International Scholars Journals

African Journal of Soil Science ISSN 2375-088X Vol. 7 (1), pp. 523-529, January, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Assessment of the concentration of heavy metals associated with landfill leachate in Gamodubu soils in the Kweneng District, Botswana

Thatayaone Popego[1], Oagile Dikinya[2], Goabaone Gaobotse[3]

[1]Dept. of Earth and Environmental Science, Botswana International University of Science and Technology, Private Bag 16, Palapye, Botswana.
[2]Dept. of Environmental Science, University Of Botswana, Private Bag 0022, Gaborone, Botswana.
[3]Dept. of Biological Sciences and Biotechnology, Botswana International University of Science and Technology, Private Bag 16, Palapye, Botswana.

Accepted 13 December, 2018

Composting is a common method of household waste in developing countries such as Botswana. However, compost can introduce heavy metals which are harmful to the environment. High concentrations of heavy metals are toxic to plants and humans and can affect soil by killing soil microorganisms. The aim of this study was to investigate the amount of four heavy metals (Cr, Co, Cu and Pb) in Gamodubu soils that are associated with leachate from a landfill in that area. Soil samples were collected from five randomly selected points around the Gamodubu landfill. A control site was established 1000m away from the landfill i.e. free from landfill leachate. Water samples were collected in a control natural pond away from the landfill and a leachate pond within the landfill. Total recovery concentrations for Cr, Co, Cu and Pb were determined using microwave digestion with nitric acid. Our findings showed no evidence of heavy metal concentration in Gamodubu soils as these metals were detected at negligible amounts. The presence of these metals in the soil was greater than their presence in water. Concentrations of all metals (except Pb) in the control water sample were within the chemical requirements of drinking water as set by the Botswana Bureau of Standards. Findings of this study will contribute to the inadequate knowledge on the soils and drinking waters of Botswana. Furthermore, this study will guide similar future studies in Botswana.

Keywords: Contamination, landfill leachate, Gamodubu area, atomic absorption spectrophotometer.

INTRODUCTION

Landfills encompass waste disposal sites and sites where producers dump waste. Some landfills are employed as temporary waste storages, accumulation sites for waste before it is transferred to be destroyed or for the direct processing of waste materials. The level of heavy metal contamination of an area is dependent on the geographic attributes of the area itself (Ghazaryan *et al*., 2016). Sanitary landfills are ubiquitously used for disposing solid waste and are the commonly preferred disposal method in this regard (Ward *et. al*., 2005). Waste that is disposed by the government often contains chemicals and other hazardous small products (Slack *et al*., 2005). Landfills can also contain pesticides, carboxylic acids and phenols which make them very dangerous (Paxeus, 2000). Mono and diesters of o-pathalic acid can also be present in landfills (Jonson *et al*., 2003). Some of these chemicals are released throughout the entirety of the landfill’s existence. Because of this, some of these toxic chemical senter the landfill leachate (Baun*et al*., 2004). Although some developed countries have engineered

Corresponding Author. E-mail: gaobotseg@biust.ac.bw

landfill facilities in order to get rid of or reduce the negative effects of waste on the environment, the production of contaminated leachate can never be avoided.

Landfill leachate has been shown to possess different kinds of heavy metals. The amount of these heavy metals in the leachate is often determined by the type of solid waste that has been disposed in the landfill as well as the sources of the waste. The quality of ground water and soils in the vicinity of the landfill can be adversely affected by the infiltration of leachate. The quality of surface water can also be compromised by untreated leachate. Contamination of ground and surface water can affect natural vegetation, plants. Moreover, water supply for humans can also be affected leading to health problems.

Because leachate contains a lot of toxic inorganic and organic compounds such as heavy metals, leachate migration has been identified as one of the causes of global environmental pollution (Slack *et al*., 2005). The effects of leachate on plants and vegetation need to be properly studied and understood. One of the reasons why heavy metal contamination is a cause of global concern is because these metals can bio-accumulate beyond the tolerance capacities of living things (Voegelin *et al*., 2003). This can negatively impact the earth's ecosystem.

Government waste and industrial waste have been shown to contain different types of toxic heavy metals. Chromium, lead, mercury, nickel, zinc and copper are some of the most common heavy metals contained in government and industrial waste. However, the concentrations of these heavy metals in soil leachate vary from one landfill to another. Because most of these heavy metals are retained in the landfill, it is expected that their leaching from landfills will continue for a long time (Fetter, 2001). It can take years to identify ground water pollution. Moreover, chemicals in the leachates often work together to affect the ecosystem. In this study, for the first time, we aimed to determine the concentrations of some of the heavy metals in soil leachate from a landfill in the Gamodubu area, in the Kweneng District, Botswana. Heavy metals can affect farming activities by compromising the soil quality. The electrical conductivity of the control and landfill soils at Gamodubu were also determined. Additionally, total dissolved solids (TDS) of water samples from the landfill leachate pond and control water were determined.

MATERIALS AND METHODS

Study area

The study was conducted at and around the Gamodubu landfill in the Kweneng District, Botswana (Figure 1). Gamodubu is about 900m above sea level with a mean annual rainfall of about 550mm. The soil of the Gamodubu area can be described as both hardveld and sandveld. Gamodubu is a traditional village, like many others in Botswana. Residents rely on pastoral and arable farming but for most, farming is done far away from their homesteads at the Gamodubu village.

Soil sampling and analysis

This study relied on primary data where soil samples were collected on selected points near and away from the landfill. A control site was established 1000m away from the landfill site because it was assumed free from leachate. Background information on the study area was obtained from literature and from the Kweneng Land Board. Random sampling was employed because it is free from errors in classification which is suitable for data analysis (For more on random sampling, see Frerichs, 2008). Random sampling is also simple and it is easy to assess sampling error when using this method. Soils were sampled five (5) times at different locations around the landfill (i.e. throughout the parts assumed to be affected by the leachate discharge) and once (1) from a control site 1000m upstream of the landfill site. Soil samples were ground and passed through a 2 mm stainless steel sieve to remove gravel and rocks.

Heavy Metals Analysis

Total recovery concentrations of the heavy metals were determined using microwave digestion with nitric acid (Bizzi *et al*., 2011). Microwave digestion allows the dissolution of heavy metals using a strong acid. This makes heavy metals soluble and therefore easy to quantify. The heavy metals were analyzed using Atomic Absorption Spectrophotometer (AAS).

Water sample collection

Water was sampled from a leachate pond inside the landfill (which was assumed to be affected by the leachate) and water control sample collected 1000m away from the landfill in a natural pond. Water collection bottles were acidified with 1ml 98% nitric acid to preserve the cations of positively charged ions. The unacidified bottles were used to collect water for anion analysis.

Electrical conductivity (EC) and Total Dissolved Solids (TDS)

EC measurements of landfill soil, control soil, leachate water and water control samples were measured using an electrical conductivity meter (See User's Guide, Extech Instruments, 2011) which was standardized using distilled water. Total dissolved solvents were then determined.

RESULTS

There was no chromium (Cr) detected in all the soil samples including the control. Negligible amounts of Cr were detected in the control water and leachate pond water samples at 0.01 and 0.05 mg/L respectively (Figure 2). Copper (Cu) was detected in all the 5 landfill soil samples. Amounts of Cu detected in these samples from

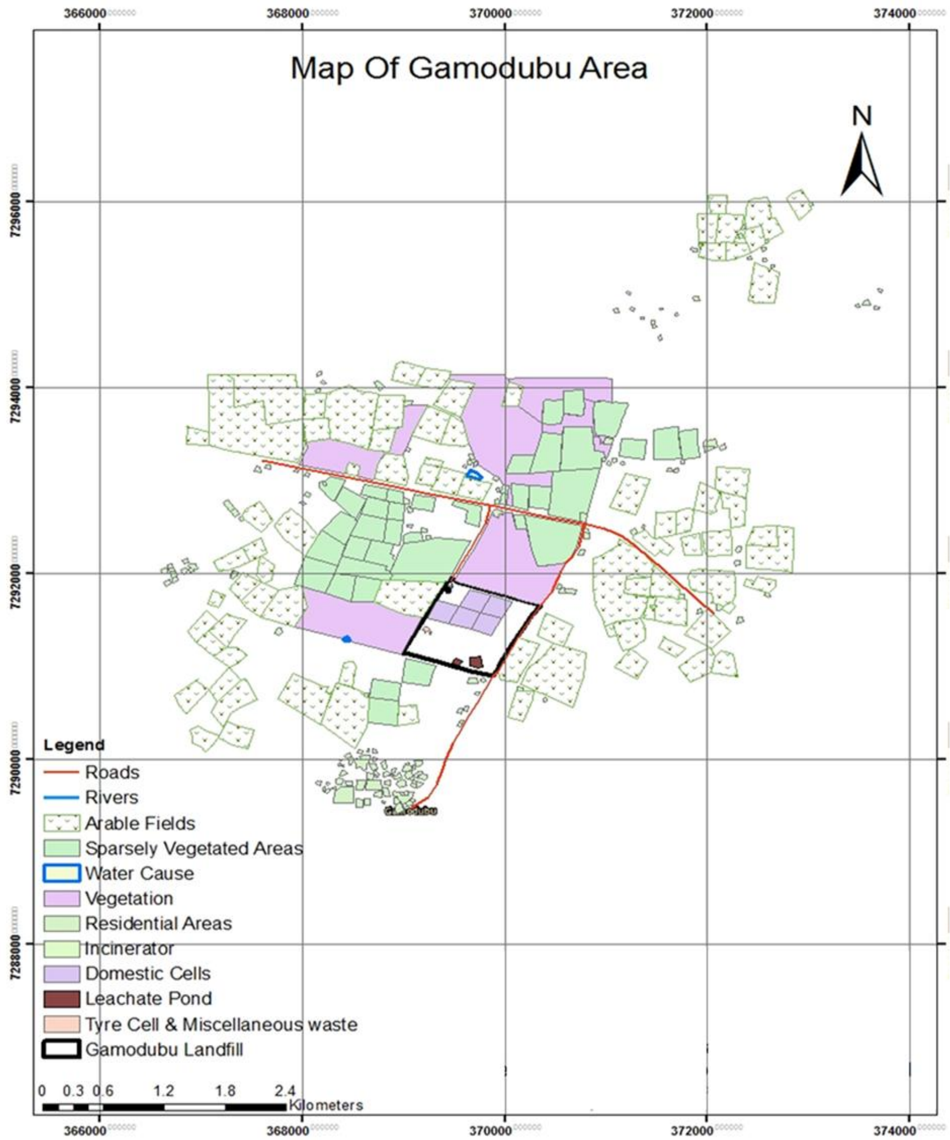

Fig 1. A map of the Gamodubu area showing the location of the study area.

landfill sample 1 to landfill sample 5 were 0.24, 0.23, 0.23, 0.19 and 0.22 mg/L respectively. 0.22, 0.04 and 0.07 mg/L of Cu were detected in the soil control sample, the water control sample and the leachate water sample respectively. Amounts of cobalt (Co) detected in landfill soil samples 1 to 5 were1.02, 0.90, 0.93, 0.78 and 0.79 mg/L respectively. Soil control sample, water control sample and leachate pond water sample recorded 1.12, 0 and 0.01 mg/l of Co respectively (Figure 2). Lead (Pb) was measured at 3.67, 3.26, 3.51, 2.87, 3.35, 3.28, 3.69 and 0 mg/L in Landfill samples 1 to 5, soil control sample, control water sample and leachate water sample respectively. Pb was the most prevalent heavy metal in the 5 landfill samples. Because Cr was not detected in any of the 5 landfill soil samples, Cu was the least prevalent heavy metal in all the five soil samples. The concentration of Pb was about three times higher than that of Co in all the 5 landfill samples. However, this was not the case in the control samples. Co had the second highest concentrations in all the landfill soil samples. In the water control sample, concentrations of all heavy metals (except Pb at 3.69 mg/L) were within the ideal limit of chemicals for drinking water as set by the Botswana Bureau of Standards, a regulatory body which determines drinking water heavy metal concentrations that are not dangerous for human consumption (Table 1). The permissible concentration of Pb is 0.01 mg/L in all the three requirement classes. Permissible concentrations for Cr and Cu are 0.05 and 1 mg/L respectively in all the three requirement classes. Co permissible concentrations are 0.25, 0.5 and 1 mg/L from class 1 to class 3 respectively (Table 1).

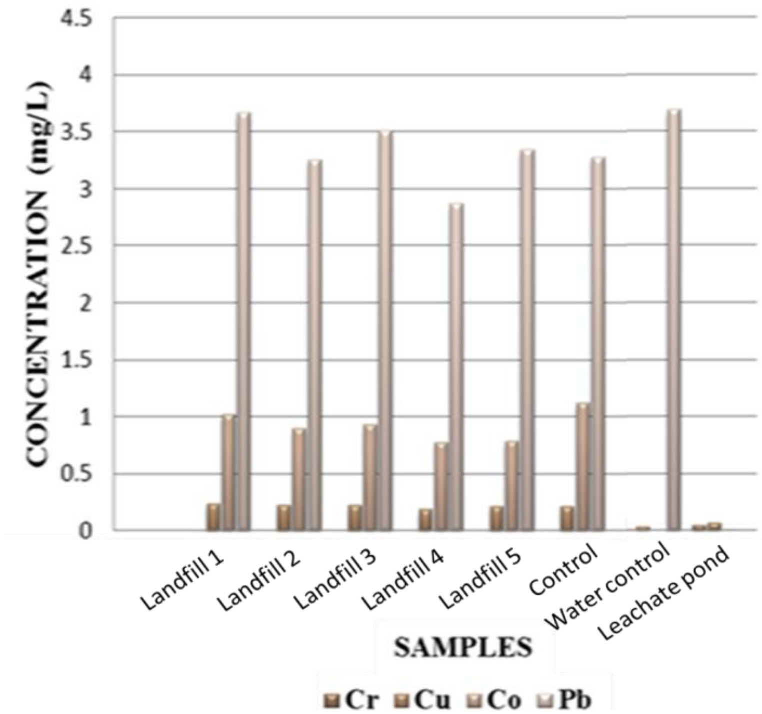

Fig 2. Concentrations of heavy metals in soil and water samples from the landfill and a soil control sample in the Gamodubu area.

Table 1. Chemical requirements of drinking water.

Chemical Requirements micro determinants	Unit	Class 1(Ideal)	Class 2(Acceptable)	Class 3(Max.allowable)
Chromium as Cr (total)	mg/L	0.05	0.05	0.05
Cobalt as Co	mg/L	0.25	0.5	1
Copper as Cu	mg/L	1	1	1
Lead as Pb	mg/L	0.01	0.01	0.01

Source: Botswana Bureau of Standards.

Electrical conductivity measured for the five landfill soil samples from sample 1 to 5 were130.9, 394, 90.3, 334 and 97.8µS/cm respectively (Figure 3). EC value for the soil control sample was measured at 121.9µS/cm while the water control and leachate pond water samples recorded EC values of 112 and 212µS/cm respectively. There were variations in the EC readings with a range of 90.3 to 394 µS/c. There was not much disparity in EC values for the soil and water controls which recorded 212 and 112µS/cm respectively. All EC values recorded were within the ideal limit of 700µS/cm as outline by the Botswana Bureau of Standards (Table 2).

Total dissolved solids values were determined for both the water control sample which was collected 1000m away from the landfill site and the landfill leachate water sample that was collected in a pond within the landfill area.TDS value was recorded at 85ppm for the water control sample and 151ppm for the leachate pond water sample (Figure 4). There was a significantly high amount of dissolved solids in landfill sample water than the control water sample. These TDS readings obtained are significantly below the requirements of Botswana Bureau of Standards requirements of 450 ppm (=450 mg/L) for drinking water (Table 2).

Electrical conductivity requirements for drinking water are 700, 1500 and 3100 µS/cm for the three requirement classes. Total dissolved solids across the three classes as specified by the Botswana Bureau of Standards are 450, 1000 and 2000 mg/L from class 1 to class 3 respectively. Table 2 below summarizes electrical conductivity and total dissolve3d solids requirement classes for drinking water in Botswana.

DISCUSSION

Any pollution or interference of soil can render that soil un-

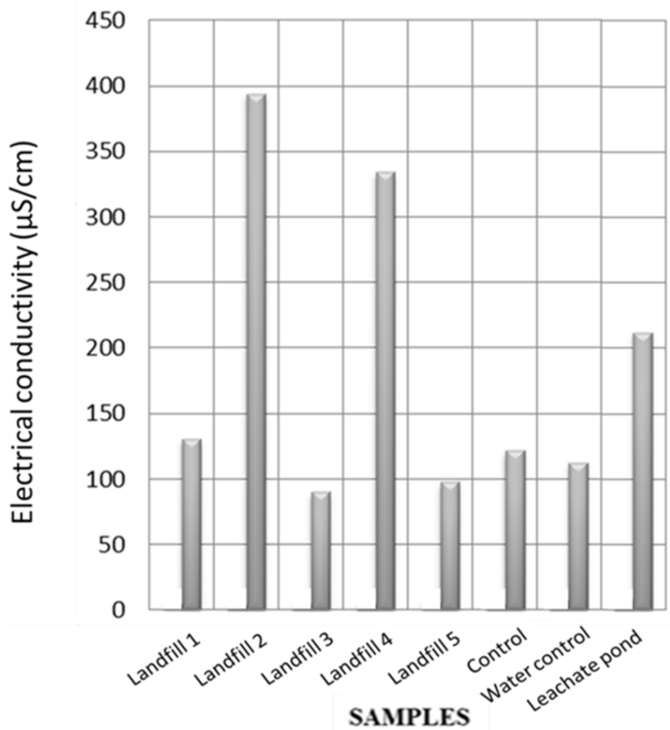

Fig 3. EC variations in soil samples in the control and landfill of Gamodubu.

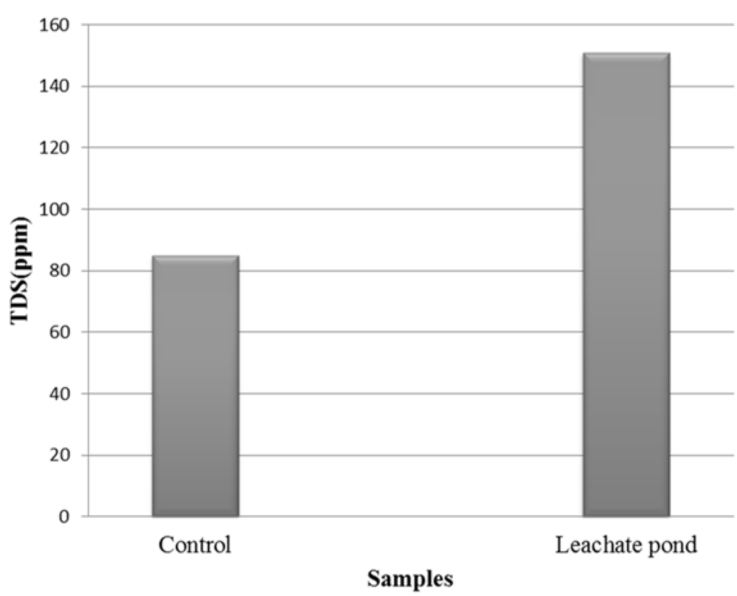

Fig 4. Total Dissolved Solids levels of the control water sample and leachate pond watersample in and near Gamodubu landfill.

productive and unsuitable for agricultural use (Zhang et al., 2010). Cu, Co and Pb were all detected in the soil samples from both the landfill and the control site, while Crwas not detected in any of the soil samples. With the exception of Pb, the heavy metals were detected in negligible amounts. Sulfide is formed from sulfate reduction during waste decomposition in landfills, and sulfide precipitation can cause low concentrations of heavy metals (Christensen *et al*., 2000). Therefore, sulfides are heavy metal scavengers. The presence of the

Table 2. Physical and organoleptic requirement of drinking water.

Variable	**Unit**			
Physical and Aesthetic	**Unit**	**Class 1(Ideal)**	**Class 2(Acceptable)**	**Class 3(max. allowable)**
Conductivity	µS/cm	700	1500	3100
Total Dissolved Solids	mg/L	450	1000	2000
pHat 25degrees Celsius		6.5-8.5	5.5-9.5	5.0-10.0
Taste	N/A	Not objectional	Not objectional	Not objectional

Source: Botswana Bureau of Standards.

different heavy metals in sample and control soils is an indication that a variety of waste is disposed in the landfill. The mean concentration of Pb in landfill soil samples was 3.33 mg**/**L, which was nearly the same to its 3.28 mg**/**L concentration in the soil control sample. According to Redondo-Gomez*et al.* (2009), soil organic matter, soil pH and soil texture can affect heavy metal accumulation. Heavy metals are absorbed by organic matter and silt/clay fraction. High pH, organic matter and clay content can increase the binding of heavy metals (Geoffrey, 2004; Nouri *et al*., 2009; Prasad and Freitas, 2003). Heavy metals can be introduced into the environment in various ways such as agriculture and mining (Tchounwou *et al*., 2012). The Gamodubu area is itself a small scale farming area.

The mean concentration of Cu in the five landfill soil samples was 0.22mg/L, perhaps an indication of low levels of insecticides, pharmaceuticals and cosmetics disposal in the Gamodubu area. This is not surprising for a rural and fairly traditional village. The high levels of Pb in both the control and landfill soils could be an indication that Pb occurs naturally at high amounts. Cuon the other hand has been found to be susceptible to accumulation in surface soil layers due to its strong binding to organic matter, clay minerals, and iron, iron and aluminum oxides (Kabata-Pendias and Sadurski,2004; Ma *et al*., 2001). Substantial leaching of Cu has been shown in humus-poor acidic soils and in soils which have received repeated application of Cu fertilizers (Xiao and Wei, 2007). However, it has been previous reported that leaching does not easily affect heavy metals in soil and these heavy metals tend to remain in the soil for prolonged periods of time (Padmavathiamma and Li, 2007;Sheoran*et al*., 2009).

The potential of a landfill to buffer changes is sufficient to maintain a neutral pH over a long period of time, therefore limiting the risk of metal solubilisation due to pH changes. Formation of oxidized compounds can cause the dissolution of some compounds containing heavy metals in leachate. The low concentrations of heavy metals in this study may signal that waste dumped was segregated or stabilized before taken to the landfill. Heavy metals were detected in negligible amounts in both the water and the leachate pond water samples. According to Kjeldsen *et al*. (2002), precipitation is one factor through which the concentration of heavy metals is soils is lowered. Cobalt (Co) is an essential element for the growth of marine algal species. At low concentrations, it has been shown to enhance plant growth but at high concentrations, it is toxic to plants and humans.

The EC value in the control site was less than the Botswana Bureau Standards permissible limits of physical and organoleptic requirements of drinking of drinking water in class 1.Therefore, the water control site was free from pollution and suitable for consumption. TDS indicates the general nature of water quality or salinity**.**TDS values of 85ppm and 151 ppm in the control and landfill water samples respectively were much less than the Botswana Bureau of Standards permissible limit (450mg/L) of chemical requirements of drinking water. The heavy metal analysis of soil and water samples shows that heavy metals rarely cause groundwater pollution at landfills. This is because soil and water samples usually contain relatively low concentrations of these metals, and they are weakened by factors such assorption and rainfall (Regadío *et. al*., 2015).

CONCLUSIONS

Heavy metals were detected at negligible amounts in the soils of the Gamodubu landfill area. The presence of these metals in soil was greater than their presence in water. Electrical Conductivity values of the soil samples were all below permissible levels in Botswana The results of this study indicate that Pb, Cu and Co concentration in the Gamodubu soils were all less than permissible limits. The findings of this study will contribute to the study of the effects of heavy metals to the soils and waters of Gamodubu in Botswana. Therefore, they will guide similar studies in other parts of the country. Furthermore, this study has provided novel knowledge that never existed before since this is the first study of its kind in the Gamodubu area.

REFERENCES

Baun, A., Ledin, A., Reitzel, A., Bjerg, P. L., and Christensen, T. H.:Xenobiotic organic compounds in leachate from ten Danish MSW landfill-chemical analysis and toxicity tests, Water Res., 38, 3845-3858, 2004.

Bizzi, C. A., Flores, E. M. M., Barin, J. S., Garcia, E. E., Nóbregad J. A.: Understanding the process of microwave-assisted digestion combining diluted nitric acid and oxygen as auxiliary reagent, Microchemical Journal, 99 (2), 193-196, 2011.

Christensen, A. G., Fischer, E. V., Nielsen, H. N., Nygaard, T., Ostergaard, H., Lenschow, S. R., Fuglsang, I. A., and Larsen, T. H.: Passive soil vapor extraction of chlorinated solvents using boreholes, in Physical and Thermal Technologies, Remediation of chlorinated and recalcitrant compounds, in: The 2nd International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California. USA, 22-25, 2000.

Fetter, C. W.: Applied Hydrogeology, Prentice Hall, New Jersey, USA, 2001.

Frerichs, R.R. Rapid Surveys (unpublished), 2008.

Geoffrey M. G.: Microbial influence on metal mobility and application for bioremediation. Geoderma,122, 109-119, 2004.

Ghazaryan, K. A., Movsesyan, H. S., and Ghazaryan, N. P.: Application of Various Methods for Evaluation of Heavy Metal Pollution in Soils around Agarak Copper-Molybdenum Mine Complex, Armenia. International Journal of Environmental and Ecological Engineering, 10, (8), 2016.

Jonsson, S., Ejlertsson, J., Ledin, A., Mersiowsky, I., and Svensson, B.H.: Mono- and diesters of o-phathalic acid in leachates from different European landfills, Water Res, 37, 609–617,2003.

Kabata-Pendias, A., and Sadurski, W.: Trace elements and compounds in soil Elements and Their Compounds in the Environment, Wiley-VCH, Weinheim, Germany, 2004.

Kjeldsen, P. I., Barlaz, M. A., Rooker, A. P., Baun, A., Ledin, A., and Christensen T. H.: Present and Long-Term Composition of MSW Landfill Leachate: A Review. Critical Reviews in Environmental Science and Technology, 32(4):297-336, 2002.

Ma, L. Q., Komar, K. M., Tu, C., Zhang, W., Cai, Y., and Kenelly, E. D.: A fern that Hyper accumulates arsenic. Nature, 409, 579-582, 2001.

Nouri, J., Khorasani, N., Lorestani, B., Karami, M., Hassani A. H., and Yousefi N.: Accumulation of heavy metals in soil and uptake by plant species with phytoremediation potential. Environ.Earth Sci., 59, 315-323, 2009.

Padmavathiamma, P.K., and Li L. Y.: Phytoremediation technology: Hyper-accumulation metals in plants, Water Air Soil Pollut., 184, 105-126, 2007.

Paxeus, N.: Organic compounds in municipal landfill leachates. Water Sci. Technol, 41 (7–8), 323, 2000.

Prasad, M.N.V., and Freitas, H.: Metal hyperaccumulation in plants - Biodiversity prospecting for phytoremediation technology. Electronic Journal of Biotechnology, 6, 275-321, 2003.

Redondo-Gomez, S., Cantos, M., Mateos-Naranjo, E., Figueroa, M. E., and Troncoso, A.: Heavy metals and trace element concentrations in intertidal soils of four estuaries of SW Iberian Peninsula, Soil & Sediment Contamin., 18, 320-327, 2009.

Regadío, M., Ruiz, A. I., Rodríguez-Rastrero, M., and Cuevas, J.: Containment and attenuating layers: an affordable strategy that preserves soil and water from landfill pollution. WasteManagement, 46, 408-419, 2015.

Sheoran, V., Sheoran, A.S., and Poonia, P.: Phytomining: A review. Minerals Engineering, 22, 1007-1019, 2009.

Slack, R. J., Gronow,J. R., and Voulvoulis, N.: Household hazardous waste in municipal landfills: Contaminants in leachate. Sci. Total Environ., 337, 119-137, 2005.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., and Sutton, D. J.: Heavy metals toxicity and the environment. In: Luch A, editor. Molecular, clinical and environmental toxicology, Berlin: Experientia Supplementum, 101, 133–164, 2012.

Voegelin, A., Barmettler, K., and Kretzschmar, R.: Heavy metals release from contaminated soils: Comparison of column and batch extraction results. J. Environ. Qual., 32, 865-875, 2003.

Ward, M. L., Bitton, G., and Townsend, T.: Heavy metal binding capacity (HMBC) of municipal solid waste landfill leachates. Chemosphere, 60, 206-216, 2005.

Xiao, H. G., and Wei, J. (2007). Relating landscape characteristics to non-point source pollution in mine waste-locate watersheds using geospatial techniques. Journal of Environmental Management, 82, 111–119, 2007.

Zhang X., Xia H., Li Z., Zhuang P., and Gao B.: Potential of four forage grasses in remediation of Cd and Zn contaminated soils. Bioresource Technology, 101, 2063-2066, 2010.