مجلة الدراسات التربوية والعلمية - كلية التربية - الجامعة العراقية
العدد السادس والعشرون - المجلد الأول - علوم الفيزياء - أيلول 2025 م
doi.org/10.52866/esj.2025.01.26.19

Assessment of Heavy Metal Pollution in Soil at Al-Tajiyat, Baghdad: An Analytical Study Using X-Ray Fluorescence (XRF) Techniques

[1]Raafat Abdul H. Muslim[2] , Saad Nafea Yaqoob , [3]Rawnq Qays Ghdban
[1]Center of Education Researches Studies, Ministry of Education – Iraq
[2]Directorate of Education, First Rusafa, Ministry of Education – Iraq
[3]College of Education for Pure Science Ibn Al-Haitham, University of Baghdad, Iraq

Abstract :

The objective of this study is to ascertain the chemical element concentrations in eight soil samples taken from a residential area in the Al-Tajiyat district of Baghdad, Iraq, using X-Ray Fluorescence (XRF) technology. They determined the concentrations of the components. In order to assess the level of environmental contamination and its potential impact on the local population's health, the Chronic Daily Intake (CDI) and Contamination Factor (CF) were calculated. The findings revealed elevated levels of some components, such as silicon (SiO2) and calcium (CaO), indicating pollution that may be harmful to the health of the local populace.

Keywords: (XRF) technology, Contamination Factor, heavy metal, (CDI), concentrations.

تقييم تلوث التربة بالمعادن الثقيلة في منطقة التاجيات - بغداد: دراسة تحليلية باستخدام تقنيات فلورة الأشعة السينية (XRF)

[1] رأفت عبد الحسن مسلم ، [2] سعد نافع يعقوب ، [3] رونق قيس غضبان
1. مركز البحوث والدراسات التربوية، وزارة التربية - بغداد، العراق
2. مديرية التربية، الرصافة الأولى، وزارة التربية - بغداد، العراق
3. كلية التربية للعلوم الصرفة، ابن الهيثم، جامعة بغداد - بغداد، العراق

مستخلص:

تهدف هذه الدراسة إلى تحديد تركيزات العناصر الكيميائية في ثماني عينات تربة مأخوذة من منطقة سكنية في قضاء التاجيات ببغداد، العراق، باستخدام تقنية فلورة الأشعة السينية (XRF). وحُددت تراكيز هذه المكونات. ولتقييم مستوى التلوث البيئي وتأثيره المحتمل على صحة السكان المحليين، حُسب المدخول اليومي المزمن (CDI) ومعامل التلوث (CF). وكشفت النتائج عن ارتفاع مستويات بعض المكونات، مثل السيليكون (SiO2) والكالسيوم (CaO)، مما يشير إلى تلوث قد يضر بصحة السكان المحليين.

الكلمات المفتاحية: تقنية (XRF)، عامل التلوث، المعادن الثقيلة، (CDI)، التركيزات.

Introduction

Heavy metal pollution is a major concern to the environment and can have long-term negative impacts on soil, groundwater, and human health. Landfills have historically been used to store a broad variety of waste materials, some of which may include heavy metals or other toxins. Concerns regarding the possibility of chronic heavy metal contamination have been raised by the redevelopment of these sites into residential areas. [1, 2, 3, 4].

The potential existence of heavy metal remains in these landfills that have since been turned into residential areas is investigated in this study report. Because of the concentrations of Ni, Cr, Hg, Cd, Pb, and other elements, these places are more likely to create long-term health problems, particularly for local children. [2, 5]. To reduce the hazards of heavy metal contamination in landfills that are converted into residential areas, the results emphasize the need of using appropriate waste management techniques and ongoing monitoring.[4, 5]. To identify the most dangerous ingredients and evaluate pollution levels, the Chronic Daily Intake (CDI) and Contamination Factor (CF) were employed.

Study area: Located in the northeastern region of Bagdad, the capital of Iraq, between latitudes 33.428507°N and longitudes 44.312196 °E (Fig. 1), the Tajyat area was once a landfill for various household and industrial waste, but its conversion to a residential neighborhood highlights the city's complex urban problems. Studies evaluating waste management issues and garbage density [6] draw attention to the environmental contamination issues that are common in residential areas because these places were once landfills. for every area in Baghdad for seventeen years, from 1981 to 1998.

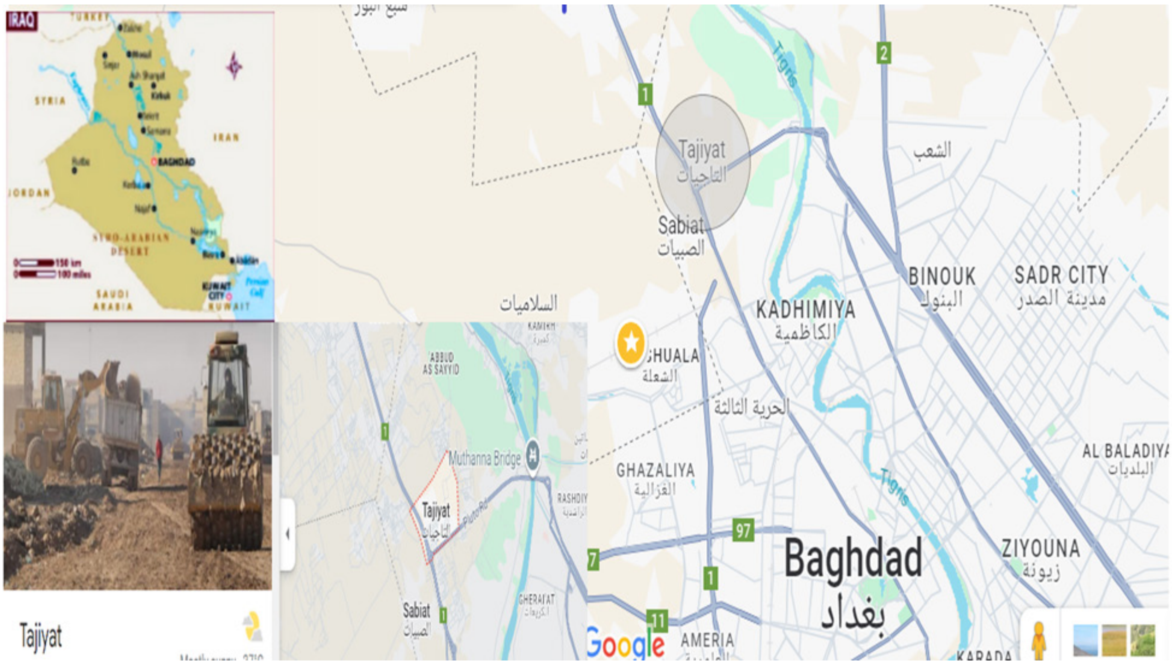

Figure 1: Geographical location of the Tajyat area

Theoretical Background:

1. Chemical Elements in Soil: Although silicon, magnesium, sodium, and aluminum are all naturally occurring elements in soil, high quantities of these elements may be a sign of environmental contamination. High concentrations for heavy metals such as iron, nickel, and chromium can be poisonous [7].

2. X-Ray Fluorescence (XRF) Technique: This non-destructive approach is used to examine a sample's chemical makeup. When the sample is exposed to high-energy X-rays, its X-ray emissions are tracked [8].

3. CF is a metric used to quantify the level of chemical pollution in soil. It is calculated using the following formula [9]:

$$CF = C_{background} / C_{element} \quad \ldots\ldots 1$$

Where: $C_{element}$ represents the element's concentration in the sample; $C_{background}$ is the element's concentration in uncontaminated soil.

4. A person's daily exposure to an element through several routes, including ingestion, inhalation, and skin absorption, . The formula below is used to compute is measured by (CDI) [10,11]:

$$CDI = C \times IR \times EF \times ED / BW \times AT \quad \ldots. 2$$

Where:

- C = element's concentration in soil (mg/kg)

- IR = ingestion rate (mg/day)
- EF = frequency of exposure (days/year)
- ED = exposure duration (years)
- BW = body weight (kg)
- AT = average time (days)

Calculations and Analysis:

1. Data Analysis:

XRF technology is one efficient, non-destructive way to ascertain the exact composition of a sample. The measurement of X-rays emitted by the sample after being injected with a high-energy beam forms its basis and allows for accurate element identification and concentration. This modern technique is used in many fields, including biology, industry, and the environment, and is a basic reference in analytical research [12]. Eight soil samples were analyzed for element concentrations using the XRF technique. The results are summarized in Table 1.

Table 1: Elemental concentrations in eight soil samples using XRF method.

Element	Symbol	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Sodium	Na2O	1.616%	1.117%	1.586%	1.611%	1.159%	1.611%	1.616%	1.117%
Magnesium	MgO	5.283%	5.215%	5.260%	5.229%	5.282%	5.231%	5.219%	5.249%
Aluminum	Al2O3	8.676%	9.214%	9.200%	8.6870%	8.668%	8.695%	8.676%	8.778%
Silicon	SiO2	38.27%	36.20%	36.19%	36.19%	36.50%	36.21%	36.88%	36.22%
Phosphorus	P2O5	0.1953%	0.8505%	0.1890%	0.1952%	0.1953%	0.8560%	0.1953%	0.1953%
Sulfur	SO3	2.023%	2.013%	1.3243%	1.7001%	2.0143%	2.023%	2.021%	2.022%
Chlorine	Cl	0.2596%	0.0406%	0.2400%	0.2403%	0.2590%	0.1235%	0.2596%	0.2765%
Potassium	K2O	1.182%	1.222%	1.182%	1.222%	1.123%	1.222%	1.166%	1.181%
Calcium	CaO	18.68%	24.98%	18.90%	18.68%	18.70%	18.71%	20.69%	22.72%
Titanium	TiO2	0.9089%	0.9157%	0.9090%	0.9150%	0.9089%	0.9157%	0.9156%	0.9090%
Vanadium	V2O5	0.0249%	0.0147%	0.0240%	0.0245%	0.0249%	0.0148%	0.0159%	0.0240%
Chromium	Cr2O3	0.05409%	0.06341%	0.05500%	0.05430%	0.05409%	0.06333%	0.05441%	0.06341%
Manganese	MnO	0.1142%	0.1187%	0.1155%	0.1142%	0.1180%	0.1185%	0.1143%	0.143%
Iron	Fe2O3	6.342%	6.380%	6.344%	6.380%	6.360%	6.390%	6.378%	6.350%
Cobalt	CoO	0.00317%	0.00209%	0.00300%	0.00220%	0.00209%	0.00300%	0.00316%	0.00317%
Nickel	NiO	0.02711%	0.02597%	0.02650%	0.02611%	0.02700%	0.02711%	0.02708%	0.02598%
Copper	CuO	0.00511%	0.00460%	0.00480%	0.00478%	0.00500%	0.00511%	0.0490%	0.0511%

Element	Symbol	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Zinc	ZnO	0.01106%	0.01163%	0.01106%	0.01106%	0.01108%	0.01106%	0.01153%	0.01106%
Gallium	Ga	0.00147%	0.00140%	0.00140%	0.00145%	0.00145%	0.00143%	0.00140%	0.00147%
Germanium	Ge	0.00001%	0.00005%	0.00005%	0.00001%	0.00005%	0.00003%	0.00005%	0.00005%
Arsenic	As2O3	0.00111%	0.00111%	0.00111%	0.00111%	0.00111%	0.00111%	0.00111%	0.00111%
Selenium	Se	0.00005%	0.00005%	0.00005%	0.00005%	0.00005%	0.00005%	0.00005%	0.00005%
Bromine	Br	0.00221%	0.00129%	0.00129%	0.0040%	0.00220%	0.00210%	0.00221%	0.00129%
Rubidium	Rb2O	0.00472%	0.00474%	0.00470%	0.00472%	0.00473%	0.00473%	0.00472%	0.00474%
Strontium	SrO	0.05946%	0.05294%	0.05388%	0.05277%	0.05246%	0.05264%	0.05288%	0.05294%
Yttrium	Y	0.00197%	0.00199%	0.00198%	0.00197%	0.00197%	0.00199%	0.00197%	0.00198%
Zirconium	ZrO2	0.01674%	0.01756%	0.01755%	0.01756%	0.01677%	0.01674%	0.01675%	0.01677%
Niobium	Nb2O5	0.00133%	0.00125%	0.00126%	0.00126%	0.00133%	0.00130%	0.00125%	0.00125%
Molybdenum	Mo	0.00142%	0.00113%	0.00133%	0.00142%	0.00113%	0.00141%	0.00133%	0.00142%
Silver	Ag	0.00020%	0.00020%	0.00020%	0.00020%	0.00020%	0.00020%	0.00020%	0.00020%
Cadmium	Cd	0.00020%	0.00020%	0.00020%	0.00020%	0.00020%	0.00020%	0.00020%	0.00020%
Tin	SnO2	0.00005%	0.00027%	0.00027%	0.00010%	0.00008%	0.00005%	0.00026%	0.00005%
Antimony	Sb2O5	0.00040%	0.00040%	0.00040%	0.00040%	0.00040%	0.00040%	0.00040%	0.00040%
Tellurium	Te	0.00030%	0.00030%	0.00030%	0.00030%	0.00030%	0.00030%	0.00030%	0.00030%
Iodine	I	0.00030%	0.00030%	0.00030%	0.00030%	0.00030%	0.00030%	0.00030%	0.00030%
Cesium	Cs	0.00197%	0.00040%	0.00040%	0.00199%	0.00197%	0.00040%	0.00040%	0.00197%
Barium	Ba	0.02614%	0.02613%	0.02613%	0.02630%	0.02634%	0.02614%	0.02613%	0.2620%
Lanthanum	La	0.00020%	0.00020%	0.00020%	0.00334%	0.00020%	0.00333%	0.00020%	0.00020%
Cerium	Ce	0.0077%	0.0076%	0.0077%	0.00020%	0.0076%	0.00020%	0.00020%	0.00018%
Hafnium	Hf	0.00018%	0.00018%	0.00016%	0.00017%	0.00016%	0.00016%	0.00018%	0.00018%
Tantalum	Ta2O5	0.00863%	0.00863%	0.00877%	0.00822%	0.00862%	0.00866%	0.00865%	0.00866%
Tungsten	WO3	0.00016%	0.00016%	0.00016%	0.0008%	0.00016%	0.00010%	0.00016%	0.0008%
Mercury	Hg	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%
Thallium	Tl	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%
Lead	PbO	0.00135%	0.00125%	0.00127%	0.00130%	0.00135%	0.00125%	0.00125%	0.00129%
Bismuth	Bi	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%	0.00010%
Thorium	Th	0.00050%	0.00045%	0.00047%	0.00050%	0.00048%	0.00048%	0.00050%	0.00043%
Uranium	U	0.00014%	0.00013%	0.00010%	0.0012%	0.0011%	0.00013%	0.00010%	0.00010%

2. Calculation of Contamination Factor (CF):

The contamination factor (CF) for each component was determined using formula (1). The basic values were adopted from previous studies [9], as in Table (2).

Table 2: The Contamination Factor (CF)

Element	CF (Sample 1)	CF (Sample 2)	CF (Sample 3)	CF (Sample 4)	CF (Sample 5)	CF (Sample 6)	CF (Sample 7)	CF (Sample 8)
Sodium (Na2O)	1.1	0.8	1.1	1.1	0.8	1.1	1.1	0.8
Magnesium (MgO)	1.2	1.1	1.2	1.2	1.2	1.1	1.1	1.2
Aluminum (Al2O3)	1.1	1.2	1.2	1.1	1.1	1.1	1.1	1.2
Silicon (SiO2)	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.2
Phosphorus (P2O5)	0.1	0.5	0.1	0.1	0.1	0.5	0.1	0.1
Sulfur (SO3)	1.5	1.5	1	1.3	1.5	1.5	1.5	1.5
Chlorine (Cl)	1	0.2	0.9	0.9	1	0.5	1	1.1
Potassium (K2O)	1	1.1	1	1.1	0.9	1.1	1	1
Calcium (CaO)	1.3	1.8	1.3	1.3	1.3	1.3	1.4	1.6
Titanium (TiO2)	1	1	1	1	1	1	1	1
Vanadium (V2O5)	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.2
Chromium (Cr2O3)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Manganese (MnO)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Iron (Fe2O3)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Cobalt (CoO)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nickel (NiO)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Copper (CuO)	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.5
Zinc (ZnO)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Gallium (Ga)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Germanium (Ge)	0	0	0	0	0	0	0	0
Arsenic (As2O3)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Element	CF (Sample 1)	CF (Sample 2)	CF (Sample 3)	CF (Sample 4)	CF (Sample 5)	CF (Sample 6)	CF (Sample 7)	CF (Sample 8)
Selenium (Se)	0	0	0	0	0	0	0	0
Bromine (Br)	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Rubidium (Rb2O)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Strontium (SrO)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Yttrium (Y)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Zirconium (ZrO2)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Niobium (Nb2O5)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Molybdenum (Mo)	0	0	0	0	0	0	0	0
Silver (Ag)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cadmium (Cd)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Tin (SnO2)	0	0.1	0.1	0	0	0	0.1	0
Antimony (Sb2O5)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Tellurium (Te)	0	0	0	0	0	0	0	0
Iodine (I)	0	0	0	0	0	0	0	0
Cesium (Cs)	0.1	0	0	0.1	0.1	0	0	0.1
Barium (Ba)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
Lanthanum (La)	0	0	0	0.1	0	0.1	0	0
Cerium (Ce)	0.1	0.1	0.1	0	0.1	0	0	0
Hafnium (Hf)	0	0	0	0	0	0	0	0
Tantalum (Ta2O5)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Tungsten (WO3)	0	0	0	0	0	0	0	0
Mercury (Hg)	0	0	0	0	0	0	0	0
Thallium (Tl)	0	0	0	0	0	0	0	0
Lead (PbO)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bismuth (Bi)	0	0	0	0	0	0	0	0
Thorium (Th)	0	0	0	0	0	0	0	0
Uranium (U)	0	0	0	0.1	0.1	0	0	0

3. Calculation of Chronic Daily Intake (CDI):

The CDI for all items was calculated using formula (2) and the following values were adopted [10, 11]:

- **Ingestion Rate (IR)**: 100 mg per day and represents the average amount of soil consumed per day, especially in residential areas; Exposure frequency (**EF**): 350 days/year: Refers to the number of days a person may be exposed to pollutants in a given year.

- **Exposure Duration (ED)**: 30 years: Denotes the amount of time that

Table 3: The Chronic Daily Intake (CDI)

Element	(CDI)							
	(Sample 1) (mg/kg/day)	(Sample 2) (mg/kg/day)	(Sample 3) (mg/kg/day)	(Sample 4) (mg/kg/day)	(Sample 5) (mg/kg/day)	(Sample 6) (mg/kg/day)	(Sample 7) (mg/kg/day)	(Sample 8) (mg/kg/day)
Sodium (Na_2O)	0.0023	0.0016	0.0023	0.0023	0.0017	0.0023	0.0023	0.0016
Magnesium (MgO)	0.0075	0.0074	0.0075	0.0075	0.0075	0.0074	0.0074	0.0075
Aluminum (Al_2O_3)	0.0124	0.0132	0.0131	0.0124	0.0124	0.0124	0.0124	0.0125
Silicon (SiO_2)	0.0548	0.0518	0.0518	0.0518	0.0522	0.0518	0.0528	0.0518
Phosphorus (P_2O_5)	0.000002	0.000012	0.000002	0.000002	0.000002	0.000012	0.000002	0.000002
Sulfur (SO_3)	0.0029	0.0029	0.0019	0.0024	0.0029	0.0029	0.0029	0.0029
Chlorine (Cl)	0.00037	0.000058	0.00034	0.00034	0.00037	0.00018	0.00037	0.0004
Potassium (K_2O)	0.0017	0.0018	0.0017	0.0018	0.0016	0.0018	0.0017	0.0017
Calcium (CaO)	0.0267	0.0357	0.027	0.0267	0.0267	0.0267	0.0296	0.0325
Titanium (TiO_2)	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
Vanadium (V_2O_5)	0.000036	0.000021	0.000034	0.000035	0.000036	0.000021	0.000023	0.000034
Chromium (Cr_2O_3)	0.000077	0.000091	0.000079	0.000078	0.000077	0.000091	0.000078	0.000091
Manganese (MnO)	0.00016	0.00017	0.00017	0.00016	0.00017	0.00017	0.00016	0.0002
Iron (Fe_2O_3)	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091
Cobalt (CoO)	4.5E-06	0.000003	4.3E-06	3.1E-06	0.000003	4.3E-06	4.5E-06	4.5E-06
Nickel (NiO)	0.000039	0.000037	0.000038	0.000037	0.000039	0.000039	0.000039	0.000037
Copper (CuO)	7.3E-06	6.6E-06	6.9E-06	6.8E-06	7.1E-06	7.3E-06	0.00007	0.000073
Zinc (ZnO)	0.000016	0.000017	0.000016	0.000016	0.000016	0.000016	0.000016	0.000016
Gallium (Ga)	2.1E-06	0.000002	0.000002	2.1E-06	2.1E-06	0.000002	0.000002	2.1E-06
Germanium (Ge)	1E-08	7E-08	7E-08	1E-08	7E-08	4E-08	7E-08	7E-08
Arsenic (As_2O_3)	1.6E-06	1.6E-06	1.6E-06	1.6E-06	1.6E-06	1.6E-06	1.6E-06	1.6E-06
Selenium (Se)	7E-08	7E-08	7E-08	7E-08	7E-08	7E-08	7E-08	7E-08
Bromine (Br)	3.2E-06	1.8E-06	1.8E-06	5.7E-06	3.1E-06	0.000003	3.2E-06	1.8E-06

a person may be exposed to contaminants. The average anticipated exposure time in residential areas is represented by this number.

- Body Weight (BW): 70 kg is regarded as the typical adult weight and is used as a benchmark in evaluations of health risks.

- Averaging Time (AT): 365 × 30 days: Represents the whole exposure duration, which is used to evaluate long-term health concerns.

Element	(CDI)							
	(Sample 1) (mg/kg/day)	(Sample 2) (mg/kg/day)	(Sample 3) (mg/kg/day)	(Sample 4) (mg/kg/day)	(Sample 5) (mg/kg/day)	(Sample 6) (mg/kg/day)	(Sample 7) (mg/kg/day)	(Sample 8) (mg/kg/day)
Rubidium (Rb2O)	6.7E-06	6.8E-06	6.7E-06	6.7E-06	6.8E-06	6.8E-06	6.7E-06	6.8E-06
Strontium (SrO)	0.000085	0.000076	0.000077	0.000075	0.000075	0.000075	0.000076	0.000076
Yttrium (Y)	2.8E-06	2.8E-06	2.8E-06	2.8E-06	2.8E-06	2.8E-06	2.8E-06	2.8E-06
Zirconium (ZrO2)	0.000024	0.000025	0.000025	0.000025	0.000024	0.000024	0.000024	0.000024
Niobium (Nb2O5)	1.9E-06	1.8E-06	1.8E-06	1.8E-06	1.9E-06	1.9E-06	1.8E-06	1.8E-06
Molybdenum (Mo)	0	0	0	0	0	0	0	0
Silver (Ag)	2.9E-07	2.9E-07	2.9E-07	2.9E-07	2.9E-07	2.9E-07	2.9E-07	2.9E-07
Cadmium (Cd)	2.9E-07	2.9E-07	2.9E-07	2.9E-07	2.9E-07	2.9E-07	2.9E-07	2.9E-07
Tin (SnO2)	7E-08	3.9E-07	3.9E-07	1.4E-07	1.1E-07	7E-08	3.7E-07	7E-08
Antimony (Sb2O5)	5.7E-07	5.7E-07	5.7E-07	5.7E-07	5.7E-07	5.7E-07	5.7E-07	5.7E-07
Tellurium (Te)	4.3E-07	4.3E-07	4.3E-07	4.3E-07	4.3E-07	4.3E-07	4.3E-07	4.3E-07
Iodine (I)	4.3E-07	4.3E-07	4.3E-07	4.3E-07	4.3E-07	4.3E-07	4.3E-07	4.3E-07
Cesium (Cs)	2.8E-06	5.7E-07	5.7E-07	2.8E-06	2.8E-06	5.7E-07	5.7E-07	2.8E-06
Barium (Ba)	0.000037	0.000037	0.000037	0.000038	0.000038	0.000037	0.000037	0.000374
Lanthanum (La)	2.9E-07	2.9E-07	2.9E-07	4.8E-06	2.9E-07	4.8E-06	2.9E-07	2.9E-07
Cerium (Ce)	0.000011	0.000011	0.000011	2.9E-07	0.000011	2.9E-07	2.9E-07	2.6E-07
Hafinium (Hf)	2.6E-07	2.6E-07	2.3E-07	2.4E-07	2.3E-07	2.3E-07	2.6E-07	2.6E-07
Tantalum (Ta2O5)	0.000012	0.000012	0.000013	0.000012	0.000012	0.000012	0.000012	0.000012
Tungsten (WO3)	2.3E-07	2.3E-07	2.3E-07	1.1E-06	2.3E-07	1.4E-07	2.3E-07	1.1E-06
Mercury (Hg)	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07
Thallium (Tl)	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07
Lead (PbO)	1.9E-06	1.8E-06	1.8E-06	1.9E-06	1.9E-06	1.8E-06	1.8E-06	1.8E-06
Bismuth (Bi)	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07
Thorium (Th)	7.1E-07	6.4E-07	6.7E-07	7.1E-07	6.9E-07	6.9E-07	7.1E-07	6.1E-07
Uranium (U)	2E-07	1.9E-07	1.4E-07	1.7E-06	1.6E-06	1.9E-07	1.4E-07	1.4E-07

4. Graphical Representations:

To show the variations among the samples, graphs were created to depict the element concentrations, contamination causes, and chronic daily consumption.

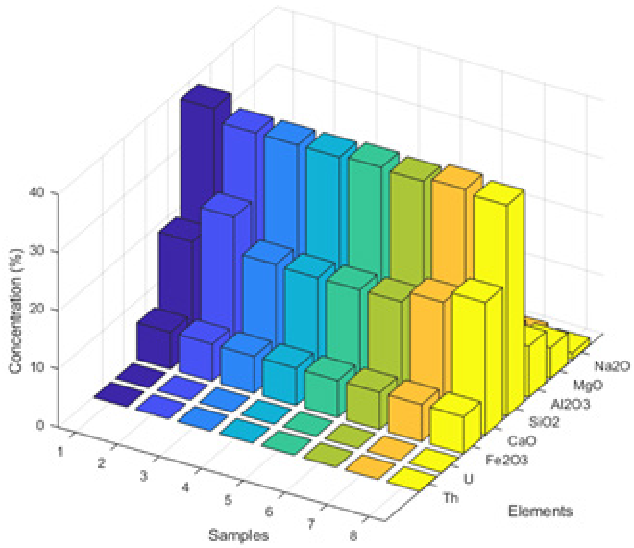

Figure 1: 3D Bar Plot for element concentration

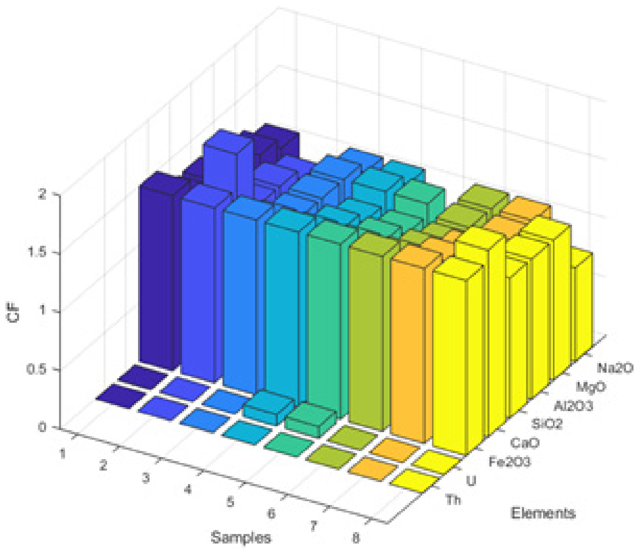

Figure 2: 3D Bar Plot of Contamination Factor (CF)

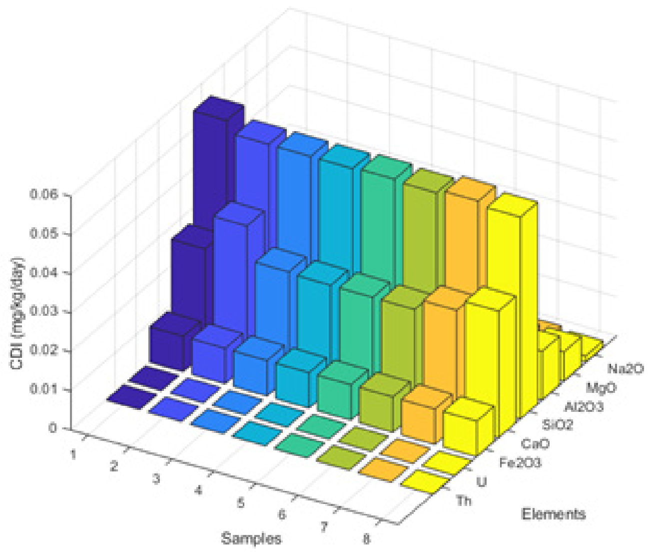

Figure 3: 3D bar Plot of Chronic Daily Dose (CDI)

Results:

The findings from the examination of soil samples demonstrate that different chemical components are present in different quantities, with certain elements exhibiting high amounts that might be harmful to the environment and human health. A thorough assessment of the results for each examined factor is given in the discussion that follows.

1. Key components (such as silicon, calcium, and aluminum):

-Silicon (SiO_2): With values ranging from 36.19% to 38.27%, silicon was present in high percentages in all samples. Although these high levels point to natural abundance, they might also be a sign of environmental pollution from things like building materials or industrial processes. The comparatively high Chronic Daily Intake (CDI) values for silicon suggested possible long-term exposure hazards, especially for the digestive and respiratory systems.

-Calcium (CaO): In comparison to the other samples, the amounts of calcium were notably high, particularly in Sample 2 (24.98%). Sample 2's calcium Contamination Factor (CF) was much greater, indicating localized contamination. Even while calcium is less harmful than heavy metals, prolonged exposure to high calcium levels in soil can cause health problems.

-Aluminum (Al2O3): The concentrations of aluminum varied somewhat between samples, ranging from 8.676% to 9.214%. Aluminum is a naturally occurring metal, however considering its possible neurotoxic effects at high quantities, its higher levels in some samples may require more research.2. Heavy Metals (e.g., Iron, Chromium, Nickel):

-Iron (Fe2O3): The concentrations of iron ranged from 6.342% to 6.390% and were constant in all samples. Iron is a necessary metal, but too much of it can cause chronic health problems like oxidative stress and organ damage if consumed or inhaled. There was no discernible contamination, as shown by the mild CF values for iron.

-Chromium (Cr2O3): Concentrations of chromium ranged from 0.054% to 0.063%, which is a comparatively low amount. Hexavalent chromium is extremely poisonous, although the toxicity of chromium varies according to its oxidation state. Chromium's CF values were modest, indicating less danger.

-Nickel (NiO): CF readings showed no discernible contamination, while nickel contents varied from 0.02597% to 0.02711%. Nevertheless, prolonged exposure to nickel might result in respiratory problems and skin sensitivities.

3. Trace elements, such as copper, cobalt, and vanadium:
Vanadium (V2O5): Sample 2 had - a CF value of 0.1, which indicates mild contamination. Vanadium concentrations were low but varied somewhat. Long-term exposure to vanadium may have carcinogenic effects and impact .the respiratory system

-Cobalt (CoO): Cobalt concentrations were below 0.00317%, indicating very low levels. Since the CF readings were nearly negligible, there may not have been any contamination. Cobalt is a necessary micronutrient, though, and excesses or deficits can have negative health effects.

- Copper (CuO): The amounts of copper ranged from 0.00460% to 0.0511%. Some samples (such as Samples 7 and 8) had elevated copper levels, which might be a sign of human inputs. Damage to the liver and kidneys can result from copper poisoning.

4. Radioactive and rare earth elements:

-Thorium (Th): Concentrations of thorium ranged from 0.00043% to 0.00050% and were constant across samples. Since thorium's CF values were zero, there was no pollution. But because thorium is a radioactive material, even tiny concentrations need to be watched for possible radiological hazards.

-Uranium (U): With the exception of Samples 4 and 5, where they reached 0.0012% and 0.0011%, respectively, uranium concentrations were typically low. These samples had CF values of 0.1, which suggests a low level of contamination. Uranium requires more research since it presents both chemical and radiological hazards.

5. Additional Notable Features:

- Zinc (ZnO): There was no sign of contamination, and zinc contents were low and constant among samples. Although zinc is a necessary vitamin, too much of it can cause digestive problems.

- Lead (PbO): Lead levels were modest, with a range of 0.00125% to 0.00135%. There was no discernible contamination, as shown by the low CF values. Lead is extremely poisonous, though, and even trace amounts may be harmful to health, particularly for young people.

- Mercury (Hg): CF values were zero, indicating very low mercury contents. Since mercury is so dangerous, it is comforting to know that it is not present in large quantities.

6. Health Risk Assessment (CDI): The Chronic Daily Intake (CDI) estimates showed that because of their high concentrations, elements including silicon, calcium, and aluminum heavily contribute to daily exposure. Even though the majority of the elements' CDI values were within safe bounds, prolonged exposure to high concentrations of these elements may eventually have a negative impact on one's health.

Conclusion:

High levels of several elements, especially silicon, calcium, and aluminum, are present in the soil in the residential area and may be harmful to long-term health. Although they don't exhibit any noticeable pollution, heavy metals like iron, chromium, and nickel still need to be monitored. There are trace levels of radioactive elements including uranium and thorium, and some samples have mild contamination. To reduce exposure concerns, waste management techniques should be implemented and monitored continuously. To evaluate the long-term health effects of these factors on inhabitants, more research is required.

References:

[1] A. Ghandeharizadeh, M. Dehghani, A. Azhdarpoor, H. Hashemi, A. B. Haghighi, and N. Shamsedini, "Accumulation, contamination, health and ecological risk assessment of heavy metals in landfill soil: Case study of Shiraz city in the Middle East," 2024. Available: 10.21203/rs.3.rs-4320875/v1.

[2] A. Podlasek, M. D. Vaverková, A. Jakimiuk, and E. Koda, "A comprehensive investigation of geoenvironmental pollution and health effects from municipal solid waste landfills," Environmental Geochemistry and Health , vol. 46, 2024. Available: 10.1007/s10653-024-01852-4.

[3] O. O. Olanipekun, O. S. Olanipekun, G. A. Idowu, and A. F. Aiyesanmi, "Impacts of solid waste management site on some toxic elements contamination of the surrounding soil in Akure, Nigeria," Science of The Total Environment, pp. 172450-172450, 2024. doi: 10.1016/j.scitotenv.2024.172450.

[4] D. Gyabaah, E. Awuah, P. Antwi-Agyei, and R. Amankwah Kuffour, "Physicochemical properties and heavy metals distribution of waste fine particles and soil around urban and peri-urban dumpsites," *Environmental Challenges*, 2023. doi: 10.1016/j.envc.2023.100785.

[5] T. O. Kolawole, O. Iyiola, H. Ibrahim, and R. A. Isibor, "Contamination, ecological and health risk assessments of potentially toxic elements in soil around a municipal solid waste disposal facility in Southwestern Nigeria," Journal of Trace Elements and Minerals , vol. 5, pp. 100083-100083, 2023. Available: https://doi.org/10.1016/j.jtemin.2023.100083 .

[6] M. Moradgholi, N. Masihi, M. Zare Bidoki, and F. Kazembeigi, "Investigation of Environmental Pollution in Residential Areas From Littered Wastes," *Journal of Advances in Environmental Health Research*, 2023. Available: 10.34172/jaehr.1331.

[7] J. Smith et al., "Heavy Metals in

Soil: Impacts on Human Health," Environmental Science Journal , vol. 45, no. 3, pp. 123-135, 2018.

[8] R. Jenkins , "X-Ray Fluorescence Spectrometry," Analytical Chemistry , vol. 89, no. 5, pp. 2345-2356, 2017.

[9] L. Hakanson, "An Ecological Risk Index for Aquatic Pollution Control," Water Research , vol. 14, no. 8, pp. 975-1001, 1980.

[10] U.S. EPA, "Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)," Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, 2020. Available: https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part.

[11] U.S. EPA, "Exposure Factors Handbook 2011 Edition (Final)," National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, 2011. Available: https://www.epa.gov/expobox/exposure-factors-handbook.

[12] R. Jenkins, "X-Ray Fluorescence Spectrometry: A Comprehensive Guide," Journal of Analytical Chemistry , vol. 45, pp. 123-145, 2017.