

Effect of Municipal Solid Waste Compost on Arsenic Leaching throughout Calcareous Soil Columns

Faranak Darvishi and Bubak Souri*

Department of Environmental Sciences, Faculty of Natural Resources, University
of Kurdistan, P.O. Box 416 Sanandaj, Iran
✉ bsouri@uok.ac.ir

Received May 3, 2016; revised and accepted September 13, 2016

Abstract: Effect of municipal solid wastes on arsenic leaching in soils is a controversial issue. Calcareous soil naturally bearing considerable amount of arsenic samples from Qorveh plain, in western Iran, was applied to assemble nine soil columns including three treatments of 0 (control), 30 and 60 percent of municipal solid wastes compost each triplicated. Four months of leaching experiment using 300 ml of 833 mg L⁻¹ ammonium phosphate twice a week showed less arsenic leaching for composted soil columns compared to the controls. The results showed that iron, phosphate, nitrate and arsenic concentration leakage significantly differed between the composted and the control columns as decreasing of arsenic leaching throughout the composted columns was also seen. Additionally, it seems soil water retention capacity influenced by amount of the compost added to the columns affects arsenic leaching intensity.

Key words: Arsenic, leaching, compost, ammonium phosphate, calcareous soil column.

Introduction

Presence of heavy metals in soil and leaching into underground water is one of the factors restricting the use of polluted soils once water resources development is concerned. Arsenic is a non-essential element to both human and other living beings (Shamberger, 1979). Arsenic particular significance is due to toxicity of its organic and inorganic forms while the latter is more toxic for human (Tseng, 1977) occurring mainly as arsenite As(III) and arsenate As(V) in natural waters (Bhattacharyya et al., 2003) whereas standard level recommended for its contamination is 10 µg L⁻¹ in drinking water (Haque et al., 2008). However, arsenic standard level for contamination in soils varies between 0 and 50 mg kg⁻¹ in different regions according to soil characteristics (Cairney et al., 1987). Among the mechanisms which affect arsenic mobilization in soil

environment its absorption to the iron oxyhydroxides, hereafter simply called iron oxides, is the most important ones (Elkhatib et al., 1984). Mobility, bioavailability and toxicity of arsenic is affected by presence of other anions such as PO₄⁻³, SO₄⁻² and CO₃⁻² that compete with arsenate as the most abundant form of arsenic for bonding to the soil particles (Smith et al., 2002).

Nowadays, stabilization of contaminants to restrict transfer of pollutants to lower soil layers and also groundwater is an applied method to contain and neutralize contaminants in polluted areas (Lee et al., 2011). Although previous studies emphasized on increasing and decreasing arsenic leaching by adding phosphate and iron oxides, respectively (Yanshan et al., 2010); existed literatures don't agree on behaviour of municipal solid wastes composted materials regarding arsenic solubility, leaching and toxicity in soil environment as some reported its accelerating

*Corresponding Author

effect (Cao et al., 2004; Tarn et al., 2008; Hartley et al., 2010) but others mentioned its restricting performance (Caporal et al., 2013). More than seventy percent of Iranian municipal solid wastes are compostable organic materials (Tataro et al., 1997) whereas the produced compost is inexpensive and reportedly suitable for soil amendment purposes in farmlands (Ramadass et al., 2007). The aim of this study is to investigate mobilization/fixation of arsenic through application of municipal solid wastes composted materials in calcareous soils with a natural contamination of arsenic from Qorveh plain, an agricultural region in western Iran, using soil columns technique.

Material and Methods

Soil Sampling

The studied calcareous soil used to fill the soil columns was obtained from a site in Qorveh plain in Kurdistan province western Iran (Figure 1) where it reportedly has the highest arsenic concentration across the region (Karimi et al., 2010).

Soil sampling was conducted from soil surface down to 50 cm depth as this range usually is interfered the most by tillage activities where five soil samples each containing about 40 kg of soil were obtained from 0-10, 10-20, 20-30, 30-40 and 40-50 cm depth intervals. Then the five soil samples were thoroughly mixed, air dried for 10 days and sieved using a 2 mm mesh size sieve. Moreover, core sampling was applied to determine bulk density of the sample once taken to the laboratory using 100 cm³ stainless steel cores.

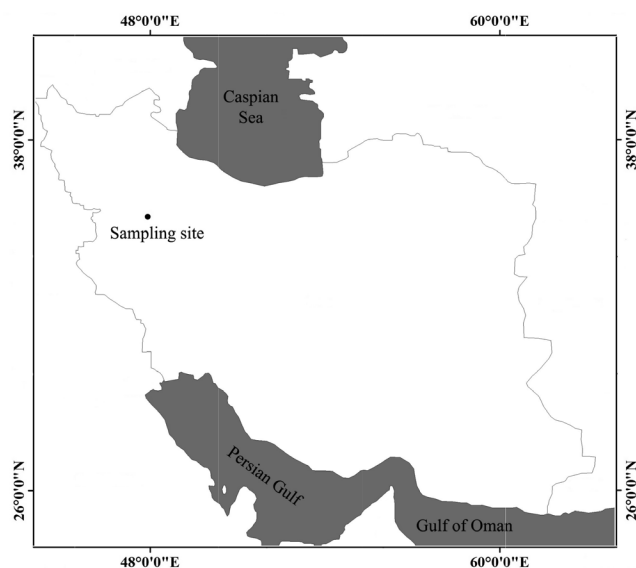


Figure 1: Location of the sampling site in Qorveh plain, western Iran, to obtain soil for filling the soil columns.

Soil Analysis

Soil pH was measured in 1: 2 ratio of soil to water using glass electrode of a pH meter (Metrohm 744). Electrical conductivity (EC) was also measured on saturation extract of soil and, following an acid neutralization, soil carbonate represented by calcium carbonate equivalent percentage (CCE %) was measured through titration (Salinity Laboratory Staff, 1954). Organic carbon content (OC) of the soil was determined through incubation and back titration of the produced carbon dioxide with diluted acid (Hopkins, 2006). After dispersion by sodium hexametaphosphate soil particle size distribution was measured (Day, 1965). Cation exchange capacity (CEC) was determined by replacement of Na⁺ and NH₄⁺ with soil cations (Rhoades, 1982). Soil phosphorus concentration was also determined through Olsen (1954) method. Total Na, Ca, K and Mg after digestion using aqua regia (ratio 3:1 of nitric acid to hydrochloric acid) by a flame photometer (BWB) were measured while concentration of total and amorphous iron oxides, Fe_d and Fe_o, (ISRIC, 1993) alongside with soil total arsenic after digestion with 10 molar hydrochloric acid (Giacomino, 2010) were measured using a flame atomic absorption spectrophotometer (Biotech, Phoneix-986).

Compost Analysis

Analytical characteristics of the municipal solid wastes compost applied were measured after 48 hours of being dried at 60 °C in oven, crushed and sieved through 1 mm mesh size sieve (Khan et al., 2009) as follows: pH was measured after adding 100 ml distilled water to 10 gr compost (Tognetti, 2008) and organic matter weigh percentage was calculated using lost weight of the compost after being five hours in an electric furnace (Nabertherm, Germany) adjusted at 550 °C (Emrani, 2010). Nitrogen of the compost was measured through Kjeldhal method (Brito et al., 2008). Phosphorus and potassium were determined after preparing the extract using dry method (Saha et al., 2010) by spectrophotometer (SPECORD 210) and flame photometer (BWB-1), respectively. Iron and arsenic were also measured in the extract after digestion with 1:3 hydrochloric acid and nitric acid using an atomic absorption spectrophotometer (PHOENIX-986) (Benton et al., 1999).

Soil Columns

A metallic grid box was applied to set nine polyethylene columns vertically each having height and diameter of 120 and 10 cm, respectively. In order to prevent spillage

of the soils and also to facilitate drainage process; white cotton fibres previously washed and sterilized with a plastic cap having a 5 cm diameter hole in the centre as the outlet were applied at the bottom of the columns. Also, a filter containing gravels with 0.5, 2 and 3 cm sizes was used in 20 cm depth over the cotton fibres. The columns were filled and compacted with the soil and compost according to the bulk density of the soil at the sampling site for 80 cm depth above the gravel filter and cotton fibres. Additionally, a size range of 2 to 5 mm gravels obtained were scattered throughout the soil columns for 5% of their weight in order to facilitate leaching process inside the columns. The gravels were carefully washed with tap water, treated with 1:2 ratio of concentrated hydrochloric acid to water and finally washed with distilled water before adding to the soil columns.

Leaching experiment was launched for each treatment of 0 (control), 30 and 60 percent of compost in the soil columns in triplicate for four months when the columns were under leaching process by adding 300 ml of 833 mg L⁻¹ ammonium phosphate solution twice a week equal to the amount of ammonium phosphate fertilizer usually used at field for the same soil volume in a growing season by farmers. Drained water after each leaching was collected at the bottom of the columns using a plastic funnel with a 10 cm diameter and in a 600 ml beaker beneath (Figure 2).

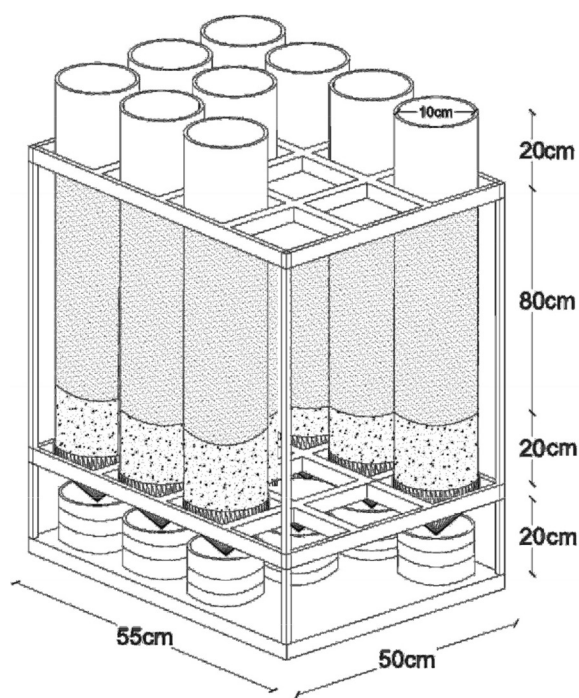


Figure 2: Schematic of the soil columns alongside with the related arrangements and sizes.

Drained Solution

After passing the drained solution through a Whatman filter paper No. 42 following each leaching, pH was measured by glass electrode of a pH meter (WTW 730) while arsenic and iron concentrations were measured using a furnace and flame atomic absorption spectrophotometer (Biotech, Phoneix-986), respectively (Far et al., 2012). Amount of phosphate and nitrate were also determined by a spectrophotometer (SPECORD210).

Statistics

The results were expressed as an average of triplicates. The data normality was tested and if necessary normalization was done through logarithmic method. Normality of variance was evaluated by Kolmogorov-Smirnov and Levene's tests. Differences among treatments were separated by least significant difference analysis at $P < 0.05$. For the data of the drained solution from the columns ANOVA was used based on a completely randomized design and factorial experiment. All the statistical analyses were performed using SPSS version 12 and SAS software.

Results and Discussion

Physico-chemical properties of the soil and the municipal solid wastes compost used in this study are presented in Tables 1 and 2.

Variation of arsenic concentration in the drained solution of the control columns ranged from 8.75 for 1st leaching stage to 25.98 for 7th leaching stage as a decreasing trend prevailed for the arsenic concentration in the drained solution for the rest of the tests' period which finally reached 2.71 mg kg⁻¹ of arsenic to dry soil for 35th leaching stage at the end of the experiments. In the columns containing 30 and 60 percent compost arsenic concentration in the drained solution changed from 4.29 and 0.47 for 1st leaching stage to 6.62 and 5.50 mg kg⁻¹ for 7th leaching stage whereas it finally reached 1.08 and 0.65 mg kg⁻¹ for 35th leaching stage at the end of the experiments, respectively. Evidently, arsenic leaching for the soil columns having 30 and 60 percent compost reduced 3.93 and 4.81 times compared to the controls (Figures 3 and 4).

Analysis of variance based on a factorial design approved that the difference between the soil columns for the control, the 30 and the 60 percent of compost treatments regarding leaching of arsenic, nitrate and iron were significant at $P < 0.001$ while regarding leaching of phosphate was significant at $P < 0.05$ (Table 3).

Table 1: Physico-chemical properties of the studied soil

Soil property	Measured value
Sand (%)	52.8
Silt (%)	28.3
Clay (%)	18.9
pH	8.03
EC (ms cm ⁻¹)	2.55
CCE (%)	25
CEC (cmol(+).kg ⁻¹)	24
Total Carbon (%)	0.73
OM (%)	1.26
Na (mg kg ⁻¹)	2392.5
K (mg kg ⁻¹)	2389
Ca (mg kg ⁻¹)	3300
Mg (mg kg ⁻¹)	1867
Fed (g kg ⁻¹)	47
Feo (g kg ⁻¹)	18
As (mg kg ⁻¹)	46.22
P (mg kg ⁻¹)	5.46
Bulk density (g cm ⁻³)	1.56

EC = Electrical conductivity

CCE = Calcium carbonate equivalent

CEC = Cation exchangeable capacity

OM = Organic materials

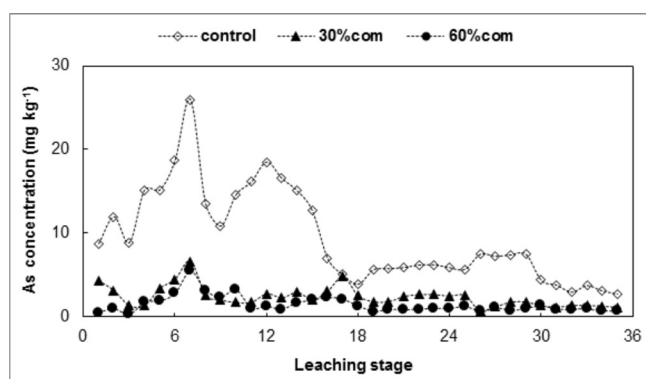
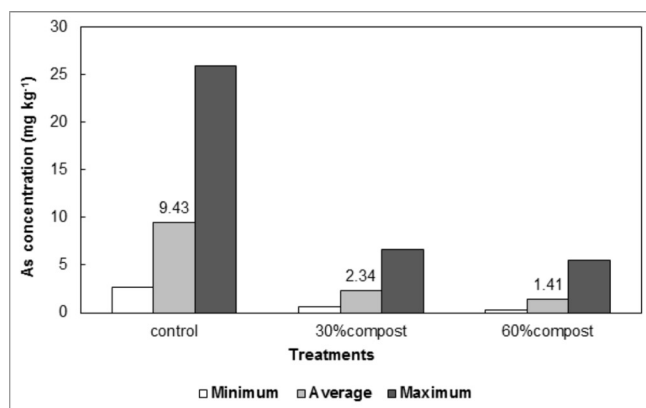
Table 2: Physico-chemical properties of the municipal solid wastes compost used in the study

Compost property	Measured value
pH	7.31
Organic carbon (%)	19.16
Total N (%)	2.05
C/N (ratio)	9.34
OM (%)	34.5
CEC (cmol(+) kg ⁻¹)	76
Total P (mg kg ⁻¹)	24.96
Total K (mg kg ⁻¹)	68.15
Total Fe (mg kg ⁻¹)	57.08
Total As (mg kg ⁻¹)	ND
Bulk density (g cm ⁻³)	1.24

ND = Not detected

OM = Organic materials

CCE = Calcium carbonate equivalent

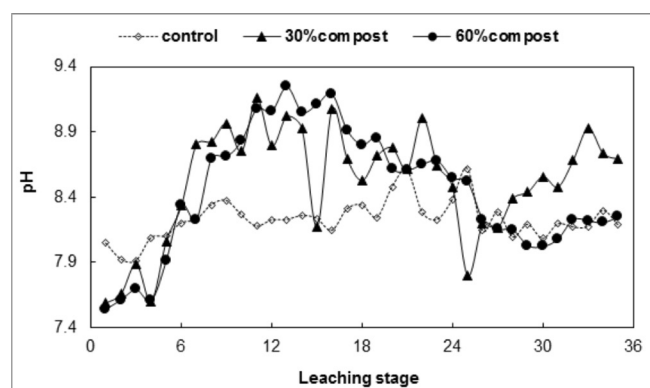
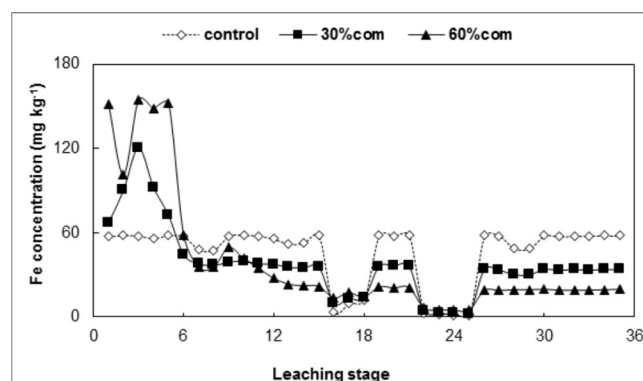
**Figure 3: Variation of arsenic concentration in the drained water of the soil columns for the control and treatments of 30 and 60 percent of compost during the leaching experiment.****Figure 4: Minimum, maximum and average of arsenic concentration in the drained water of the soil columns for the control and treatments of 30 and 60 percent of compost during the leaching experiment.**

Soil pH and concentration of iron oxides are two important soil properties which influence arsenic mobility and absorption in soils (Smedley et al., 2002). Regarding time consuming processes for compost dissolution, pH decreasing is not so sensible and, therefore, arsenic leaching for the composted columns is not considerable during early leaching stages (Figures 3 and 5). As presented in Table 3; concentration of arsenic in drained solution is significantly different ($P < 0.001$) between the composted and the control columns while leaching of arsenic is declined during the leaching stages generally (Figure 3). In the composted columns most of the water is absorbed in the organic compost whereas for the control columns water has more chances to keep soil columns under the field capacity moisture and then to concentrate on arsenic dissolving and mobility. Moreover, soil pH increase for the composted columns is not high enough to decrease arsenic bonding to organic materials (Cao et al., 2004).

Table 3: Variance analysis of outlet water samples from the columns

Source	df	Mean square			
		Arsenic	Phosphate	Nitrate	Iron
Treatment	2	0.56772310***	1.99052091***	1.8124593***	2.27179665***
Stage	34	0.15966044 ^{ns}	0.19810365 ^{ns}	0.14537308 ^{ns}	0.19564963 ^{ns}
Treatment* stage	68	0.15209973*	0.16542884 ^{ns}	0.14914197 ^{ns}	0.11721810 ^{ns}
Error experiment	210	0.16256426	0.211143138	0.17989671	0.18429338

ns = not significant;

* = $P < 0.05$ *** = $P < 0.001$ **Figure 5: Variation of pH in the drained water of the soil columns for the control and treatments of 30 and 60 percent of compost during the leaching experiment.****Figure 6: Variation of iron concentration in the drained water of the soil columns for the control and treatments of 30 and 60 percent of compost during the leaching experiment.**

Also, the highest arsenic concentration and a fairly low iron concentration in the drained solution of the control columns were measured at the leaching stage 7th whereas for the columns with 30 and 60 percent of compost iron leaching was more than control columns until leaching stage 7th (Figure 6) apparently motivated by relatively lower pH during this period of time (Lindsey, 1979).

Organic matter can form mobile complexes with iron in soils resulting in more iron mobility (Tsang et al., 2013) which may explain more iron reaching from the composted columns till leaching stage 5th compared to the control columns. Following intensified iron leaching in the composted columns till leaching stage 5th, most of the leachable iron is washed out and that's why iron leaching is decreased in the composted columns since leaching stage 6th compared to the control columns (Figure 6) which justifies significant difference between the composted and the control columns at $P < 0.001$ (Table 3).

Moreover, adding compost to soil usually result in macronutrients increasing (Caporale et al., 2013); so

more phosphorous concentration in the drained solution till leaching stage 4th for the composted columns compared to the control columns is explainable (Figure 7) which is also approved through significant difference between the two at $P < 0.001$ (Table 3). For the rest of the leaching stages especially since leaching stage 19th phosphorous leaching from the control columns exceeded the composted columns which might be related to phosphorous fixation role of organic materials in the composted columns (Ying et al., 2003) evident through insignificant phosphorous leaching through various stages of leaching during the experiment (Table 3).

Presence of phosphate in soils with low concentration of iron oxides causes arsenic leaching acceleration (Smith et al., 2002) and that's why low leaching of phosphate happened simultaneous to arsenic leaching increase during the first half of the leaching experiments (Figures 3 and 7).

Until the leaching stage 5th process, nitrate concentration in the drained solution from the control columns was less than of the composted columns. Apparently,

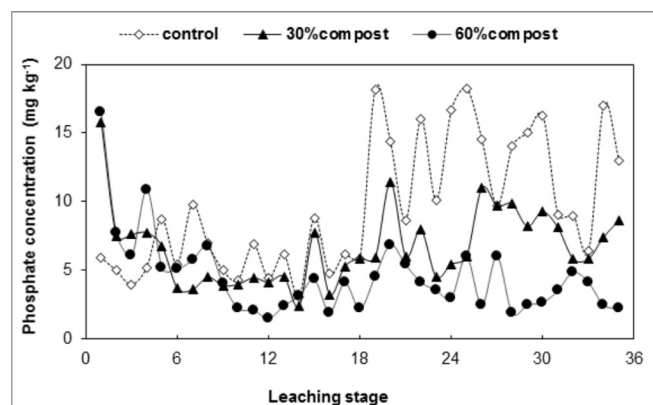


Figure 7: Variation of phosphate concentration in the drained water of the soil columns for the control and treatments of 30 and 60 percent of compost during the leaching experiment.

unsterilized soil and the nitrification phenomenon caused a sudden increase in nitrate leaching for the control columns since the stage 6th of the leaching process. Ammonium ions usually are absorbed to the organic materials in the composted columns so nitrification is scarce which justifies less nitrate leaching from the 60% composted columns and more nitrate leaching from the control columns since the stage 6th of the leaching process (Figure 8) with a difference significant at $P < 0.001$ (Table 3).

Conclusion

Adding ammonium phosphate fertilizer alongside with municipal solid wastes composted organic materials to the studied calcareous soil decreased arsenic leaching significantly. Although soil type and amount of compost are vital, municipal solid wastes composted materials not only boost soil nutrients but also increase soil water retention capacity which encourages arsenic fixation and prevention of its leakage to underground water resources.

Acknowledgement

Authors acknowledge Mr. H. Gavilian from Department of Environmental Sciences (University of Kurdistan, Sanandaj, Iran) for his help during laboratory analysis of the samples.

References

Babaiefar, L., Souri, B., Hedari, M. and R. Khoshnavazi (2012). Evaluation of iron and manganese-coated pumice

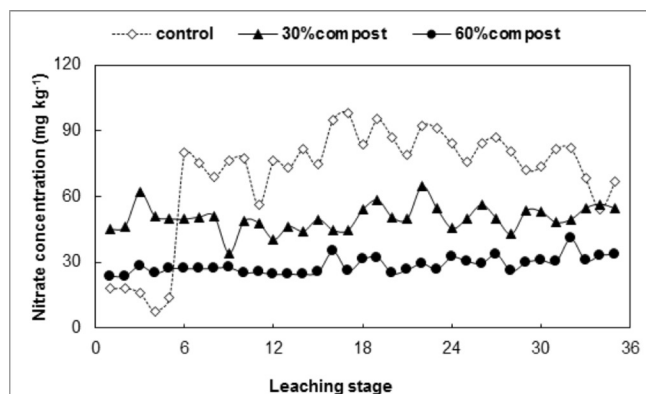


Figure 8: Variation of nitrate concentration in the drained water of the soil columns for the control and treatments of 30 and 60 percent of compost during the leaching experiment.

application for the removal of As(v) from aqueous solutions. *Iranian Journal of Environmental Health Research and Engineering*, **9(21)**: 1-9.

- Benton, J., Jones, J.R. and V.W. Case (1999). Sampling, handling and analyzing plant tissue sample. *In*: R.L. Westerman (Ed.), *Soil Testing and Plant Analysis*. SSSA, No. 3, Madison, WI.
- Bhattacharyya, M., Langstaff, T.M. and W.A. Berzonsky (2003). Effect of frozen storage and freeze-thaw cycles on the rheological and baking properties of frozen dough. *Food Res Int*, **36**: 365-372.
- Brito, L.M., Coutinho, J. and S.R. Smith (2008). Methods to improve the composting process of the solid fraction of dairy cattle slurry. *Bioresource Technology*, **99**: 8955-8960.
- Cairney, T. (1987). Soil cover reclamations. *In*: Reclaiming contaminated land. T. Cairney (ed.). Blackie, Glasgow.
- Cao, lena Q. (2004). Effects of compost and phosphate on plant arsenic accumulation from soil near pressure-treated wood. *Environmental Pollution*, **132**: 435-442.
- Caporale, A.G., Sommella, P.M., Dynes, A., Cozzolino, J. and V.A. Violante (2013). Influence of compost on the mobility of arsenic in soil and its uptake by bean plants (*Phaseolus vulgaris*) irrigated with arsenite contaminated water. *Journal of Environmental Management*, **128**: 837-843.
- Day, P.R. (1965). Particle fractions and particle-size analysis. *In*: Black, C.A. (ed.) *Methods of soil analysis: Part 1*. American Society of Agronomy, Madison.
- Elkhatib, E.A., Bennett, O.L. and R.J. Wright (1984). Arsenite sorption and desorption in soils. *Soil Sci. Soc. Am. J.*, **48**: 1025-1030.
- Emrani, Q. (2010). *Solid Waste*. Islamic Azad University Publications.
- Giacomino, A.M., Malandrino, O., Abollino, M., Velayutham, T. and E. Mentasti (2010). An approach for arsenic in a contaminated soil: Speciation, fractionation, extraction and effluent decontamination. *Environmental Pollution*, **158**: 416-423.

- Haque, N. and G. Morrison (2008). Iron-modified light expanded clay aggregates for the removal of arsenic(v) from groundwater. *Microchem J*, **88**: 7-13.
- Hartly, W., Dickinson, N.M., Riby, P. and E. Lesse (2010). Arsenic mobility and speciation in a contaminated urban soil are affected by different methods of green waste compost application. *Environmental Pollution*, **158**: 3560-3570.
- Haw Tarn Lin, M.C., Wang, B.K. and B. Sessaiah (2008). Mobility of adsorbed arsenic in two calcareous soils as influenced by water extract of compost. *Chemosphere*, **71**: 742-753.
- Hopkins, D.W. (2006). Carbon mineralization. In: Crater, M.R. and Gregorich, E.G. (eds), Soil sampling and methods of analysis. Taylor & Francis Group.
- ISRIC (1993). Procedures for soil analysis. Vol. 4. International Soil Reference and Information Center.
- Karimi, N., Ghaderian, S.M., Marofi, H. and H. Schat (2010). Analysis of arsenic in soil and vegetation of a contaminated area in Zarshuran, Iran: Identify two angiosperm arsenic hyperaccumulators. *International Journal Phytoremediation*, **12**: 159-173.
- Khan, M.A., Ueno, I., Horimoto, K., Komai, S., Somia, F., Inous, T., Tanaka, K. and Y. One (2009). CIELAB color variables as indicator of compost stability. *Waste Management*, **29**: 2969-2975.
- Lee, S-H., Park, H., Koo, N., Hyun, S. and A. Hwang (2011). Evaluation of the effectiveness of various amendments on trace metals stabilization by Metal Polluted Wastes and Sites. *Waste and Biomass Valorization*, **1**: 163-174.
- Lindsay, W.L. (1979). Chemical equilibria in soils. New York, John Wiley and Sons.
- Olsen, S.R., Cole, C.V., Watanabe, F.S. and L.A. Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular. Gov. Printing Office Washington D.C. **939**: 1-19.
- Ramadass, K. and S.P. Alaniyandi (2007). Effect of enriched municipal solid waste compost application on soil available macronutrient in the rice field. *Journal of Archive of Agronomy and Soil Science*, **53**: 497-506.
- Rhoades, J.D. (1982). Cation exchange capacity. In: Page, A.L., Miller, R.H. and Keeney, DR (eds), Methods of soil analysis, 2nd edn. American Society of Agronomy, Madison.
- Saha, J.K., Panwar, N. and M.V. Singh (2010). An assessment of municipal solid waste compost quality produced in different cities of India in the perspective of developing quality control indices. *Waste Management*, **30**: 192-201.
- Salinity Laboratory Staff (1954). Diagnosis and improvement of saline and alkali soils. United States Department of Agriculture Handbook, vol 60.
- Shamberger, R.J. (1979). Beneficial effects of trace element. In: Oehme, F.W. (ed.), Toxicity of Heavy Metals in the Environment. Marcel Dekker, New York.
- Smedley, P.L. and D.G. Kinniburgh (2002). A review of the source, behavior and distribution of arsenic in natural water. *Geoderma*, **17**: 517-568.
- Smith, E., Naidu, R. and A.M. Alston (2002). Chemistry of inorganic arsenic in soils: II. Effect of phosphorus, sodium, and calcium on arsenic sorption. *Journal of Environmental Quality*, **31**: 557-563.
- Tataro, A. and A. Asefi (1997). The effects of municipal compost output from Tehran on tomato, cauliflower and potato cropping and the effect of that's reminder on wheat and barley cropping (final report). Recycle Organization Press.
- Tognetti, C., Mazzarino, M.J. and F. Loas (2007). Improving the quality of municipal solid waste. *Bioresource Technology*, **98**: 1067-1076.
- Tsang, D.C.W., Old, W.E., Weber, A.W. and A.C.K. Yip (2013). Soil stabilization using AMO sludge, compost and lignite: TCLP leachability and continuous acid leaching. *Chemosphere*, **93**: 2839-2847.
- Tseng, W.P. (1977). Effects and dose-responds relationships of skin cancer and black foot disease with arsenic. *Environ Health Perp*, **19**: 109-119.
- Yanshan, C., Xin, D., Liping, W., Willem, H. and R. Van (2010). Assessment of in situ immobilization of lead (Pb) and arsenic (As) in contaminated soils with phosphate and iron: Solubility and bioaccessibility. *Water Air Soil Pollut*, **213**: 95-104.
- Ying, X.C., Zhu, G.W., Tian, G.M. and H.L. Chen (2003). Phosphorus and copper leaching from dredged sediment applied on a sandy loam soil: Column study. *Chemosphere*, **53**: 1179-1187.

Contents

<i>Editorial</i>	i
❑ <i>Snapshots</i>	ii
Measurement of Water Productivity in Seasonal Floodplain <i>Beel</i> Area <i>Md. Istiaque Hossain, Md. Mahmudul Alam, Chamhuri Siwar and Mazlin Mokhtar</i>	1
A Comparative Evaluation of the Water Quality Standards of Different Countries <i>Chidozie Charles Nnaji, Cordelia Nnennaya Mama, Christopher Ifiokobong Ekong and Chizoba Chinelo Agu</i>	15
Open Channel Discharge Measurement Using 0.127 Metre (5 Inch) Long-Throat Flume <i>Milan Nayek, Rajib Das, Subhasish Das, Prasun Dutta and Asis Mazumdar</i>	29
Water Quality Assessment with Varied Lake Depths by Using Multivariate Statistical Approach <i>Abdul Jalil, Li Yiping, Ijaz Ahmad and Khalida Khan</i>	39
Brunauer-Emmett-Teller (B.E.T.), Langmuir and Freundlich Isotherm Studies for the Adsorption of Nickel Ions onto Coal Fly Ash <i>Ajay K. Agarwal, Mahendra S. Kadu, Chandrashekhar P. Pandhurnekar and Ishwerdas L. Muthreja</i>	49
An Assessment of Development of a Transboundary Small Lake: Calibato Lake, San Pablo City and Rizal, Laguna, The Philippines <i>Bing Baltazar C. Brillo</i>	55
Spatial and Seasonal Variations of Water Soluble Ions in PM ₁₀ of Mid-Brahmaputra Plain of Assam Valley <i>Pranamika Bhuyan, Nivedita Barman, Sabrina Begum, Dharitri Gogoi, Sudakshina Borah, Manish Kumar, Kali Prasad Sarma and Raza Rafiqul Hoque</i>	69
Spatio-temporal Variability in Soil Macronutrients and Their Relation with Other Soil Properties in a Man-made Wetland of India <i>Ridhi Saluja and J.K. Garg</i>	83
Assessment of Highway Noise and Predictive Models along NH-316 <i>Bijay Kumar Swain, Shreerup Goswami and Madhumita Das</i>	97
❑ <i>Short Note</i>	
Effect of Bisphenol-A on Nucleic Acids during Germination in Mung Bean Seedlings <i>K. Jayasri, K. Padmaja and P. Eswara Prasad</i>	107
<i>Environment News Futures</i>	111