Engineering and Technology Journal 41 (05) (2023) 673- 686

Engineering and Technology Journal
Journal homepage: https://etj.uotechnology.edu.iq

Assessment of the Environmental and Health risks of Chromium in the Soil of Tanning Factories (Baghdad City - Iraq)

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HIGHLIGHTS

- Chromium concentration, mean, and median values were calculated.
- The lowest value of (Igeo) was (2.36), which is moderately strongly polluted because Igoe is from (2-3).
- The values of HI were found to be at a safe level (<1) for adults and children

ARTICLE INFO

Handling editor: Imzahim A. Alwan

Keywords:
Chromium, Health risk,
Integrated pollution index
Environmental pollution

ABSTRACT

The present study assesses the pollution level and health risk of heavy metal (Cr) in the area surrounding the tanning factories' soil in Baghdad city-Iraq. Chromium concentration, mean, and median values were calculated. The geoaccumulation index (Igeo), the enrichment factor (EF), and the integrated pollution index (IPI) have been used in the assessment of pollution. The lowest value of (Igeo) at the surface to the north of the factory was (2.36), and the highest value of (Igeo) at a depth of 100 cm from the surface to the south of the factory was (94.94). All values of (EF) were greater than 40. The values of (IPI) at the surface and a depth of 100 cm from the surface of the soil are considered to cause an extreme level of contamination. A depth of 50 cm from the surface of the soil to the north of the factory is considered to have a high level of contamination. In addition, the estimated health risk was assessed by calculating the values of hazard quotient (HQ), health index (HI) for non-carcinogenic, lifetime average daily dose (LADD) for carcinogenic heavy metals, and lifetime cancer risk (R). The values of HI were found at a safe level (<1). Moreover, carcinogenic risks were estimated by the exposure results, where the highest value of R was 51.9, and the lowest value was 0.231.

1. Introduction

Chromium (Cr) is considered to have carcinogenic and mutagenic properties, and the United States Environmental Protection Agency (USEPA) has designated chromium (Cr) as a priority pollutant because of its impact on groundwater and soil. Toxic waste produced by industrial activities like electroplating, tanneries, and chemical industries can be identified as the source of anthropogenic Cr pollution [1]. In the natural environment, Cr exists in two primary oxidation states, including chromium hexavalent [Cr(VI)] and trivalent [Cr(III)]. Due to its function in the metabolism of glucose and/or the hormone insulin in the pancreas, the latter is a necessary trace element. However, due to its ability to penetrate cell membranes and high water solubility and oxidation potential, Cr(VI) is toxic in biological systems. As a result, Cr(VI) is more harmful than Cr(III) because it can cause chronic ulcers and dermatitis, with adverse reactions in the lungs and nasal septum [2].

Soil is the recipient of many wastes of products and chemicals used in industrial processes. Heavy metals are the greatest significant pollutants agreed upon by studies because of their toxicity, clear impact on human health, and the acceptability of environmental standards [3-6].

The pollution of soil by heavy metals is caused by the soil's capability to absorb their ions. Absorption is contingent on the properties and forms of metals, and it depends on the physicochemical parameters of soil [7]. The metals absorption in soil poses a danger of passage to ground waters, and several research works proposed to understand the processes occurring in soil and find the supportive properties of different kinds of soil and peat relative to heavy metal ions [8].

The chromium element is discarded in many industries, like the tanning industry, the paint industry, chromium plating, and steel. Chromium tannery effluents can be extremely harmful to human health, and the United States Environmental Protection Agency (US EPA) selected Cr as an important pollutant because of its severe effects on human health [9]. Heavy metals are

http://doi.org/10.30684/etj.2023.137146.1337
Received 29 November 2022; Accepted 14 March 2023; Available online 5 April 2023
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important because of their long-term harm [10,11], and they can be ingested, inhaled, or absorbed via contact with the skin through inhalation, ingestion, or inhalation of dust and soil [12,13].

In many research works, the source of pollution by heavy metals was found to be humans, which are considered the main factor, especially in urban areas for matters of environmental pollution. Some of these heavy metal sources (tire wear particles, fuel burning in the engine, and automobile exhaust atoms), industrial release (vehicle repair shops, coal burning, chemical factories, metallurgy manufacturing, power plants, and tanning) [14].

Numerous global studies on pollutants in groundwater and soil have utilized the USEPA's health risk assessment (HRA) method. For instance, the studies of Baig et al. (2016), and Naz et al. (2018) dealt with heavy metals in groundwater and the human health risk assessment of chromium [15-17].

Various exposure pathways to Cr(VI) have been the focus of other studies [18,19]. In addition, numerous studies have emphasized the health risk posed by Cr in the soil through inhalation, dermal contact, and ingestion [20-23].

Many research works indicated the spread of heavy metals in Baghdad. For example, the study of Al Obaidy and Al Mashhadi 2013 dealt with eight heavy metals, namely Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn, in different areas of Baghdad, including industrial areas [24].

In recent years, many studies have shown that the characterization of heavy metals in soil and road dust has become increasingly important [25]. This interest has been attributed to potential public health risks, as heavy metals in soil and road dust can accumulate in humans through direct ingestion, inhalation, and absorption through skin contact [26–33]. Pollution of soils by heavy metals due to intense industrialization and urbanization has become a serious concern in numerous developing countries [34]. Breathing in the Cr-contaminated environment results in lung cancer and aspirator diseases, as well as rashes of the skin and eyes brought on by direct contact with chromium in workstations [35]. Because of the high cost of treatment technology, little attention is given to the suitable dumping of industrial waste [36].

The purpose of this paper is to assess the carcinogenic and the non-carcinogenic health risks posed by this toxic heavy metal to humans and to compare the concentrations of chromium deposited in soil by the tannery industry to the permissible range.

2. Materials and Methods

2.1 Area of the study

The capital of Iraq is Baghdad city, and it is a city that mediates Iraq with the coordinates (33.312805,44.361488). The factory site is located in the north of Baghdad, in Al-nahrawn area, Iraq at (33.21 55 Nourth,44.51 11 East).

2.2 Collection of the samples

Thirty-six samples of soils were taken from different directions (north, south, east, and west), with distances of (50, 500, and 1000) meters, and with different depths of (0, 50, and 100) cm from the study site surrounding the factory. The samples were collected from the vertical section of the soil (1 Kg) by hand with a stainless steel spatula. The samples were then taken to the laboratory, left at lab temperature until they were dried, and passed through a sieve of (2) millimeters to remove large stones, which were placed in polyethylene bags and digested using a combination of hydrochloric acid and nitric acid.

2.3 Concentration of heavy metal in soil

Heavy metal determinations are done by Atomic Absorption Spectrometry (AAS 6300, Shimadzu, Japan) in the Laboratory of the Environmental Research Center, University of Technology, Baghdad, Iraq. The concentrations of chromium that were taken from the study area were compared with the concentration of the unpolluted mean of soils worldwide (83.0 mg/Kg) [37] and compared with the average value from the world literature (84.0 mg/kg) [38].

2.4 Contamination level assessment

In this research, Igeo, EF, and IPI were calculated to evaluate the contamination levels of heavy metal using the background standards taken from Riley and Chester (Earth crust mean) [39].

2.4.1 The geo-accumulation index (Igeo)

The Igeo, developed by Muller, has been utilized since the late 1960s to evaluate metal pollution in European trace metal studies. The Igeo was used to compare the current and background concentrations of heavy metals in soils to assess their pollution [40]. The Igeo is calculated as follows [41]:

$$Igeo = \log_2\left(\frac{Cn}{1.5Bn}\right) \quad (1)$$

Where Cn is the measured content of metal in soil and Bn is the geochemical background content of a similar metal. The (1.5) is provided to lessen the impact of possible background value variations, which could be documented as anthropocentric effects [42,43].

2.4.2 Enrichment factor (EF)

The Enrichment Factor (EF) is calculated by normalizing an element and comparing it to a reference element. Common reference elements include Al, Mn, Ti, Fe, Sc, and Ca [44-46].

Iron (Fe) was selected as a traditional tracer to differentiate natural from anthropogenic constituents due to the assumption that its content in the earth's crust has not been disturbed by anthropogenic activities, and it was selected as the standardization element since natural sources of (98%) vastly dominate its input [47]. The EF can be determined as follows [48]:

$$EF= \frac{\left(\frac{M}{Fe}\right) sample}{\left(\frac{M}{Fe}\right) background} \tag{2}$$

Where (M/Fe) sample is the ratio of metal and the Fe content of the sample and (M/Fe) background is the ratio of metal and the Fe content of the background. Five contamination groups are documented based on the enrichment factor [49].

2.4.3 Integrated pollution index (IPI)

Integrated pollution index (IPI) makes it possible to evaluate the soil's contamination, which is found at all polluted sites [50], and it can be calculated as follows:

$$IPI = \frac{Ci}{Bi} \tag{3}$$

where Ci is the concentration of the element and Bi is the value of the element's background.

The (IPI) can be determined using the following equation:

$$IPI = (IP1 + IP2 + IP3 + IPn)/n \tag{4}$$

where the value of IPI≤1 is considered the lowest contamination, a moderate level of contamination is 1<IPI≤2, a high level of contamination is 2<IPI≤5, and an extreme level of contamination is IPI>5 [51].

2.5 Health risk assessment

The process of predicting the likelihood of adverse health effects in people who are currently or in the future exposed to contaminants in a contaminated environment is known as human health risk assessment. There are three ways that people can be exposed to heavy metals: intake through the mouth, inhalation, and skin contact with contaminants [52 ,53]. In this research, the health risks were evaluated based on the concentration of heavy metals in the study area, depending on the average daily dose (ADD) (mg/kg/day) of the inhalation exposure pathways, using the following formula [54-56].

$$ADD = (C \times Rinh \times EF \times ED)/(PEF \times BW \times AT) \tag{5}$$

The supplementary file Table (1) shows the exposure factors with EPA guidelines.

The American classic (US EPA, 1989) and EPA standards were used in this study to assess the health risks for children and adults. Due to prolonged contact, heavy elements in dust are likely to have a greater impact on adults than on children [56-59].

2.5.1 The non-carcinogenic risk assessment:

The non-carcinogenic risk assessment was calculated for the studied metal by dividing the average daily dose (ADD) by a particular reference dose (RFD) and estimating the health index using the following formula:

$$HQ = ADD/RFD \tag{6}$$

Moreover, HI symbolizes the sum of the HQ for metal:

$$HI = \sum HQi \tag{7}$$

Where (ADD) is defined as the average daily dose, (RFD) is the reference dose, and (HI) is a health index, and to find threshold values: non-significant risk H≤1, significant risk H>1[56,57].

2.5.2 Carcinogenic risk assessment (LADD):

The lifetime average daily dose was practical to estimate the carcinogenic risk as determined by the International Agency for Research on Cancer (IARC) classification list using the following formula [58-60]:

$$LADD = \frac{C \times EF}{AT} \times \left(\frac{Rinh\ child \times ED\ chitd}{BW\ child} \times \frac{Rinh\ adult \times ED\ adult}{BW\ adult}\right) \tag{8}$$

where all the factors are annotated in the supplementary file Table (1). The lifetime cancer risk is calculated using the formula [59]:

$$R = \frac{LADD}{SF} \tag{9}$$

where SF is the compare slant factor. The range of values (10^{-6} to 10^{-4}) is the level of cancer risk in soil by contact with Cr, what is above these values is considered an environmentally unacceptable risk [59].

3. Results and Discussion

3.1 Concentration of heavy metal in soil

The chemical and physical properties of soils are linked to the characteristics of heavy metal content in soils. As a result, the basic properties of the soil, including pH, phosphorus, sulfur, nitrogen, and water content, influence the concentrations of heavy metals of (Cr, Cd, Pb, Ni, Zn, Cu, Hg, As, and Fe) [61]. However, Chen et al. (2020) reported Cr as the most abundant toxic metal in soil [62]. Chromium concentration, mean, and median values were found and calculated using the Excel program. Figure 1 shows the concentration of Cr mg/kg at the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory in four directions (north, south, east, and west) to the north of the factory, where the lowest concentration of chromium was 66 mg/kg at a distance of 1000 m from the factory, while the highest concentration was 2000 mg/kg at a distance of 50 m from the factory. Moreover, to the south of the tanning factory, the highest concentration of chromium was 18100 mg/kg at a distance of 50 meters from the tanning factory, and the lowest concentration was 160 mg/kg at a distance of 1000 m from the tanning factory. In addition, to the east of the tanning factory, the highest concentration of chromium was 14830 mg/kg at a distance of 500 meters from the tanning factory, and the lowest concentration was 317 mg/kg at a distance of 1000 m from the tanning factory. The lowest concentration of chromium was 1940 mg/kg at a distance of 500 m from the tanning factory, while the highest concentration was 3880 mg/kg to the west of the factory.

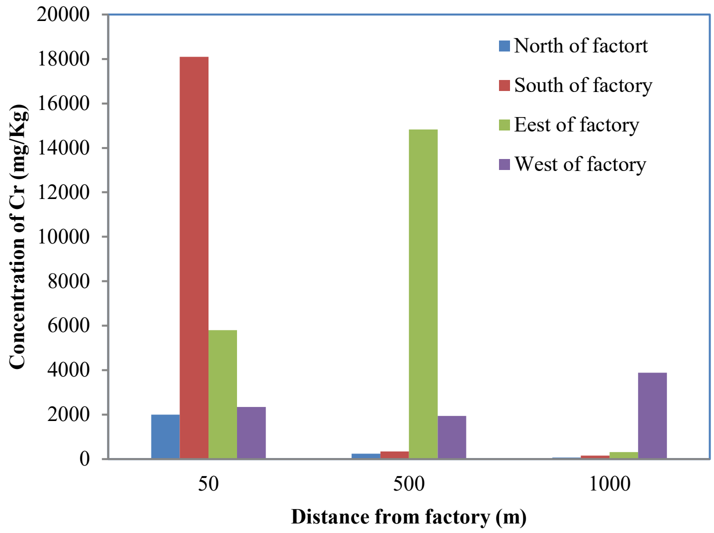

Figure 1: Concentration of Cr mg/kg at the surface of the soil at distances of (50, 500, and 1000 m)from the tanning factory for the four directions (north, south, east, and west)

Figure 2 shows the concentration of Cr mg/kg at a depth of 50 cm from the surface of the soil at distances of (50, 500, and 1000 m) to the north of the factory, where the lowest concentration of chromium was 69 mg/kg at a distance of 1000 m from the factory, while the highest concentration was 336 mg/kg at a distance of 500 m from the factory. To the south of the tanning factory, the highest concentration of chromium was 23150 mg/kg at a distance of 500 m from the tanning factory, and the lowest concentration was 235 mg/kg at a distance of 50 m from the tanning factory. Furthermore, to the east of the tanning factory, the highest concentration of chromium was 7070 mg/kg at a distance of 50 meters from the tanning factory, and the lowest concentration was 610 mg/kg at a distance of 500 m from the tanning factory. While the lowest concentration of chromium was 276 mg/kg at a distance of 1000 m from the tanning factory, and the highest concentration was 2219 mg/kg at a distance of 500 m from the factory to the west of the factory.

Figure 3 shows the concentration of Cr mg/kg at a depth of 100 cm from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west), to the north of the factory, where the lowest concentration of chromium was 70 mg/kg at a distance of 50 m from the factory, while the highest concentration was 1800 mg/kg at a distance of 500 m from the factory. To the south of the tanning factory, the highest concentration of chromium was 24396 mg/kg at a distance of 500 m from the tanning factory, and the lowest concentration was 170 mg/kg at a distance of

1000 m from the tanning factory. Moreover, to the east of the tanning factory, the highest concentration of chromium was 9290 mg/kg at a distance of 500 meters from the tanning factory, and the lowest concentration was 2210 mg/kg at a distance of 1000 m from the tanning factory. While the lowest concentration of chromium was 971 mg/kg at a distance of 50 m from the tanning factory, and the highest concentration was 3050 mg/kg at a distance of 1000 m to the west of the factory.

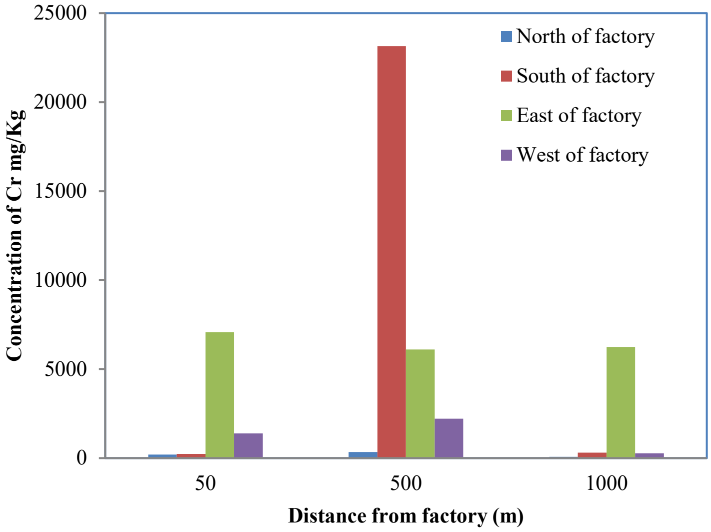

Figure 2: Concentration of Cr mg/kg at a depth of 50 cm from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east and west)

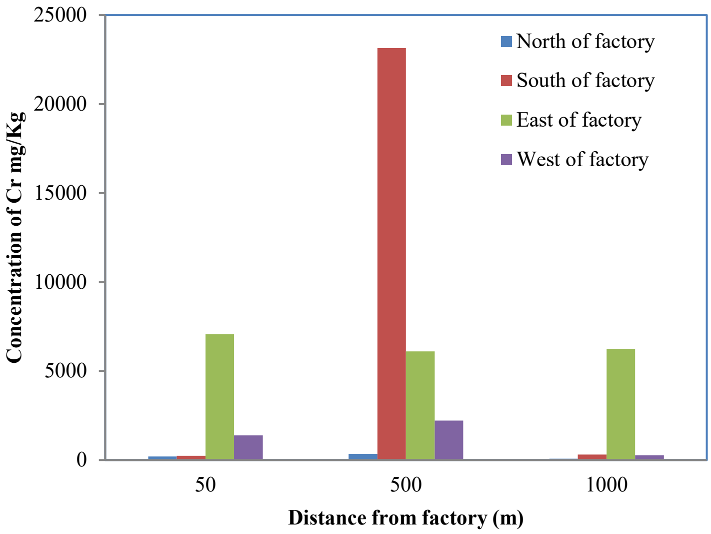

Figure 3: Concentration of Cr mg/kg at a depth of 100 cm from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east and west).

The values of chromium concentrations for the four directions of the tanning factory indicate a high percentage of chromium contamination in all directions, and the effect of chromium reaches a distance of 1000 meters from the tanning factory. Figure 4 shows the mean and the median values at the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west). The highest value and the lowest value of the mean and the median were (6982, 772) and (5800, 250), respectively. These values are higher than the concentrations of the unpolluted mean of soils worldwide (83.0 mg/kg) [37] and higher than the average value from the world literature (84.0 mg/kg) [38]. All the values of mean and median exceed the permissible values, which confirms the high contamination of chromium within the study area.

Figure 5 shows the mean and the median values at a depth of 50 cm from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west). The highest value and the lowest value of the mean and the median were (7897, 200) and (6240, 195), respectively. These values are higher than the concentrations of the unpolluted mean of soils worldwide (83.0 mg/kg) [37] and higher than the average value from the world literature (84.0 mg/kg) [38]. Moreover, in this way, all the values of the mean and the median exceed the permissible values, which confirms the high contamination of chromium within the study area.

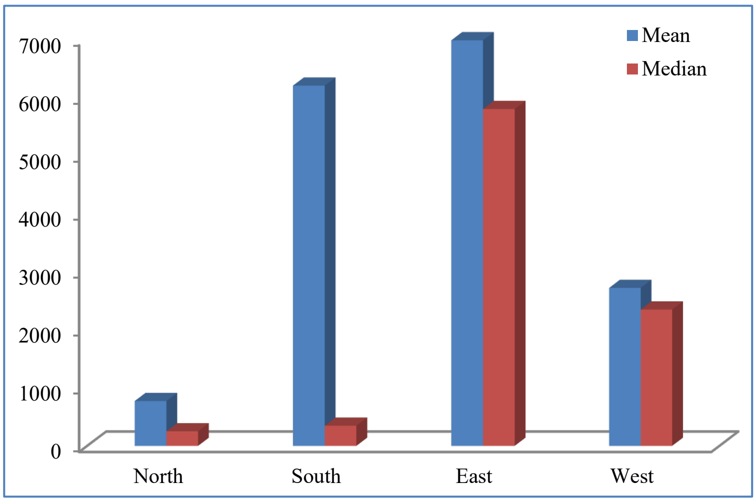

Figure 4: Mean and median values at the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west)

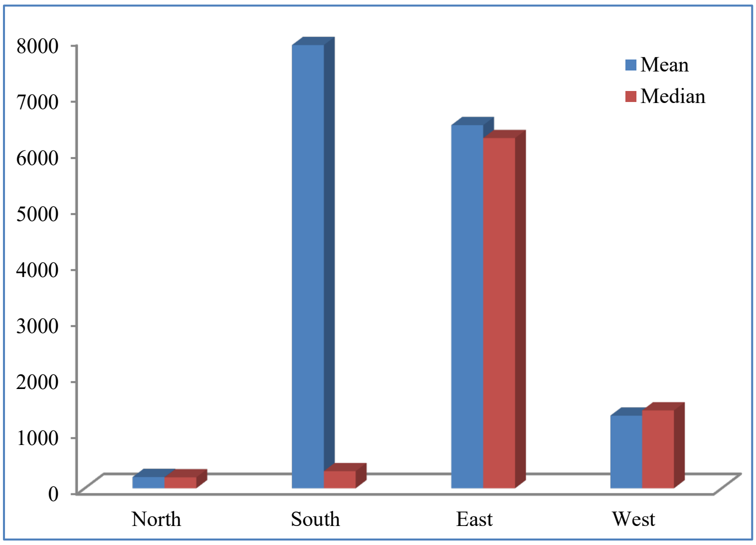

Figure 5: Mean and median values at a depth of 50 cm from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west)

Figure 6 shows the mean and the median values at a depth of 100 cm from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west). The highest value and the lowest value of the mean and the median were (14241,702) and (18158, 236), respectively. These values are higher than the concentrations of the unpolluted mean of soils worldwide (83.0 mg/kg) [37] and higher than the average value from the world literature (84.0 mg/kg) [38]. In addition, all the values of the mean and the median exceed the permissible values, which confirms the high contamination of chromium within the study area. The reasons for this high concentration of chromium include the wrong methods followed in the disposal of industrial waste for the tanning plant, problems in the tanning factory's treatment plant, and the high pollution levels, following the wrong paths in the throwing away of industrial waste for the tanning plant, the presence of leaks in the pipes of sewage or ignorance of the environmental hazards of heavy metals in the soil.

3.2 Contamination level assessment

Microsoft Excel was utilized for both descriptive analysis (mean, median, maximum, and minimum) and pollution indices (EF, Igeo, and IPI).

3.2.1 The geo-accumulation index (Igeo)

Figure 7 shows the values of the geo-accumulation index (Igeo) at depths of (0, 50, and 100 cm) from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west). At the surface of the soil, when comparing the values of the Igeo with the reference values, the following points were noticed. To the north, the value of the Igeo is 2.36, and hence, it is considered moderately strongly polluted because Igoe is from (2-3). To the south, the Igeo value is 5.37, and to the east, the Igeo value is 5.54, which is considered extremely polluted because Igoe >5. To the west, the Igeo value is 4.18, which is considered strongly extremely polluted. At a depth of 50 cm from the surface of the soil, to the north, the value of the Igeo is 1.33, and hence, it is considered moderately polluted because Igoe is from (1-2). To the south, the Igeo value is 52.64, to the east, the Igeo value is 43.13, and to the west, the Igeo value is 8.63, which is considered extremely polluted because Igoe >5. At a depth of 100 cm from the surface of the soil, to the north, the value of the Igeo is 4.68, and hence, it is considered strongly-extremely polluted because Igoe is from (4-5). To the south, the Igeo value is 94.94, to the east, the Igeo value is 41.27, and to the west, the Igeo value is 23.87, all of which are considered extremely polluted because Igoe >5 [41].

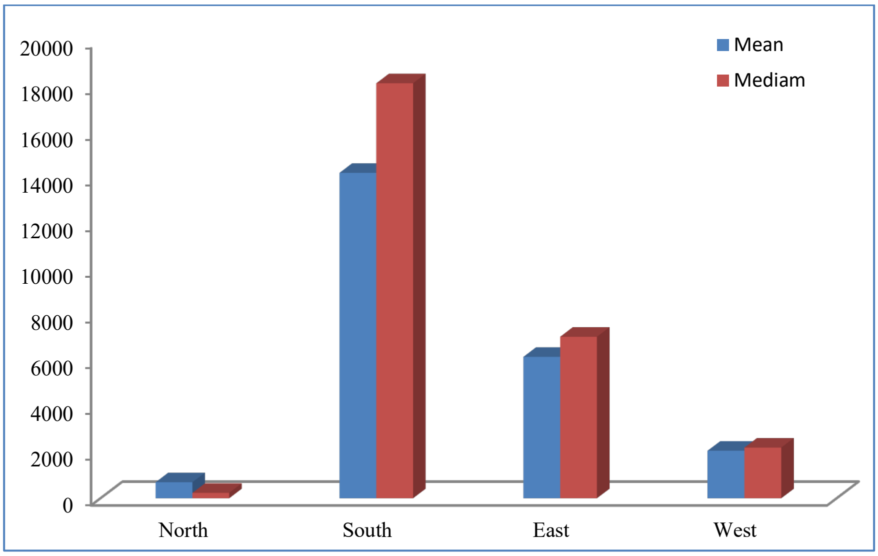

Figure 6: Mean and median values at a depth of 100 cm from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east and west)

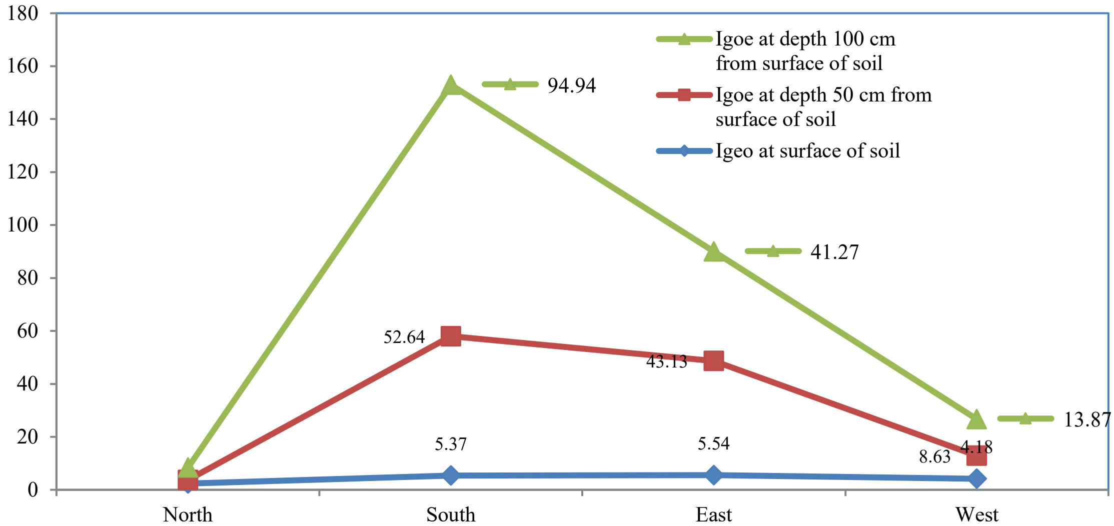

Figure 7: The values of the geoaccumulation index (Igeo) at depths of (0, 50, and 100 cm) from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west)

3.2.2 Enrichment factor (EF)

The EF can be used to estimate enrichment factors, which are differences between the presence of individual metals derived from human activities and those of natural origin or derived from a mixed source of heavy metals. In the calculation of EF, the reference for the element content is the unpolluted Earth's crust. Typically, Fe is used [63,64].

Figure 8 shows the values of the enrichment factor (EF) at depths of (0, 50, and 100 cm) from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west). At a depth of (0), the values of the EF to the north, south, east, and west of the factory are (87.81, 705.46, 794.18, and 309.7) > 40, and hence, it is considered extremely high enrichment.

At a depth of 50 cm from the surface of the soil, the value of the EF to the north is (22.784), which is a very high enrichment because EF is from (20-40). The values of the EF to the south, east, and west of the factory are (898.17, 735.9, and 147.24) > 40. Therefore, it is considered extremely high enrichment.

At a depth of 100cm from the surface of the soil, the values of the EF to the north, south, east, and west of the factory are (79.85, 1619.82, 704.05, and 236.58) > 40. Therefore, it is considered extremely high enrichment [49].

This indicates that the tanning factory's industrial activities were a significant source of heavy metal pollution. Heavy metals may not originate from the soil itself, but rather from more natural and/or anthropocentric sources in industrial areas, as evidenced by the soil at depths of 50 cm and 100 cm [24].

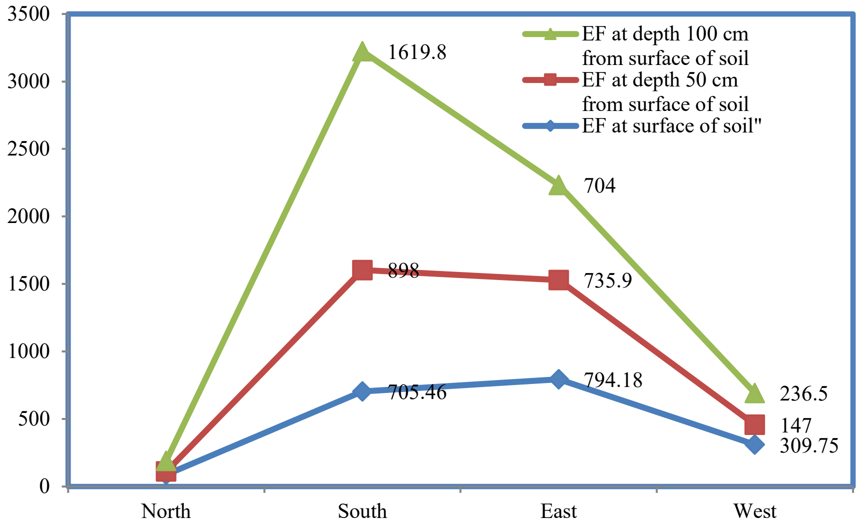

Figure 8: The values of the enrichment factor (EF) at depths of (0, 50, and 100 cm) from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west).

3.2.3 Integrated pollution index (IPI)

The Single Pollution Index (PI) is an index that can be used to determine which heavy metal poses the greatest threat to the soil environment[65,66].Figure 9 shows the values of the integrated pollution index (IPI) at depths of (0, 50, and 100 cm) from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west). At the surface of the soil, the values of IPI were (7.72, 62, 69.82, and 27.23), which is considered an extreme level of contamination because IPI>5.

At a depth of 50 cm from the surface of the soil, to the north, the value of IPI was (2), which is considered a high level of contamination because 2<IPI≤5, and the values of IPI to the south, east, and west were (78.97, 64.7, and 12.9). Therefore, this is considered an extreme level of contamination because of IPI>5.

At a depth of 100 cm from the surface of the soil, the values of IPI were (7.02, 142.4, 61.9, and 20.8), which is considered an extreme level of contamination because IPI>5 [51].

3.3 Health risk assessment

The environment and, consequently, living things are affected by heavy metal contamination, and heavy metal contamination in the environment poses a threat to human health in the food chain. Primacy metals like Cr, As, Cd, and Pb should be evaluated for public health because of their high toxicity. These elements are categorized as human carcinogens and are thought to be toxic even at the lowest immunity levels, causing damage to multiple organs [67-69]. The USEPA method was used to conduct exposure and risk assessments in this work. Heavy metals are mostly absorbed by humans through the inhalation of dust, inhaled aerosols, and food, as well as through consuming contaminated water [70]. Heavy metals' toxicity to human health is directly proportional to the amount consumed each day. However, this study took into account inhalation ingestion. The first step in the non-carcinogenic analysis is the calculation of values of the average daily dose (ADD). In this study, carcinogenic and non-carcinogenic human health risks were evaluated.

Table 1 and Table 2 show the values of the average daily dose (ADD) (mg/kg/day) for non-carcinogenic at the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west) for adults and children. The result of (ADD) showed high health risks for adults through the inhalation route than for children, which can be associated with the high exposure duration and the inhalation rate of adults compared to those in children [71].

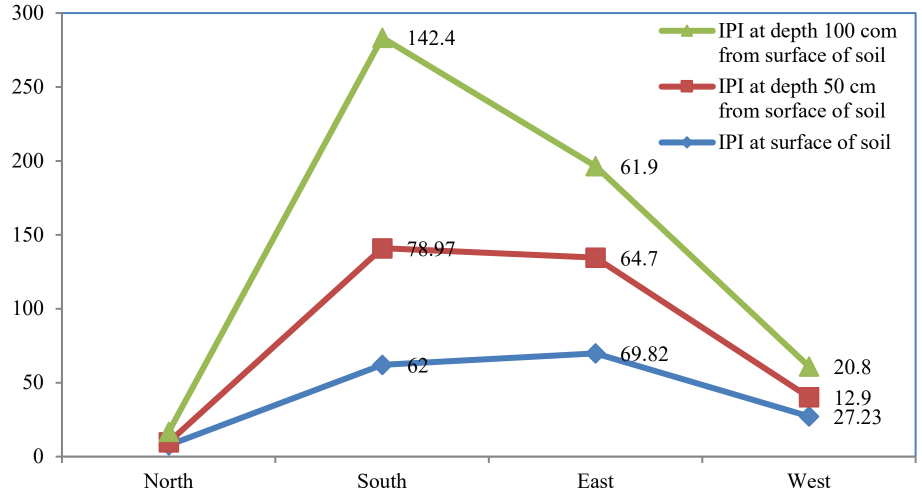

Figure 9: The values of the integrated pollution index (IPI) at depths of (0, 50, and 100 cm) from the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east and west).

3.3.1 The non-carcinogenic risk assessment:

The values of HQ and HI for non-carcinogenic in the surface for Cr of a soil depth of (0 cm) for adults and children are shown in Table 1 and Table 2. For adults, the highest assessment for HI was 0.07, while the lowest assessment for adults was 0.007. For children, the maximum assessment for HI was 0.02, and the minimum was 0.002. These results indicate that HI< 1 non-significant risk [71]. Therefore, the results are considered within the acceptable levels for US EPA [46, 47].

Table 1: lists the values of the average daily dose (ADD) (mg/kg/day), hazard quotient (HQ), and the health index (HI) for non-carcinogenic at the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west) for adults.

Location	**Concentration mg/Kg**	**ADD_{Cr} (10^{-8})** Mg/Kg/day	**HQ_{Cr}**	**HI**
			north	
(A) 50 m from the site	2000	20	6×10^{-3}	
(B)500 m from the site	250	2.6	8×10^{-4}	7×10^{-3}
(c) 1000 m from the site	66	0.68	2×10^{-4}	
Location			**south**	
(A) 50 m from the site	18100	187	6×10^{-2}	
(B)500 m from the site	347	3.6	1×10^{-3}	6×10^{-2}
(c) 1000 m from the site	160	1.65	5×10^{-4}	
Location			**East**	
(A) 50 m from the site	5800	60	2×10^{-2}	
(B)500 m from the site	14830	153	5×10^{-2}	7×10^{-2}
(c) 1000 m from the site	317	3.3	1×10^{-3}	
Location			**West**	
(A) 50 m from the site	2350	24	8×10^{-3}	
(B)500 m from the site	1940	20	6×10^{-3}	7×10^{-2}
(c) 1000 m from the site	3880	40	1×10^{-2}	

3.3.2 Carcinogenic risk assessment (LADD):

Heavy metals, such as Pb, Cr (VI), Cd, and Ni, may increase human cancer risk [45, 46]. As a result, a wide range of cancers could develop as a result of long-term exposure to low levels of toxic metals. The residents' total exposure to Cr (VI) as a carcinogen was evaluated using the LADD values. Table 3 shows the values of lifetime average daily dose (LADD) and lifetime cancer risk for carcinogenic (R) at the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west) for adults. In particular, R less than (1×10^{-6}) for heavy metals is considered insignificant, and the cancer risk can be ignored; whereas a cancer risk above (1×10^{-4}) is problematic and considered harmful [59].

According to Table 3, the highest value of R was 51.9, and the lowest value was 0.231; consequently, all values exceed the USEPA safe level, indicating a high risk to health in the area under study, making it an unacceptable risk.

Table 2: lists the values of the average daily dose (ADD) (mg/kg/day), hazard quotient (HQ), and the health index (HI) for non-carcinogenic at the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west) for children.

Location	Concentration Mg/Kg	ADD_{Cr} (10^{-8}) mg/Kg/day	HQ_{Cr}	HI
		north		
(A) 50 m from the site	2000	6.12	2×10^{-3}	
(B)500 m from the site	250	0.765	2×10^{-4}	2×10^{-3}
(c) 1000 m from the site	66	0.201	6×10^{-5}	
Location		**south**		
(A) 50 m from the site	18100	55	1×10^{-2}	
(B)500 m from the site	347	1.06	3×10^{-4}	1×10^{-2}
(c) 1000 m from the site	160	0.489	1×10^{-3}	
Location		**East**		
(A) 50 m from the site	5800	17	6×10^{-3}	
(B)500 m from the site	14830	45	1×10^{-2}	2×10^{-2}
(c) 1000 m from the site	317	0.97	3×10^{-4}	
Location		**West**		
(A) 50 m from the site	2350	7.191	2×10^{-3}	
(B)500 m from the site	1940	5.9	1×10^{-3}	8×10^{-3}
(c) 1000 m from the site	3880	0.118	3×10^{-3}	

Table 3: lists the values of lifetime average daily dose (LADD) and lifetime cancer risk for carcinogenic (R) at the surface of the soil at distances of (50, 500, and 1000 m) from the tanning factory for the four directions (north, south, east, and west) for adults [71].

Location	Concentration Mg/Kg	$LADD_{Cr}$	R_{Cr}
		north	
(A) 50 M from the site	2000	294	7
(B)500 M from the site	250	36.75	0.87
(c) 1000 M from the site	66	9.702	0.231
Location		**South**	
(A) 50 M from the site	18100	2660	63
(B)500 M from the site	347	51	1.21
(c) 1000 M from the site	160	23.52	0.56
Location		**East**	
(A) 50 M from the site	5800	852.6	20.3
(B)500 M from the site	14830	2180	51.9
(c) 1000 M from the site	317	46.5	1.1
Location		**West**	
(A) 50 M from the site	2350	345	8.2
(B)500 M from the site	1940	285	6.7
(c) 1000 M from the site	3880	570	13.5

4. Conclusion

Chromium concentration, mean, and median values were calculated, and the mean and the median values were compared with the concentration of unpolluted mean of soils worldwide (83.0 mg/kg) [37], where all values of the mean and the median were higher than the allowed reference values.

The lowest value of (Igeo) was (2.36), which is moderately strongly polluted because Igoe is from (2-3), and the highest value was (94.94), which is extremely polluted because Igoe >5. All values of (EF)> 40, and hence, it is considered extremely high enrichment. Moreover, the integrated pollution index (IPI) values at the surface and a depth of 100 cm from the surface indicated an extreme level of contamination because IPI>5. At a depth of 50 cm from the surface to the north of the factory, there is a high level of contamination because 2<IPI≤5, and to the south, east, and west, there is an extreme level of contamination because IPI>5. These results suggest a significant role for the wastes from the industrial activities of tanning.

To estimate health risk assessment, the values of HI were found to be at a safe level (<1) for adults and children. Therefore, there was a lack of significance for non-carcinogenic health risks. Moreover, carcinogenic risks were estimated by exposure results, which showed the critical risks for human health in the studied soils (R) for Cr, which are higher than the levels of the tolerable range for inhalation exposure of carcinogenic risks (10^{-6} to 10^{-4}), where the highest value of R was 51.9 and the lowest value was 0.231. Consequently, this indicates a high risk to health in the area under study, making it an unacceptable risk.

Author Contribution

All authors contributed equally to this work.

Funding

This paper received no external funding

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of Interest

The author declares that there're no conflicts of interest for declaration.

Reference:

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Appendix

Exposure factors for dose models that were used for this study.US EPA1989

Factor	Definition	Unit	Value	
			Children	Adult
C	concentration of an element in soi	mg/kg		
EF	exposure frequency	days/year	180	180
ED	exposure duration	years	6	24
BW	average body weight	kg	15	70
AT	average time	days	365×ED	365×ED
CF	conversion factor	kg/mg	1×10^{-4}	1×10^{-6}
Rinh	inhalation rate	m3/day	7.6	20
PEF	particle emission factor	m3/kg	1.36×10^{9}	1.36×109
AT	average time carcinogenic	days	25,550	25,550