Leachate and Pollution Levels of Heavy Metals in the Groundwater near Municipal Solid Waste Landfill Site of Mashhad, Iran

Borhan Mansouri[1], Javad Salehi[2], Mehri Rezaei[3]*

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ABSTRACT

Background: The purpose of this study is to investigate the concentration of metals (lead, cadmium, chromium, copper, and nickel) in the landfill leachate and heavy metals in wells downstream of municipal solid waste landfill site in the city of Mashhad.

Methods: In both winter and summer seasons in 2009 samples were collected from five wells that were in landfill downstream in Mashhad.

Results: Among heavy metals, nickel concentration in summer and lead concentration in winter had the highest levels. The results showed that the mean concentration of heavy metals in the studied wells was below the national standards of drinking water of Iran, WHO, and the United States. Pearson correlation coefficients also indicated that there was a significant correlation among the studied metals in the wells.

Conclusion: Cd and Cu concentrations in all of the wells (except Pb in winter and Ni in summer) did not pose any significant water quality problems since these concentrations were below the standards acceptable levels of drinking water.

Keywords: Contamination, Landfill, Leachate, Metals, Quality Water.

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INTRODUCTION

Pollution is typically resulting from industrial technology patched with political, economic, and social issues driven by especially the current century [1]. One of the major concerns of this century is the preservation of environmental quality [2]. Water contamination and shortage of clean water reservoirs are two of the most urgent problems of our times. Amounts of water used in industrial processes and for households' demands are enormous and so are amounts of wastes and number of various contaminations [3]. The assessment of water quality can be the first and the most important step toward applying an appropriate quality management plan in order to eliminate water pollution [4].

One of the water pollutant sources are heavy metals. Heavy metals, including both essential and non-essential elements, have a particular significance in ecotoxicology since they are highly persistent and all have the potential to be toxic to living organisms [5]. Heavy metals do not exist in soluble forms for a long time in waters; they are present mainly as suspended colloids or are fixed by organic and mineral substances.

Landfills are identified as primary threats for groundwater resources for the disposal of waste metals and in open areas provide a way for pollution to get in groundwater sources [6, 7]. Solid wastes gradually lose their interstitial water and get decomposed to secondary liquid compounds involving organic and mineral compounds called leachate. Leachate can remain on the surface of the landfills and permeate into the soil [7,8]. The contamination rate of the groundwater waters located near landfills is higher for the potential polluting sources that are around. Many landfills lacking drainage systems lead to the prevalence of toxic and threatening metals involving heavy metals in groundwater tables [9]. Several researchers from around the world have studied the influence of heavy metals existing in landfills on contamination of groundwater [7, 8, 10, 11]. Taking this significance into account, the

1. Kurdistan Environmental Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran.
2. Department of Environmental Sciences, Faculty of Agriculture, University of Birjand, Birjand, Iran.
3. PhD Student, Iranian national institute for Oceanography and Atmospheric Sciences, Tehran, Iran.
*Corresponding author: E-mail: javad.salehi.sky@gmail.com

objective of the current study is to calculate the amount of heavy metals including Pb, Cd, Cr, Cu, and Ni existing in tap and drinking water wells located downstream the compost factory and landfill leachate of Mashhad, Iran.

MATERIALS AND METHODS

Site description

The study area is located in East of Iran, Mashhad, which is the capital city of Razavi Khorasan Province. It is situated at the latitude of 36˚ 18' N and longitude of 59˚ 36' E, about 985 m above sea level (Figure. 1). Mashhad features a steppe climate with hot summers and cool winters. Its average rainfall is 250 mm and unevenly distributed throughout the year. The average annual temperature is 14.1 °C with the warmest month in July (average 34.4 °C) and the coldest in February (average -3.8 °C). The sunlight of the year is 120 days. Mashhad landfills are located in the southeast 5 km away from Mashhad-Neishabour Road in a 220 hectare land. The soil of this land consists of granite, metamorphic, and sedimentary rocks of mostly the first and the second geologic periods. The per capita waste production of Iran is between 600 to 640 grams. Mashhad waste production rate is 700 tons per normal day that increases to 2400 tons per day when the pilgrims habitat in the city. After Tehran with the waste production of 7500 tons a day, Mashhad has the second rank in producing waste.

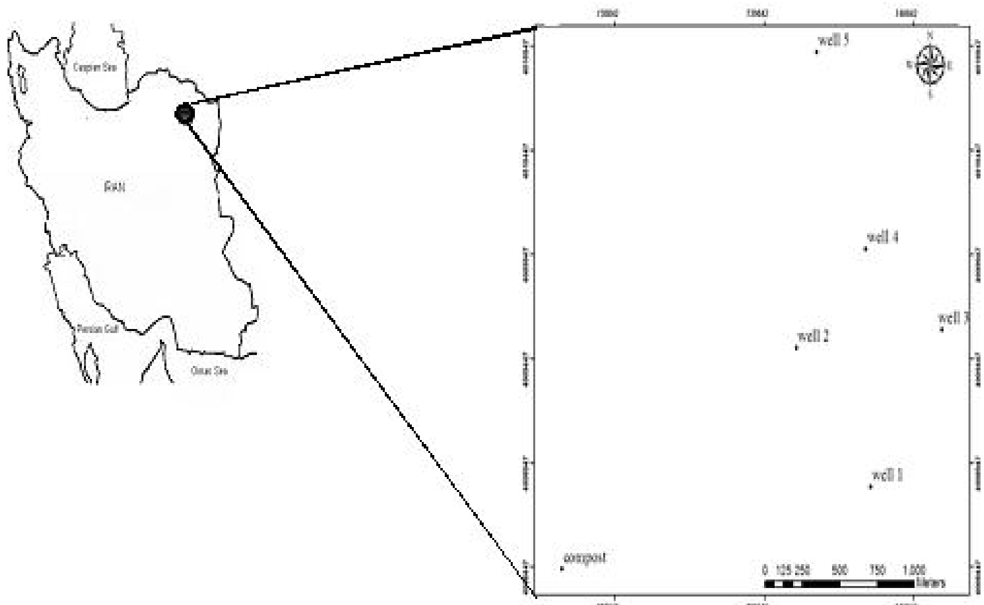

Figure 1. Location of compost (landfill) and wells.

Procedure

To sample the water sources for the 2009 experiments, 5 drinking water wells were chosen with 3 duplications in the season's summer and winter using PE plastic and glass bottles holding 1 liter of water and completely sterilized. The samples were kept in low temperature until they were carried to the laboratory. There, a nitrocellulose membrane filter was used to filter the sampled cases. Then, to stabilize samples characteristics, 2 mL of HNO_3 was added to them. Heavy metals that were measured were cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and nickel (Ni). The wells' samples that were analyzed for heavy metal concentrations were determined by Varian 2004 atomic absorption spectrophotometer instrument. Finally, the resulted data was compared with the national and international standards specified for the maximum rate of heavy metals allowed in drinking water (Table 1). One-way analysis of variance (ANOVA) was used to evaluate differences between heavy metals concentrations (Pb, Cd, Cr, Cu and Ni) of the wells of drinking water (period of two seasons) by Turkey–Kramer multiple comparison test. Pearson's correlation coefficients (r) were used when calculating the correlations among these parameters. Data analyses were carried out using the statistical package Minitab (Release 15).

RESULTS

The results of the analyses of the heavy metal concentrations of the wells' samples for a period of two seasons are given in Tables 2 and 3. The mean concentrations of the wells were between 0.006 and 0.166 μg/L, 0.004 and 0.024 μg/L, 0.007 and 0.105 μg/L, 0.002 and 0.004 μg/L, and 0.020 and 0.190 μg/L for Ni, Cu, Cr, Cd, and Pb, respectively. The concentration values for the winter were generally higher than those of the summer (except for Ni). This can be attributed to the runoff from land during the winter.

Table 1. Mean heavy metals concentration (μg/L) in the wells in Mashhad compared to international guidelines for drinking water.

	Drinking water*					Present study	
	ISIRI	WHO	EU	USA	TSE-226	Summer	Winter
Pb	0.1	0.01	0.05	0.015	0.05	0.020	0.149
Cd	0.01	0.003	0.005	0.005	0.005	BDL**	0.0 3
Cr	0.05	0.05	0.05	0.1	0.05	0.04	0.5
Cu	1.3	2	0.1-3	1.3	1.5	0.007	0.01
Ni	-	0.02	0.05	-	-	0.16	0.02

*Data from WHO World Health Organization (2006), the United States of America (2009), TS-226 (1984) TSI Turkey Standard Institute, ISIRI (Institute of Standards and Industrial Research of Iran 1992).
**BDL: Below Detection Limit

Table 2. Mean concentration (μg/L) of heavy metals in the wells in Mashhad, Iran.

No. wells	UTM		Summer					Winter				
	Y	X	Ni	Cu	Cr	Cd	Pb	Ni	Cu	Cr	Cd	Pb
1	74 05 64	40 08 85	0.162	BDL	0.059	BDL*	0.020	0.049	0.005	0.105	0.002	0.136
2	73 95 43	40 09 57	0.154	0.007	0.038	BDL	0.020	0.006	0.012	0.066	BDL*	0.150
3	74 05 26	40 10 00	0.161	BDL	0.036	BDL	0.020	0.036	0.024	0.068	0.004	0.109
4	74 02 39	40 10 90	0.161	BDL	0.056	BDL	BDL	0.019	0.013	0.050	BDL	0.160
5	72 99 77	40 21 57	0.166	BDL	0.041	BDL	BDL	0.030	0.004	0.007	BDL	0.190
	Overall Mean		0.161	0.007	0.04	BDL	0.020	0.028	0.011	0.590	0.003	0.149

*BDL: Below Detection Limit

Table 3. Pearson correlation coefficients of heavy metals from wells samples in two seasons.

	Pb	Cd	Cr	Cu	Ni		Pb	Cd	Cr	Cu	Ni
Summer						**Winter**					
Pb	1					Pb	1	1			
Cd	0.45	1				Cd	0.052	0.46			
Cr	0.72*	0.85**	1			Cr	-0.43	0.65*	1		
Cu	0.70*	0.006	0.21	1		Cu	0.48	-0.24	0.42	1	
Ni	-0.95**	-0.40	-0.67*	-0.77**	1	Ni	-0.94**	1	0.16	-0.70*	1

Degree of significance (*p < 0.01, **p < 0.001)

DISCUSSION

Cd and Cu concentrations of in the wells did not pose any significant water quality problems because these concentrations were below the acceptable standard levels of drinking determined by ISIRI [12], WHO [13], USA [14], and TSE-226 [15] (Table 1). The metal Cd is considered toxic in drinking water. The concentrations of Cd were below the acceptable standard levels of drinking water determined by ISIRI [12], WHO [13], this might be due to its possible absorbance by the soil strata or by the organic matter in soil [7]. On the contrary, the concentrations of Pb in winter and Ni in summer were higher than the acceptable standard levels of drinking water determined by ISIRI [12], WHO [13], USA [14] and TSE-226 [15]. Pb has been known to be toxic to human and its effect on the mental development of children causes the most concern. It has been shown that lead can cause a reduction of between 5-15% of a child's intelligence depending on the amount found in water [8]. In other words, the high concentrations of Ni in wells may be due to the concentration of Ni in leachate which migrates to groundwater via soil.

Leachate leaves the site as the situation changes. Leachate is a strong reducing liquid formed under methanogenic conditions and upon coming into contact with aquifer materials has the ability to reduce heavy metals absorbed in the aquifer matrix [7]. The characteristics of leachate samples collected from Mashhad landfill site are presented in Table 4. The Cd value is low in the collected sample (0.007 μg L^{-1}). The presence of Pb (0.20-0.45 μg L^{-1}) in the leachate samples indicates the disposal of Pb batteries, chemicals for photograph processing, Pb-based paints and pipes at the landfill site (15, 7). Cr (0.218 μg L^{-1}), Cu (0.03-0.4 μg L^{-1}), and Ni (0.20-0.46 μg L^{-1}) were also present in the leachate samples. A wide variety of wastes are dumped at Mashhad landfill site which indicates the origin of Cd, Pb, Cr, Cu and Ni in leachate [7,15]. Al-Sabahi *et al.* [8], Mor *et al.* [7] and Christensen et al. [16] have also reported the presence of these compounds in leachate. Pb and Ni concentrations were the highest concentration of heavy metals with the range of 0.20- 0.45 μg/L, whereas the lowest concentration of heavy metals was recorded for Cd with a value of 0.007 μg/L. The results of Pb and Ni for leachate are higher than the results obtained by *Yoshida et al.* [17] and Banar *et al.* [11]. On the contrary, these results are lower than the results obtained by Al-Sabahi *et al.* [8] 2.60-2.85 μg/L (Table 4).

Results of analysis using ANOVA test showed that there were no significant differences between heavy metal concentrations (Cr, Pb, Ni) in the wells at two seasons ($P > 0.01$). Pearson correlation coefficients of heavy metals are shown in Table 4. There was a highly negative correlations between Pb and Ni ($P<0.001$) and between Ni and Cu ($P< 0.001$). Moderately negative correlations were found between Ni and Cr ($P< 0.01$). There was, however, a highly positive correlation between Cr and Cd ($P<0.001$). Also, a moderately positive correlation was found between Cu and Cd ($P< 0.01$).

Table 4. Concentration of heavy metals in the leachate landfill site compared to in different leachate.

Parameters	Mor et al(2006)	Yoshida et al(2002)	Banar et al(2006)	Al-Sabahi et al(2009)	Present study
Pb	1.54	0.01-0.18	0.00-0.065	2.60-2.85	0.20-0.45
Cd	0.06	0.01-0.03	0.00-0.06	0.25-0.30	0.007
Cr	0.29	0.14-1.80	0.00	0.145-0.150	0.218
Cu	0.93	0.04-0.09	0.00-5.63	21.50	0.03-0.4
Ni	0.41	0.13-0.067	0.19-0.95	1.70-1.80	0.20-0.45

COCLUSION

It can be hypothesized that metals with a high positive correlation are possibly from the same pollution source [18] and metals with a highly negative correlation are possibly from different pollutant sources.

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