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Original Research

An investigation of contaminants release from the Golistan Peyvand cement factory, Iran

Authors:
Hassan Darabi[1]
Saeid Toyor Parvaz[2]

Institution:
1. Assistant Professor, Tehran University, Iran.

2. Graduated student, Tehran University, Iran.

Corresponding author:
Hassan Darabi

ABSTRACT:

Soil is recognized as a primary natural resource, and its quality is a measure of a country's sustainable development. Preserving soil fertility is thus considered a priority in the economic development of countries. In this regard, the cement industry is well known as an important source of environment pollutants that degrade the quality of the soil. The industry releases contaminants to the environment from the early (i.e., the extraction of raw materials) to the final stages of cement production. In particular, the rapid industrialization that has allowed the cement industry to flourish, causes heavy metal contamination and dust pollution. Motivated by these issues, this research was conducted to characterize contaminant release from Golestan Payvand cement factory and identify heavy metal concentrations and affected areas in the site. To these ends, random soil sampling was conducted at different zones (500, 100, and 1500 m) in the site, after which the data obtained were analyzed using statistical methods, such as univariate analysis of variance. The results revealed significant differences among the chrome, lead, zinc, nickel, and cadmium concentrations in the sampled zones ($p<0.05$). The significance level of the chrome, lead, zinc, and nickel concentrations is 0.000, whereas that of the cadmium concentration is 0.008 ($p<0.05$).

Keywords:

Heavy metals, Cement industry, Contamination, Sustainable development, Soil.

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INTRODUCTION

Soil is a significant natural resource (Gerasimova *et al*., 2003), whose quality is measured to determine countries' sustainable development. Preserving soil fertility is a priority concern in the economic development of a given country (Alekseenko *et al*., 2017) as soils are regarded as the final depositories of harmful substances, such as heavy metals. Heavy metal concentration can thus serve as an appropriate indicator of environmental pollution (Prasad, 2007; Cao *et al*., 2009; Pekey *et al*., 2004).

The geochemical characteristics of soil have substantially changed in the recent decades because of human activities worldwide. The extraction and processing of mineral resources, for example, produce mineral waste deposits that have contaminated more than 10% of the soils; the negative effects of these activities also stem from poor safety and reconstruction standards (Il'in *et al*., 2003). Another human activity that is responsible for environmental problems, including dust and heavy metal pollution, is rapid industrialization (Qingjie *et al*., 2008). Compounding these problems are the activities of the cement industry, which is recognized as one of the most dangerous industries worldwide in terms of pollutant release (Mehraj *et al*., 2013; Wu *et al*., 2010). Environmental contamination by the industry arises from different cement production stages, beginning from the extraction of raw materials and extending to chopping and final production. The negative environmental effects of the cement industry are manifested in several ways. First, cement factories cause noise pollution (Zerrouqi *et al*., 2008). Second, cement

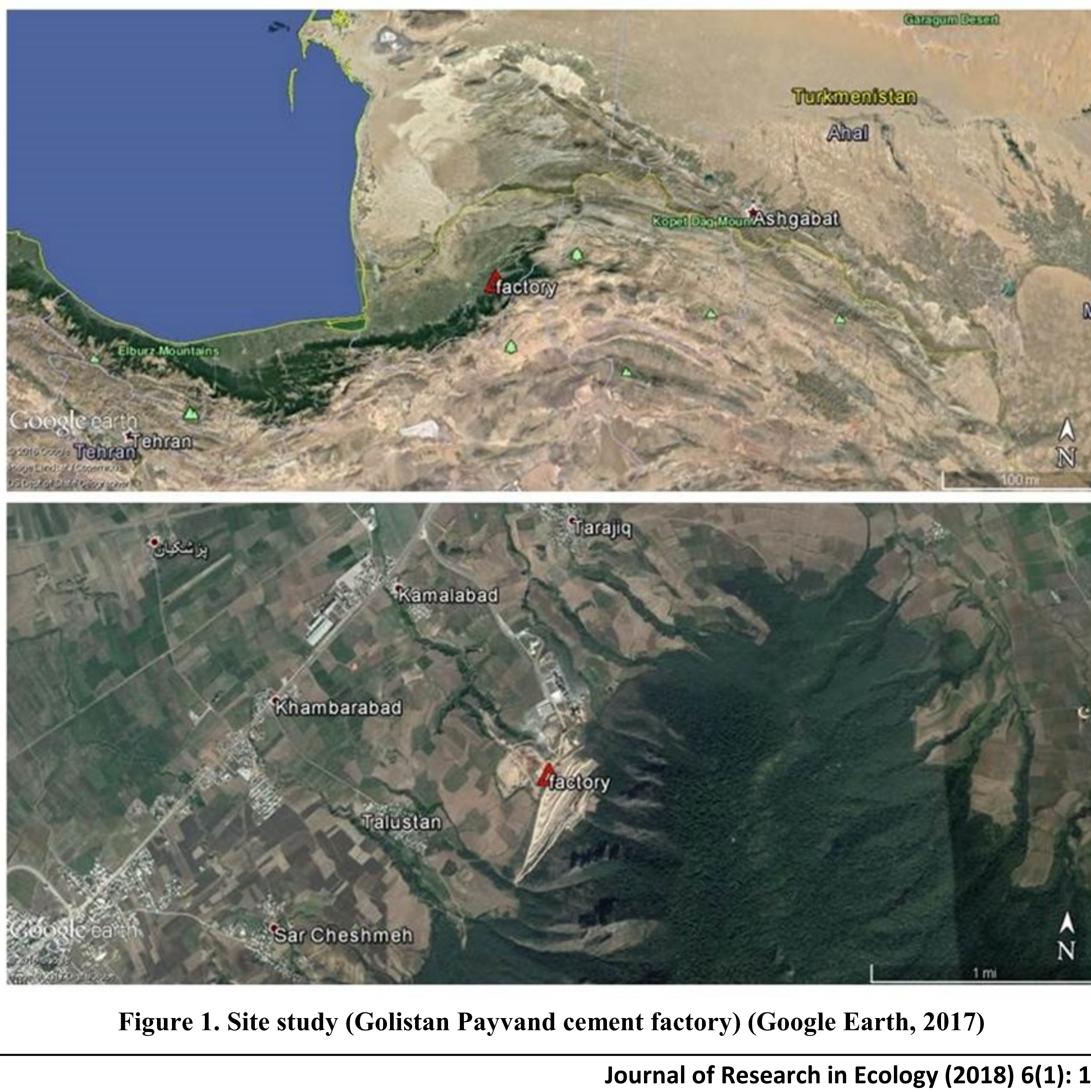


Figure 1. Site study (Golistan Payvand cement factory) (Google Earth, 2017)

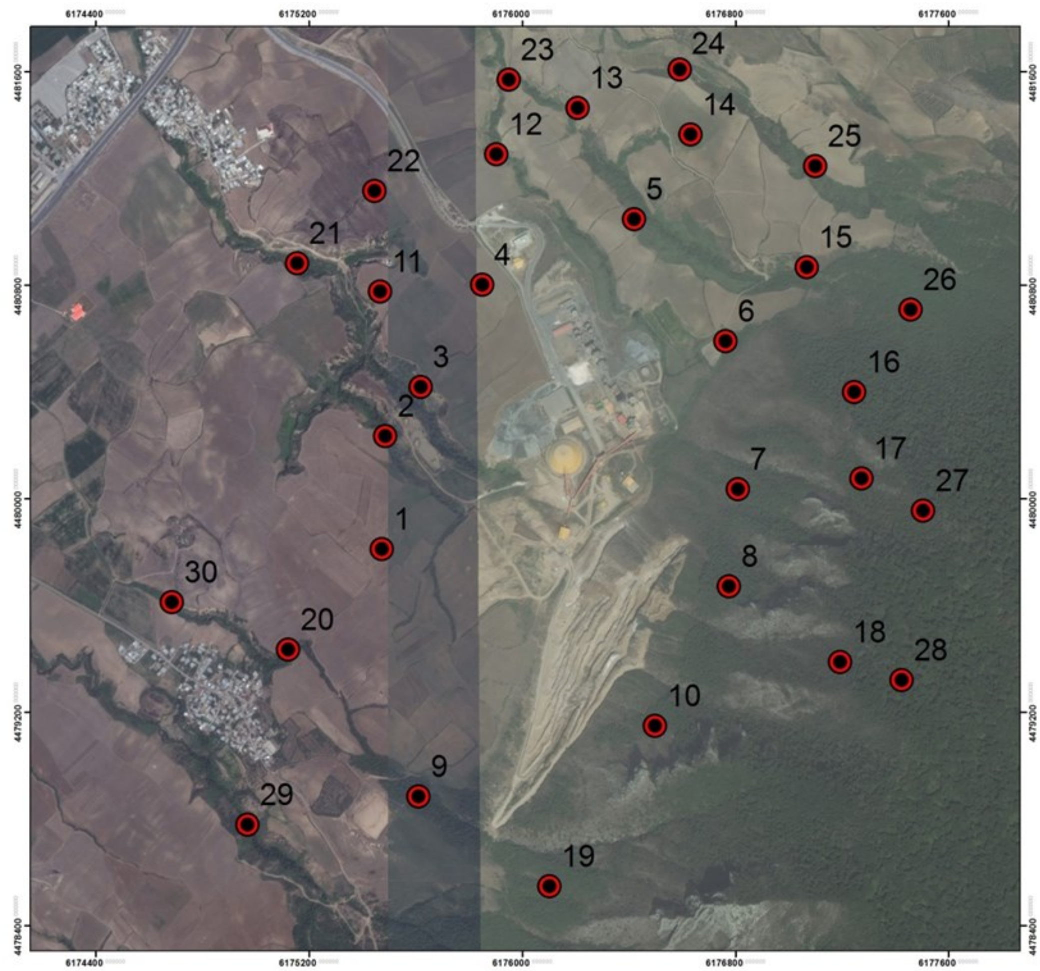
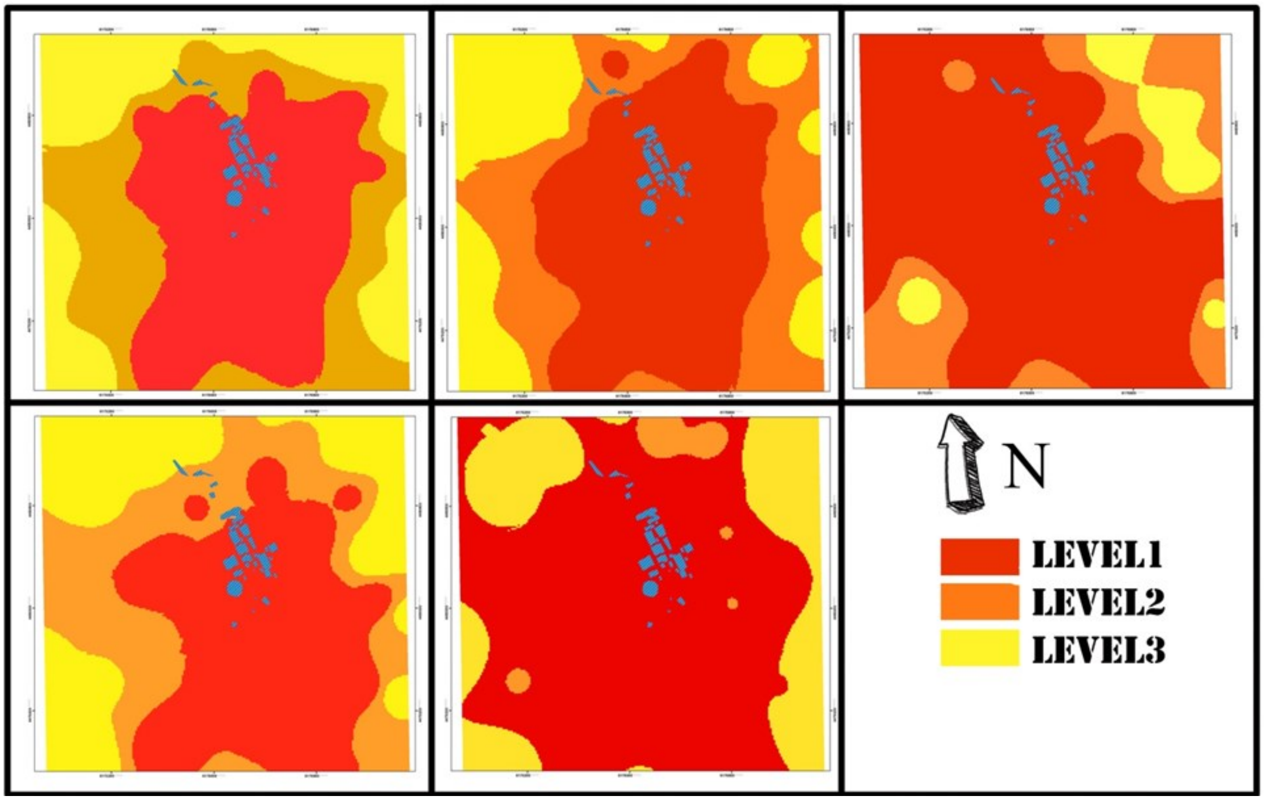


Figure 2. Sampled sites [context image provided by Arc Bru Tile (2017)]

production is a major contributor to environmental contamination because it releases a considerable amount of dust and heavy metals, which are later decomposed in soils and act as deposition metals (Al-Khashman and Shawabkeh, 2006; Ogunkunle and Fatoba, 2013; Fairbrother *et al*., 2007). Soils containing heavy metals may, in the long term, pollute underground aquifers and thereby influence the social and economic lifestyles of people living in polluted regions. Third, dust particles emitted from the chimneys of cement factories add to the volume of greenhouse gases, such as carbon dioxide, sulfur oxide, and nitric oxide, in the atmosphere (Kumar *et al*., 2008). The elements in factory-released dust are likewise deposited onto and absorbed by biological resources, such as soil, through leaching or other natural solvent processes (Abril *et al*., 2014).

Cement is one of the extensively used raw materials in construction, civil engineering, and extended urbanization projects, thus leading to a considerable increase in its consumption (Global Cement, 2013). Cement production, as an industrial activity, releases contaminants that disrupt terricolous microorganism-related sequences and cause instability in soil texture. The main contaminants generated by the cement industry are alkaline particles that originate from the reactions between the raw materials used in the industry (Saravanan *et al*., 2004). On this basis, some researchers indicated that the primary effects of cement industry activities are the emission of dust and changes in the chemical structures of soils and lifecycles of organisms in an ecosystem (Ashraf and Ali, 2007). The growth and evolution of organisms in soil are affected by excessive



Level 1 indicates the highest concentration of contaminants and other levels were formed based on the reduction of concentrations, respectively.

Figure 3. The risk level based on contaminants release from Upper right: Cd, Pb, Zn, bottom-right: Ni, Cd (in 500, 1000 and 1500 m of factory).

concentrations of heavy metals in dust, such as copper, zinc, manganese and iron (Mehrotra, 2009).

The use of heavy metal-contaminated soil in crop production and the absorption of heavy metals by agricultural crops, animals, and humans result in a number of irreparable effects. For instance, heavy metals expose humans and animals to potential toxicants and easily penetrate into vital organs (Liang *et al*., 2011; Banat *et al*., 2005; Sun *et al*., 2010; Nogaj *et al*., 2012; Pekey *et al*., 2004).

Given the above-mentioned problems, contamination due to the activities of different industries has become a global concern, prompting researchers to study the soil pollution issues caused by heavy metals and conduct geochemical surveys to determine the potential risks arising from heavy metal contamination (Liang *et al*., 2011). Ogunkunle and Fatoba (2013), for instance, stated that information related to soil and contamination due to heavy metals can be used to evaluate

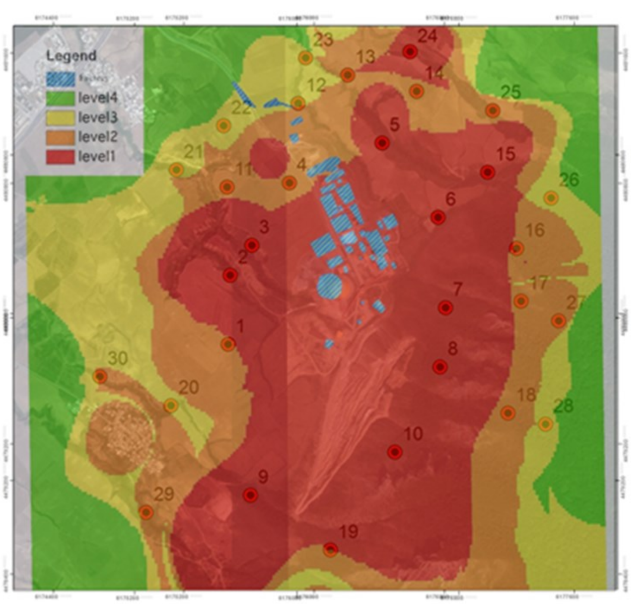


Figure 4. Dispersion layers weighting of the heavy metals concentration in AHP method

Table 1. The level of heavy metals in samples (in ppm)

S. No	Zone No.	Cd	Cr	Zn	Ni	Pb
1	1	0.12	7.12	14.96	10.48	9.41
2	1	0.268	8.52	15.42	11.15	9.16
3	1	0.318	7.92	15.87	11.92	10.72
4	1	0.249	7.64	16.66	11.87	10.14
5	1	0.24	8.19	16.19	12.72	11.12
6	1	0.31	8.63	18.74	13.14	10.63
7	1	0.221	9.13	18.11	13.12	11.64
8	1	0.219	8.91	17.72	10.86	11.92
9	1	0.29	9.1	17.94	10.94	10.45
10	1	0.268	8.74	17.9	12.65	9.92
11	2	0.303	6.75	16.42	11.74	6.02
12	2	0.298	5.84	13.3	11.42	9.42
13	2	0.49	6.49	11.72	19.13	5.78
14	2	0.83	7.13	11.36	15.67	10.43
15	2	0.73	7.94	17.42	9.42	9.06
16	2	0.88	4.19	15.74	10.73	8.42
17	2	0.21	8.82	14.09	12.58	6.69
18	2	0.202	8.24	12.36	10.42	7.21
19	2	0.59	6.35	13.1	9.77	7.39
20	2	0.68	5.84	14.76	13.47	6.84
21	3	0.38	5.41	8.92	9.13	3.12
22	3	0.42	4.73	8.94	8.42	3.87
23	3	0.12	6.2	9.42	7.51	4.81
24	3	0.57	3.88	9.13	6.43	4.16
25	3	0.44	4.58	7.77	7.12	4.42
26	3	0.48	4.18	9.14	6.92	5.12
27	3	0.18	5.5	9.62	6.8	5.19
28	3	0.63	5.39	9.59	8.72	4.29
29	3	0.52	3.78	8.63	8.69	3.1
30	3	0.28	6.09	8.78	8.8	3.17

Zone No. 1: 0-500m; Zone No. 2: 500-1000 m; Zone No.3: 1000-1500 m.

the quality of biochemical environments. Mandal and Voutchkov (2011) reported that the surface and upper soils in Rockfort, Kingstone and Jamaica contain lead, zinc, cadmium, and mercury, which are emitted by the furnaces of cement factories. Al-Khashman and Shawabkeh (2006) revealed that regions near a cement factory in southern Jordan exhibit the highest levels of lead, zinc, and cadmium in surface soils with a depth of 1 to 5 cm. In a similar study, Zerrouqi *et al*. (2008) observed that calcium oxide and sulfur oxide are the main contaminants around a Moroccan cement factory. The results of primary chemical analysis, explained in terms of the weight percentage of oxide indicated that raw material dust produced from abrasion contains calcium oxide, silicon dioxide, aluminum oxide, and ferrous ferric oxide (Ahn *et al*., 2004). Asubiojo *et al*. (1991) calculated the calcium/silicon ratio in soil and found that soil pollution caused by the cement industry significantly decreases as the distance to a polluted region and depth-to-ground surface increase. Semhi *et al*. (2011) investigated dust deposition by the cement industry in Oman and found high concentrations of heavy metals in soil located 2km from surrounding cement factories.

The present research contributes to the literature by characterizing contaminant release from Golestan Payvand cement factory and identifying heavy metal concentrations and affected areas in the site on the basis of observations regarding levels of zinc, chrome, cadmium, lead, and nickel in the region (Figure 1).

MATERIALS AND METHODS

Study area

The site chosen for investigation is Golestan Payvand Cement Factory, which was established in 2011 with a capacity of more than 1 million tons of annual gray cement (PG Cement, 2016). It is located in the northeastern section of Galikesh city, Golistan, Iran and proximal to Hirkani forests and the foothills of the Nilkooh mountains. In geographical coordinates, the factory is located at 37° 17' 64" longitude and 55° 28' 56" latitude (Figure 2).

Heavy metal extraction and analysis

Field soil sampling was carried out, and contaminant concentration in soil was analyzed to obtain statistical data. Surface soils (0-15cm) were sampled in the eastern, western, and southern axes of the site using random sampling (Gbadebo and Bankole, 2007). Specifically, 30 samples were systematically taken from the

Table 2. Descriptive statistics of obtained heavy metals

	No.	Min.	Max.	Mean	SD
Cd	30	0.12	0.88	0.3912	0.20671
Cr	30	3.78	9.13	6.7077	1.71904
Zn	30	7.77	18.74	13.3240	3.61561
Ni	30	6.43	19.13	10.7247	2.77911
Pb	30	3.10	11.92	7.4540	2.87291

study site at radii of 500, 1000, and 1500 m. The samples were then stored in polyethylene bags and transferred to a laboratory. In the laboratory, waste products, such as pebbles, plastic, and plant fragments, were manually removed from the samples, after which they were dried at 25°C to 30°C. The dried samples were s of pollutants and finer sediments (due to the high absorption of these particles), inductively coupled plasma-mass spectrometry (ICP-MS) was carried out to determine the presence of heavy metal particles in finely grained components. An ICP-MS instrument is an element analysis system that releases spectroscopic emissions and executes atomization through plasma. In this method, plasma is used as the driving source for the qualitative and quantitative analyses of heavy metals (Ogunkunle and Fatoba, 2013).

Statistical analysis

On the basis of the research goals, the obtained measurements were analyzed using SPSS version 23. One-way analysis of variance (ANOVA) was conducted to examine the effects of soil collection distance on variations in heavy metal concentrations in the soil from the case factory (Table 2) (Clements *et al*., 2000)

Layer weighting and zoning

To determine areas in the study site that are exposed to different levels of risk, heavy metal contamination maps were prepared, and the layers in the maps were overlaid using the Analytic Hierarchy Process (AHP). For these purposes, the effects of each heavy metal on soil quality were initially determined (Table 1), on the basis of concentration, after which the AHP was used to weight the map layers; layering was determined via the geographic information system (GIS) in ArcGIS version 10.3.1 (Kara and Doartli, 2012) (Figure 4).

RESULTS

The data obtained from the field were analyzed onsite and with the use of appropriate statistical tests. The results indicated differences in the mean concentrations of heavy metals in the soil where the factory is located. For example, the mean concentration of zinc is 13.32 (maximum concentration), whereas that of cadmium is 0.39 (minimum concentration). The standard deviations reflected the concentration dispersion of the substances; that is, as the standard deviation increases, the dispersion of the metals rises and expands. For instance, the standard deviation of zinc is 3.6, indicating a more extensive range of dispersion compared with the dispersion of the other identified heavy metals.

Table 3 shows the distribution of heavy metal concentration. A significance level greater than 5% corresponds to the normal distribution of variables studied. The findings derived in this work indicated that the distribution of heavy metal concentration is normal. The presence or absence of significant differences between the samples obtained from the three sites (500, 1000, and 1500m) was determined using univariate ANOVA. The results showed that the samples significantly differ

Table 3. Kolmogorov-Smirnov test for identifying the distribution in variables

S. No		Cd	Cr	Zn	Ni	Pb
1	Number	30	30	30	30	30
2	Test statistic	0.205	0.126	0.181	0.095	0.145
3	Sig. level	0.052	0.200	0.064	0.200	0.107
4	Probability level	95%	95%	95%	95%	95%
5	State	Normal	Normal	Normal	Normal	Normal

in terms of heavy metal concentration. The significance level of the chromium, zinc, lead, and nickel concentrations is 0.000, whereas that of the cadmium concentration is 0.008 ($p<0.05$). The results illustrated in Figure 3 show that the heavy metal concentrations in the study site fall under four classes: red, which indicates very high risk; orange, which denotes high risk; yellow, which represents low risk; and green, which pertains to very low risk.

DISCUSSION

As previously stated, the results reflected statistically significant differences in heavy metal concentration in the three sampled zones. As the distance from the central contamination core (cement factory) increases, the heavy metal concentration in the soil samples significantly decreases. The results are consistent with those of Al-Khashman and Shawabkeh (2006), who reported that sites near a cement factory in southern Jordan exhibit the highest level of lead, zinc, and cadmium in soil with a depth of 1 to 5 cm. The findings in the current work are also consistent with those derived by Asubiojo *et al*. (1991), who revealed that soil contamination due to cement industry activities decrease as the distance from a factory increases. Finally, our results correspond with those obtained by Semhi *et al*. (2010), who indicated that a high concentration of heavy metals is observed at a radius of 2km around cement factories.

CONCLUSION

The results suggested that greater the distance from a factory, the lower the heavy metal concentration. Additionally, as the distance from a factory increases, heavy metal concentration in a basin decreases. Appropriate planting design could be an alternative to reduce the contaminated area and also the intensity of soil pollution. Therefore, investigation of environmental design framework, species selection and the ability of native species in heavy metals removal in integrated basis could be the subject of further researches.

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