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Assessing landfill leachate heavy metal effect on the surface water quality: A case of Gheshlagh River, Sanandaj City, Iran

Shahab Mohammadi[1], Masomeh Heidari[2], Behzad Shahmoradi[3], Gilas Hosseini[3]

1 Department of Natural Resources and Environment, Islamic Azad University, Science and Research Branch, Hamedan, Iran
2 Department of Environment, School of Technology, Islamic Azad University, Sanandaj Branch, Sanandaj, Iran
3 Kurdistan Environmental Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran

Original Article

Abstract

Pollution resulted from the leachate of the Sanandaj City landfill into Gheshlagh River is an important environmental and health issue, which has endangered the river. Having a population of more than 400,000 and four municipality districts, the solid waste generation rate is approximately more than 300 tons/day in Sanandaj City. The wastes generated are disposed of at the Sanandaj City landfill with an area of approximately 35 hectares located on the off-road at the Sanandaj-Kamyaran highway. The leachate formed is discharged into the Gheshlagh River through seasonal Kilak River during the succulence (winter and spring) seasons due to the un-sanitary conditions of the landfill. In this study, we investigated the effects of the heavy metals [mercury (Hg), lead (Pb), zinc (Zn), and copper (Cu)] existing in the leachate on the Gheshlagh River and its autopurification capacity. For this purpose, we selected five stations and performed random sampling during two above-mentioned seasons and analyzed the samples. The data were analyzed using one-way analysis of variance and t-test. In general, our results showed that the concentration of the measured elements was more at the leachate confluence station compared with the control station. The mean concentration of the heavy metals in different sampling times and stations was observed in the order of Cu > Zn > Pb > Hg. However, the autopurification of the river resulted in statistical insignificancy of the data, except for Hg.

KEYWORDS: Leachate, Chemical Quality, Contamination, Gheshlagh River, Heavy Metals

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Introduction

Solid waste disposal is an important environmental issue in both developed and developing countries.[1] In spite of efforts to find alternatives for municipal solid waste disposal, landfills are still the most common waste disposal option in many countries.[2,3] Leachate is a hazardous liquid produced in landfills as a result of decomposition of organic materials in municipal solid wastes by microorganisms, and its volume is influenced by surface and ground water excess rainwater penetrating through the waste layers.[4] Landfill leachate mainly consists of organic matter, inorganic macro-components, and heavy metals.[5,6]

Heavy metals distribution in landfill leachate has shown that significant fraction of them is associated with waste-derived dissolved organic matter. The mobility of the heavy metals may

Corresponding Author:
Behzad Shahmoradi
Email: bshahmorady@gmail.com

enhance leachate-polluted waters.[7,8] In recent years, most of the current concerns with regards to the environmental quality were focused on the water quality, because of its importance in maintaining the human and ecosystem health.[9] Landfill leachate can severely influence the quality of water. Maqbool et al. reported that landfill leachate might affect the sustainability of the aquatic life. Therefore, the solid waste dumping site must be kept away from the natural water resources.[10] At the moment, there is no sanitary landfill in Iran. Therefore, moving leachate through soil, groundwater, and surface water is highly possible.

Surface waters contamination by leachate can transmit the heavy metals. Therefore, the effluence of heavy metals into the environment is great concern due to their serious effects on the food chain and furthermore on animal and human health.[11] The aim of this investigation was to assess mercury (Hg), zinc (Zn), lead (Pb), and copper (Cu) concentrations in Gheshlagh River before and after landfill leachate entrance at different times and stations.

Materials and Methods

Sanandaj landfill site located at latitude of 35°10' North and longitude of 46°59' East has an area of about 3.5 × 10^5 m^2 and receives approximately 300 tons of municipal solid waste per day. Gheshlagh River located with a distance of 1250 m in the downstream of the studied landfill is one of the four major branches of the Sirvan River. The unsanitary landfill does not have daily soil coverage. Therefore, a substantial part of the leachate may leak into the Gheshlagh River.

In this study, five sampling stations were selected. Figure 1 shows the location of sampling stations. The most important criterion in selecting the sampling stations was the Gheshlagh River distance from the landfill. Sampling was carried out 6 times during January-June, 2012.

Water samples were collected 0.1-0.2 m below water surface[12] using 1.5 L polyethylene bottles. The bottles were first washed with nitric acid,

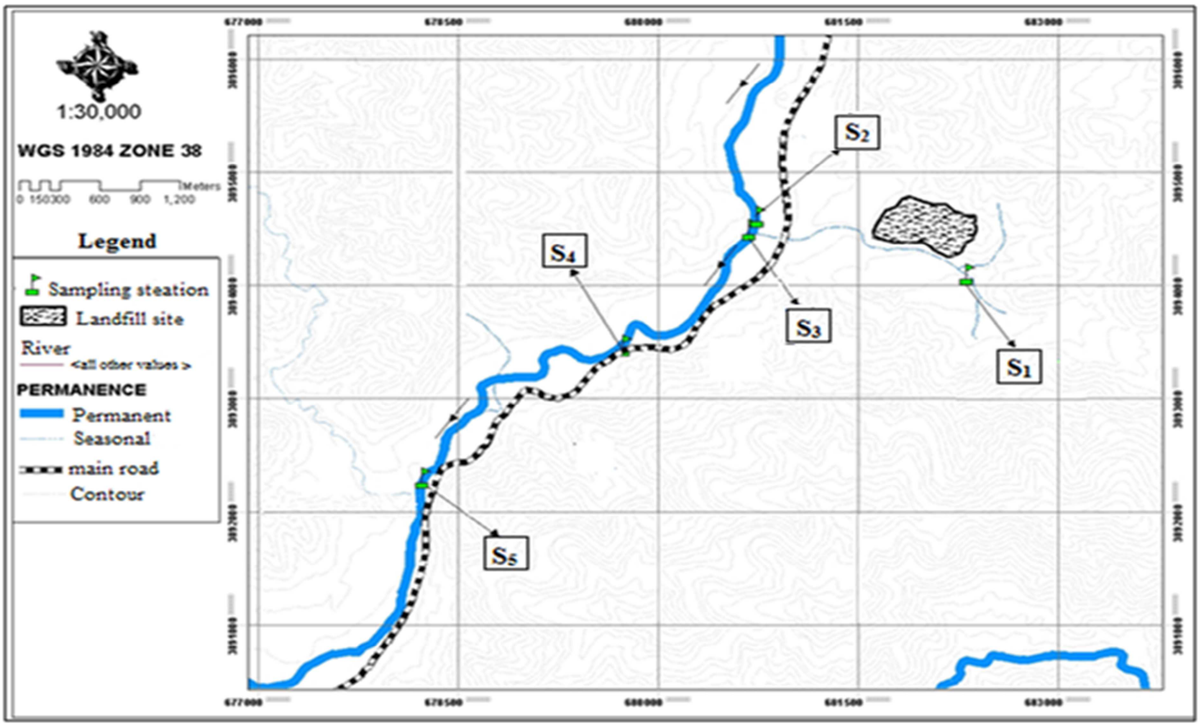

Figure 1. Location of sampling stations in the study area

detergent, and hot water respectively and finally rinsed with distilled water.[10] Samples for heavy metals were first digested using nitric-acid-sulfuric digestion method[12] and then analyzed by atomic absorption spectrometry 220 (Varian model).

Various statistical analyses were done to check whether changes in the concentrations at the studied times and stations are statistically significant. One-way analysis of variance (ANOVA) (for normal data) and Kruskal-Wallis (for nonparametric data) tests were used to compare the heavy metal concentrations in samples collected in different dates and stations. Turkey multiple comparisons tests were used to compare means of heavy metals in leachate among studied times and different sampling stations.

One sample t-test (for normal data) and one sample Wilcoxon (for nonparametric data) tests were used to compare respectively the mean and median of the studied heavy metals with World Health Organization (WHO) standards for heavy metals in surface water. Statistical computations were undertaken with SPSS for Windows (version 20, SPSS Inc., Chicago, IL, USA).

Results and Discussion

The mean concentration of the heavy metals in different sampling times and stations was observed in the order of Cu > Zn > Pb > Hg (Tables 1 and 2). We compared our results with the standard values determined by WHO (Tables 3 and 4). The results for each of the metals investigated are discussed in the following sections.

Hg

Hg had its lowest and highest concentrations on January and June, respectively. Kruskal-Wallis test results showed that there is a significant difference between Hg concentrations at different sampling times ($P < 0.05$) (Table 1). On the other hand, Hg concentration changed by the variation of stations. Since the first station that is, upstream of leachate-Kilak confluence point in Kilak stream, had the lowest, and the fourth station that is, 2 km downstream of the Kilak-Gheshlagh confluence point in Gheshlagh River, had the highest concentration of Hg. According to ANOVA test results, these variations at different stations were not statistically significant ($P > 0.05$) (Table 2). According to tables 3 and 4, one sample t-test and one sample Wilcoxon test results for Hg showed that Hg concentrations at all sampling times and stations were significantly lower than WHO standards for Hg in surface water ($P < 0.05$); thus, Hg might not pose any significant health problems. James et al. in a study showed that Hg and lead (Pb) concentrations at all of stations leachate above standard values.[13] The lowest concentrations of Hg were observed in the month of January after heavy rainfall flushing and dilution of metal may have occurred, but the highest concentrations were in June that are attributed to the high temperatures, increase evaporation and low precipitation at the site that results in concentrating of pollutant. Watananugulkit et al. reported that the comparison of surface water quality showed that the quality in the rainy season is much better than in the dry season. Surface water Hg was analyzed in both seasons (rainy and dry), and the results showed that Hg concentration is lower in the rainy season.[14] Table 2 shows that Hg concentration was higher at site 4 than the other site, which implied that the contamination might have occurred due to pesticides and fertilizers used in the adjacent field areas. Magombeyi and Nyengera showed that the concentration of Hg is higher at stations downstream from the landfill compared with upstream locations. The difference in Hg concentrations between upstream and downstream indicates the contribution of the landfill to stream pollution.[12]

Zn

Table 1 shows that Zn concentration do changed at different sampling times. Samples taken on January had the lowest (28.70 µg/l) and those of February had the highest (48.97 µg/l) mean concentrations of Zn. Significant difference

Table 1. Descriptive and analytical results of the investigated heavy metals

Heavy metals	Number of samples	Mean ± SD (μg/l)							Kruskal-Wallis	
		January	February	March	April	May	June	Total	Chi-square	P*
Hg	30	0.00 ± 0.00	0.89 ± 0.50	0.72 ± 0.36	0.66 ± 0.36	1.03 ± 0.02	1.10 ± 0.02	0.73 ± 0.45	15.81	0.007
Zn	30	28.70 ± 1.57	48.97 ± 13.12	46.93 ± 5.43	44.73 ± 2.45	43.51 ± 1.54	43.59 ± 1.64	42.74 ± 8.62	13.68	0.018
Pb	30	11.65 ± 1.26	46.21 ± 19.84	28.32 ± 25.16	27.58 ± 36.14	11.89 ± 1.04	9.75 ± 1.12	22.57 ± 22.3	9.52	0.09
Cu	30	45.17 ± 3.18	76.70 ± 18.44	80.72 ± 13.70	68.18 ± 14.83	55.12 ± 8.26	40.85 ± 2.80	61.12 ± 18.78	20.07	0.001

* P-value < 0.05 is considered as significant; SD: Standard deviation, Hg: Mercury, Zn: Zinc, Pb: Lead, Cu: Copper

Table 2. Descriptive and analytical results of the investigated heavy metals in studied stations

Heavy metals	Number of samples	Mean ± SD (μg/l)						ANOVA	
		S_1	S_2	S_3	S_4	S_5	Total	F	P*
Hg	30	0.60 ± 0.53	0.68 ± 0.46	0.79 ± 0.48	0.80 ± 0.47	0.79 ± 0.46	0.73 ± 0.45	0.204	0.934
Zn	30	40.97 ± 10.62	43.08 ± 8.50	42.69 ± 6.36	44.24 ± 11.64	42.71 ± 7.94	42.74 ± 8.62	0.097	0.982
Pb	30	31.76 ± 34.48	18.49 ± 18.16	26.22 ± 22.74	18.17 ± 19.4	18.18 ± 17.27	22.57 ± 22.30	0.426	0.788
Cu	30	59.66 ± 21.60	63.94 ± 16.32	67.17 ± 24.06	58.57 ± 16.43	56.27 ± 19.28	61.12 ± 18.78	0.295	0.879

*P-value < 0.05 is considered as significant; SD: Standard deviation, ANOVA: Analysis of variance, Hg: Mercury, Zn: Zinc, Pb: Lead, Cu: Copper

among Zn concentrations in different sampling times was proved by Kruskal-Wallis test (P < 0.05). Table 2 reveals that the first and fourth stations had the lowest and highest concentrations of Zn, respectively. This table also shows that based on ANOVA test result variation of Zn is not significant (P > 0.05). Tables 3 and 4 show that Zn concentrations at different sampling times and stations were significantly lower than WHO standards for Zn in surface water (P < 0.05). Therefore, Zn might not pose any significant health problems. Kar et al. showed that the highest concentration of Zn was observed in monsoon, which may be due to a sudden rainfall followed by high discharge from upstream environment into the river,[15] while in this study the highest concentration of Zn was observed in winter. Zn concentration was higher at site 4 than the other site, which implied that the contamination might be due to the agricultural effluents.

Pb

Table 1 shows that Pb concentration was in its lowest in June and highest in February. Kruskal-Wallis test revealed that Pb concentration at sampling period did not significantly change (P > 0.05). It also revealed that fourth and fifth sampling stations had the lowest concentration, and the first sampling station showed the highest concentration for Pb (Table 2). Moreover, table 2 shows that there is not any significant difference among the Pb concentrations at different sampling stations (P > 0.05). Pb concentration in January, February, April, and May, and also stations 1, 3, and 5 were significantly higher than the WHO standards for Pb in surface water (P < 0.05) (Tables 3 and 4); thus, Pb might has significant health problems. When water is contaminated with leachate containing Pb, the mechanism leading to health hazards is bioaccumulation. Many living organisms are capable to accumulate Pb in their bodies.[13,10] In this study, the highest concentration of Pb was observed in the month of February. It implied that waste either consist of the sources of Pb such as batteries, photography, old based paints and Pb pipes or the erosion of Pb containing deposits in the landfill occurred in February. Moreover, acidity in leachate can cause Pb to be extracted from waste and move through in it. Maqbool et al. reported that the high Pb concentration was in the month of December, and the low concentration of Pb was observed in the month of September after heavy precipitations in this month.[10] Pb concentration was higher at site 1 than the other sites, which implied that the contamination might have occurred due to exist in residual sediments of Pb in bottom seasonal Kilak stream.

Table 3. Statistical results of comparing the investigated heavy metals in studied times with the standards determined by World Health Organization

Heavy metals	WHO standard value (μg/l)	P*											
		January		February		March		April		May		June	
		OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test
Hg	1	-	-	-	0.0420$^{\downarrow}$	-	0.0430$^{\downarrow}$	-	0.0430$^{\downarrow}$	< 0.0001$^{\downarrow}$	-	-	0.0390$^{\downarrow}$
Zn	500	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	-	0.0430$^{\downarrow}$	< 0.0001$^{\downarrow}$	-
Pb	10	0.0430$^{\uparrow}$	-		0.0430$^{\uparrow}$	-	0.2250	-	0.0430$^{\uparrow}$	0.0150$^{\uparrow}$	-	0.6400	-
Cu	2000	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-

* P-value< 0.05 is considered as significant; OST-test: One sample t-test; OSW-test: One-sample Wilcoxon test; WHO: World Health Organization; Hg: Mercury, Zn: Zinc, Pb: Lead, Cu: Copper

Table 4. Statistical results of comparing the investigated heavy metals in studied stations with the standards determined by World Health Organization

Heavy metals	WHO standard value (μg/l)	P*									
		S_1		S_2		S_3		S_4		S_5	
		OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test	OST-test	OSW-test
Hg	1	0.0010$^{\downarrow}$	-	0.0010$^{\downarrow}$	-	-	0.0270$^{\downarrow}$	-	0.0280$^{\downarrow}$	-	0.0270$^{\downarrow}$
Zn	500	< 0.0001$^{\downarrow}$	-	-	0.0280$^{\downarrow}$	< 0.0001$^{\downarrow}$	-	-	0.0280$^{\downarrow}$	< 0.0001$^{\downarrow}$	-
Pb	10	-	0.0460$^{\uparrow}$	-	0.0750	-	0.0460$^{\uparrow}$	-	0.2250	-	0.0280$^{\uparrow}$
Cu	2000	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-	< 0.0001$^{\downarrow}$	-

* P-value < 0.05 is considered as significant; OST-test: One sample t-test; OSW- test: One-sample Wilcoxon test; WHO: World Health Organization, Hg: Mercury, Zn: Zinc, Pb: Lead, Cu: Copper

Cu

Cu, which had the highest concentration among the studied heavy metals, had its lowest and highest concentrations in June and March, respectively. This result was not matched with findings of Kar et al. (Pb > Zn > Cu).[15] Differences among the Cu concentrations in the studied times were significant (Table 1). Table 2 reveals that station number 3, that is, Kilak-Gheshlagh confluence point, had the highest and station number 5 that is, 5 km downstream of the Kilak-Gheshlagh confluence point had the lowest Cu concentrations among other stations. ANOVA test result showed that the changes in Cu concentration in the different stations were not significant (P > 0.05). According to tables 3 and 4, one sample t-test results revealed that compared with WHO standard for Cu in surface water, Cu concentration in all sampling times and stations, was significantly low (P < 0.05), showing that Cu might not pose any significant health problems. Table 2 shows that Cu concentration was higher in March than the other months, which implied that the contamination might have occurred due to pesticides and fertilizers used in the adjacent field areas in this month. Cu concentration at station 3 was the highest that implied probably waste has contaminations consist of Cu. The lowest Cu concentration was in station 5 that showed the river has self-purification capacity high. According to tables 3 and 4, Cu might not pose any significant health problems.

We collected the water samples only in two seasons due to finance constraints. This might affect our results. On the other hand, it is suggested to monitor the river at least for 1 year through weekly randomized sampling and analyzing river water quality and leachate characteristics is recommended to be determined, at least, seasonally in order to interpret results achieved more precisely and scientifically.

Conclusion

The investigation evaluated the heavy metal concentration (Hg, Zn, Pb, and Cu) of Gheshlagh River before and after entrance of Sanandaj landfill leachate. For comparison purpose, we considered to stations as monitoring stations to check whether the river itself or the tributary seasonal river contain heavy metal. The results showed that Pb concentration in January, February and April, and stations number 1, 3, and 5 exceed the standards, which present a potential hazard to the public and environmental health. Moreover, it was found that the autopurification capability of the Gheshlagh river could to somewhat reduce the heavy metal concentration. Therefore, Gheshlagh river water should be treated prior to use for any domestic purposes in the downstream.

Conflict of Interests

Authors have no conflict of interests.

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