pb > Cu >Cd.

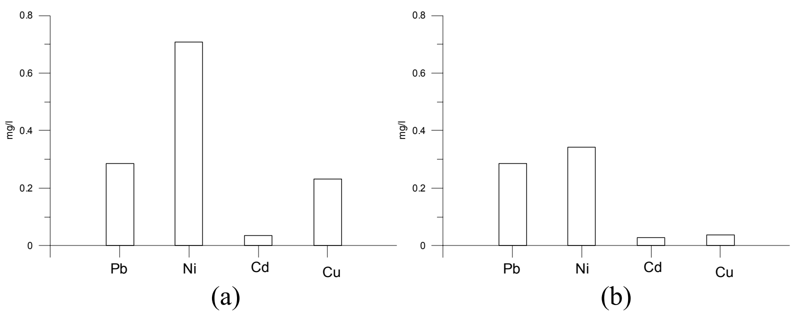

Figure 3: a) Metal contents in leachate samples collected in dry (May) and b) rainy (October) seasons of year 2004.

4.2 Soil

Metal content (Pb, Ni, Cd, Cu, Cr, Fe, Mg and Mn) in soil beneath the dumpsite (layers 0-150 cm depth) generally decreases with depth, fig. 4, 5 and 6.

The observed decrease in metal concentrations with depth may be grouped in two general patterns. One for Pb, Cu, Cd with a pronounced decrease in the first layers to 60-80 cm, and no significant variation thereafter, fig. 4.

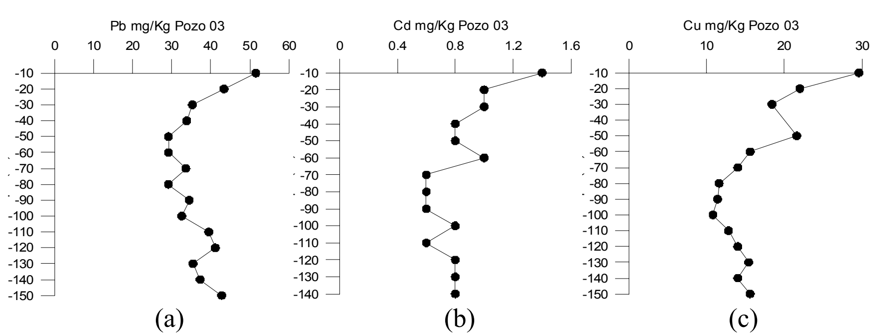

Figure 4: (a) Pb, (b) Cd and (c) Cu contents in soil profile beneath the dumpsite.

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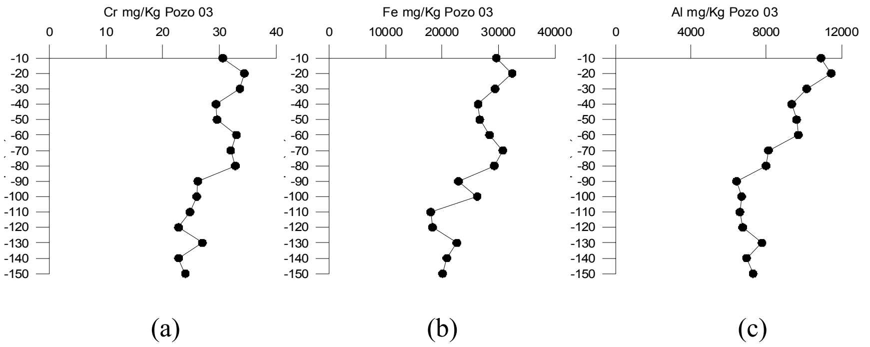

Figure 5: (a) Cr, (b) Fe and (c) Al contents in soil profile beneath the dumpsite.

The second pattern is observed with Cr, Fe and Al where it is evident that a nearly linear decrease tendency of metal content with depth, fig. 5.

Variations of concentration with depth for Ni does not fit within these two patterns. Vanadium concentrations appears rather constant between 49.2-67 mg/kg., except in 60 and 90 cm depth layer. At this point a sudden increase was observed. The concentration of calcium contained in the sediments, its show an inversely proportional relation with Vanadium, which was observed high concentration in 60-90 cm depth, fig. 6(a) and 6(b).

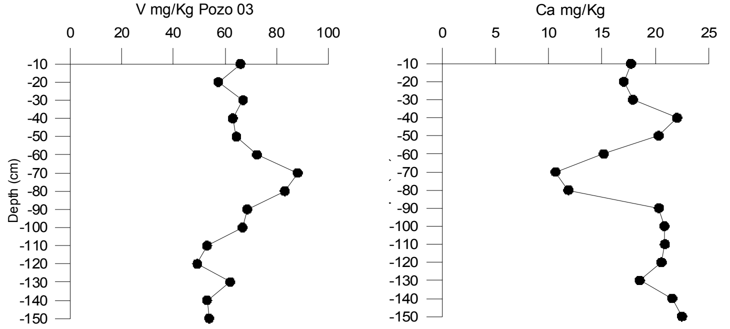

Figure 6: (a) Vanadium and (b) Calcium contents in soil profile beneath the dumpsite.

5 Discussion

The comparison of leachate metal contents between dry and rainy seasons denotes a considerable dilution effect. The characteristic of the proportional concentration of leached metal concentration is compared with concentrations of these metals in Ehrig [4]. The author presents the metal concentration in typical leachate from a landfield. The average concentration presented for Pb, Ni, Cd and Cu, corresponds to 0.090, 0.200, 0.006, and 0.080 μg/l with the next expression: Ni>Pb>Cu>Cd. A similar proportion is reported to minimum and maximum conditions in metal concentrations in a German landfield. This condition is similar to our results of Zapote dumpsite, fig. 3a and 3b.

The comparison of the soil metal contents from Zapote dumpsite with "Screening Quick reference table for inorganic in solids", Buchman [5] gives an idea of the alteration level of our samples based on the reference data reported for freshwater and marine contaminated sediments. According to Buchman's criteria, the Zapote soil correspond to sediments with low to intermediate affectation in 0-50 cm layers for the metals analyzed here. It is important to mention that the proportional metal concentrations of background sediments correspond to Pb, 16000 ppb, Ni 13000 ppb, Cd ≅ 0.0 and Cu 17000 ppb or (Pb=Cu)>Ni>Cd, while contaminated sediments correspond to Pb 46700-218000 ppb, Ni 20900-51600 ppb, Cd 1200-9600 ppb and Cu 34000-270000 ppb or Pb>Cu>Ni>Cd.

The limits established for contaminated soils according to MENVIQ [6] correspond to class "A" (natural background concentrations) for the layers between 0-50 cm.

The results for layers between 0 and 60-90 cm depth, exceeds concentrations reported for contained metals in sediments of local lagoon systems. Villanueva et al. [7], Villanueva and Botello [8], Vázquez et al. [9], Alvarez-Rivera et al. [10] and Botello et al. [11]. The metal concentrations reported for layers 90 a 150 cm are close to reported concentrations of the metals, however, is higher than the criteria for sediments of freshwater and closer than natural marine sediments.

The reported data allows us to infer, according to the affectation of the sediments criteria of Buchman [5] correspondent zone 0-60 cm prevails affectation conditions from medium to low, here the condition is Pb>Cu>Ni>Cd. According to this criteria the soil in the 50-90 cm layers where the affectation conditions are less important, fig. 6, the condition Pb>Ni>Cu>Cd, can be considered as a transition zone. At last we deduct the proportion to finalize the metal concentration, which characterizes with Pb>(Cu=Ni)>Cd.

6 Conclusions

The conditions of dry and wet seasons impact the concentration of metals due to a dilution effect. We showed evidence of metal transfer from leachate downwards into soil layers beneath Zapote dumpsite. The higher concentrations observed in superficial layers (0-50 cm) may be evidence of clay both impermeability and adsorption capacity. The metal concentration in the 60-90 m and 90-150 m depth correspond to lower metal concentration zones closer to natural background.

This study is prospective in nature and will be complemented by a more intensive sampling protocol of both leachate and soil, either in time and space. However, our results shed the first light into to possible environmental impacts of this ample and long lived dumpsite unwisely opened and operated for 25 years in a marshland.

References

[1] Tamayo J.I. Geografía Moderna de México, Editorial Trillas, Mexico, 398 p. 1975.
[2] UAT-DEP-FI-, DM-MT and CICATA-UA-IPN SES Rehabilitation of the Isleta del Zapote Tampico, Mexico, Proposals for the rehabilitation of the closed municipal dumpsite, Tampico, Tamaulipas, Mexico 22 p, 2004.
[3] Environmental Protection Agency Method 3051, 14 p., 1994.
[4] J. Ehrig H.-J., Stau-und Sickerwasser-behandlungsverfahren Überblick. Had, 7. Erg.-Lfg.2.Aufl.,Mai pp 1-17 , 1997.
[5] M. Buchman., Screening Quick Reference Table for Inorganics in Solids. NOAA, HAZMAT.1999
[6] MENVIQ (Ministere de l'Environnement de Québec). Terrains contaminés, guide des methodes de conservation et d'analyses des echantillons déau et de sol. 93 p. 1990.
[7] S. Villanueva-Fragoso, A. Botello A., F. Páez-Osuna., Evaluación de algunos Metales Pesados en Organismos del Río Coatzacoalcos y de la Laguna del Ostión, Ver., México. Contaminación Ambiental, 4:19-31, 1988.
[8] S. Villanueva-Fragoso., A. Botello. Metales Pesados en la Zona Costera del Golfo de México: Una Revisión. Rev. Int. Contam Ambiental 8(1):47-61, 1992.
[9] F. Vázquez., L. Aguilera., V. Sharma., Metals in Sediments of San Andres Lagoon,Tamaulipas, México. Bull. Environ. Contam. & Toxicol. 52:382-387, 1994.
[10] U. Alvarez-Rivera , L. Rosales-Hoz, A. Carranza-Edwards. Heavy Metals in Blanco River Sediments, Veracruz, México. An. Inst.Cienc.del Mar y Limnol.13:1-10, 1986.
[11] A. V. Botello, S. Villanueva-Fragoso y L. Rosales-Hoz, Distribución y contaminación de metales en el Golfo de México. en Caso M., I. Pisanty y E. Ezcurra (eds) Diagnostico ambiental del Golfo de México, SEMARNAT, INE, IEAC, Harte RIGOMS., Mexico pp 683-712. 2004.