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# Ecological and health risks assessment of heavy metal in soils and leaves around CIMTOGO cement factory, Lomé, Togo

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**Abstract**
Heavy metals are released into the environment due to anthropogenic activities. Cement industries are classified among the main sources of environmental pollutants. This study aims to evaluate the ecological and human health risks of heavy metals in soils and leaves from the CIMTOGO cement factory area in Lomé, Togo. Samples were dried successively in open air and in oven at 105 °C for 24 hours. Samples ground and sieved were used in the analysis using a ZEEnit 700 atomic absorption spectrometer and Ion chromatograph IC 1500 Dionex. The amount of heavy metals in the samples as well as the pollution indices were investigated. High concentration of and Cadmium in the soil, and of chromium and lead in the leaves were found. High potential ecological risk index of 157.26 and 303.73 and the pollution load index of 1.02 and 1.39 were found for the soil and the leaf, respectively confirming the deterioration of the quality of the soil and leaves. The hazard index (0.86) closer to 1 indicates that the cement production activities could have harmful impacts on the health of the surrounding populations and the decision makers have to think about the decontamination of the area.

**Keywords**
*Cement factory, Heavy metal, Pollution indexes, Environmental monitoring, Togo*

## Introduction

Anthropogenic activities release heavy metals and constitute an environmental pollution sources that cause significant health issues (Wan et al., 2024). Due to the different natures and the toxic effects of heavy metals on living organisms, an environmental monitoring is crucial in the industrial activities area (Madhav et al., 2024). The emissions generated during the cement manufacturing depend on a number of factors such as the filtration and abatement system, the geographical configuration of the area, wind direction or speed, precipitations, etc. (Abatemi-Usman et al., 2023). Coal combustion and cement manufacture are two major sources of heavy metal emissions into the atmosphere (Mallongi et al., 2023; Jafari Jafari et al., 2023; Yetesha et al., 2023). Heavy metals released during the cement manufacture, can originate from raw materials, fuel and waste combustion, or during the clinkering process (Mallongi et al., 2023). Generally, the non-volatile metals (Cr, Cu, Mn, and Zn) remain within the clin-

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ker, while the semi-volatile (Pb, Cd) and volatile metals (Hg) can be spread by wind and can contaminate the air, water, soil and plants from the surrounding areas (Mallongi et al., 2023). Heavy metals represent an important category of pollutants because of their potential toxicity, high persistence and non-degradation (Abatemi-Usman et al., 2023; Fikadu & Mekassa, 2023). Bioaccumulation in plant tissues can induce metabolic disorders (Amiri et al., 2022). Toxic effect depends on metal type, concentration, exposure time, plants species or the presence of other elements (Parlak et al., 2023). Heavy metals have a negative impact on plants by interfering with several mechanisms like the soil nutrient uptake, photosynthesis, germination, cell division and growth (Angon et al., 2024; Park et al., 2023). The presence of heavy metals in the form of cations can compete with other cations in the soil that serve as essential nutrients for the plant (calcium, potassium, magnesium, etc.). These metals also would cause the decrease of chlorophyll concentration in acting on the photosynthesis processes (Amiri et al., 2022). Heavy metals are very toxic and have harmful effect on human health. It can be responsible of anemia, digestive disorders, chest burns, the mucous membranes and lung inflammation, skeleton and respiratory troubles and ulcers, irreversible damage to the kidneys and liver, lung and nasal cavity cancers and fibrosis of the lung, fever (Mallongi et al., 2023). Chronic exposure to heavy metals can cause irritation of affected areas including mucous membranes, nasal cavities, eyes, headaches and diarrhea and reproductive disorders (Mishra et al., 2022; Das et al., 2023). In Togo, one of the cement producing industries is CIMTOGO, which manufactures cement and is located in the center of Lomé, where the surrounding population are farming in garden and are doing other commercial activities due to the position of the Port of Lomé. Many studies (Dzagli et al., 2022; Hazou et al., 2021; Aduayi-Akue and Gnandi., 2014; Aduayi-Akue et al., 2015), were carried out on phosphate industries in Togo but not on cement factories. This study aims to assess the quality of soil and vegetation from the vicinity of the CIMTOGO industry in Togo through the monitoring of heavy metals contents and pollution indices using spectroscopic techniques. To do this, the mean concentration of heavy metals in the soil and leaves samples and the pollution indices from the study area were investigated using Flame Atomic Absorption Spectrometry and cathode lamps and the results were compared to the limit value of the international standard from World Health Organization (WHO). The results will be useful for estimating the possible impact of cement manufacturing on environmental quality and data can be useful for the authorities and decision makers concerning the existence of this factory in Lomé town.

## Materials and Methods

### Study area

The present study is carried out in the vicinity of a mass production industry of cement, CIMTOGO that uses clinker (1,700,000 tons/year from 2021) (CIMTOGO, 2024). CIMTOGO is almost lying in the capital, Lomé, Togo and is located at the latitude 6°9'8.69" N and the longitude 1°17'13.52" E, closed to the Port of Lomé. The climate is of type Guinean with four seasons: two dry seasons (November-March and August), and two rainy seasons (April-July and September – October). The average annual rainfall in south Togo is between 800 and 1200 mm/year. The average temperatures range from 24 °C to 32 °C (Badameli & Dubreuil, 2015). Relative humidity ranges is 80-90%. Geomorphological units are the sandy coast, the lagoon depression and the sandy clay plateau. Three main types of soils are hydromorphic soils, colluvial and alluvial (Grey) soils and non-hydromorphic soils on sandy clay. The soil in the area is ferralitic comprising a sandy clay texture (Atakpama et al., 2021; Worou, 2002; Worou et al., 2020). Sample's locations were shown on the figure 1. Workers, neighboring populations, and visitors of the Port of Lomé are exposed to dust from the industry.

### Sample collection

A random sampling was implemented to select soils and leaves in the area of CIMTOGO factory to assess

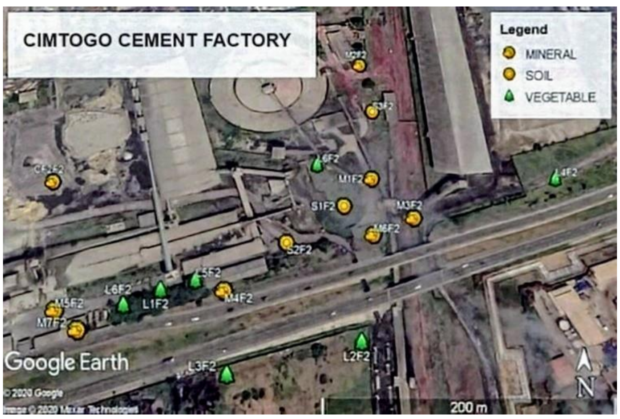


**Figure 1.** *The location of the study area showing samples positions*

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heavy metal contents and its impacts. Topsoil (0 – 10 cm depth) samples of 150 - 500 g were collected. Seventeen samples including eleven soils and six vegetation samples (leaves and grasses) as the positions are indicated in figure 1, using a clean stainless steel shovel. Leaves samples are made of edible leafy vegetables cultivated around the study area comprising *Brassica Oleracea*, *Lactuca Sativa*, *Vernonia Amygdalina*. The sampling points are chosen to cover the entire area closed to the industry and are marked by GPS readings. These sites included the diverse soil types, vegetation types and land use types. The samples are put into labeled polyethylene bags, well-sealed, before being transported to the laboratory where they were dried in open air, at ambient temperature, for two weeks. Macroscopic roots and organic material, with a diameter larger than 2 mm, are removed by sieving (Vittori Antisari et al., 2014).

**Chemicals and instrumentation**

All acids and reagents used in this study are of analytical reagent grade. Hydrochloric acid (37%) and nitric acid ($HNO_3$, 65%) and perchloric acid ($HClO_4$, 70%) are from Merck (Germany). The Memmert UNB 400 oven (Germany) is used to dry the soil samples at 105 $^oC$ for 24 hours. Samples are ground using a mortar and are sieved. Heavy metals analysis is performed using a ZEEnit 700 atomic absorption spectrometer with acetylene–air flame and cathode lamps at Babeş-Bolyai University, Faculty of Environmental Science and Engineering, ISUMADECIP, Cluj-Napoca, Romania.

**Quality assurance and control**

For quality assurance and control purposes, the stock solutions are prepared using individual standard solutions of Ni, Cd, Cr, Pb, Zn, Cu having a concentration of 1000 mg/l in $HNO_3$ (0.5 mol/l) and were used for metals calibration. A digest without the soil sample is made to remove incertitude relating to possible materials and method. High-purity water (0.055 µS/cm, 18.2 MΩ/cm) obtained from Ultra Clear TWF UV water system (SG GmbH, Germany) is used. All glass wares are acid-washed using nitric acid (10 %) before used. A method blank contained detectable concentrations of metals are used and these concentrations are subtracted from the sample concentration.

**Preparation of samples**

The soil samples were subjected to acid digestion method, the nitric-hydrochloric acid digestion (1:3, volume ratio), this method was adapted from those reported previously (ISO 11466, 1995;Uddin et al., 2016; Barbizzi et al., 2004; de Zorzi et al., 2005) for trace metal analyses in soil and leaf samples. For a homogeneous sample and to increase the efficiency of acid attack by increasing the surface area of the particles, soil samples were ground, using a mortar, to a size less than 150 µm. One hundred grams (100g) of ground soil was sieved using a 150 µm sieve according to references (ISO 11464, 2006; Vittori Antisari et al., 2014) before used to investigate the content of Cu, Cr, Cd, Zn, Ni, and Pb. Then, an amount of 3 g of dried and ground soil was transferred to a digestion vessel where 21 ml of hydrochloric acid (37%) and 7 ml of nitric acid (HNO3, 65%) were added successively (Roba et al., 2015). The mixture was left to stand for 16 hours at room temperature for a slow oxidation of the organic matter from the sample. Digested samples were filtered and the filtrate was collected in a volumetric flask. The volume was brought to 100 ml with $HNO_3$ (0.5%). Leaves samples were cleared and washed with distilled water, dried at 80 – 90 ºC for 15 to 30 minutes and then at 65 ºC for 12 to 24 hours (Vittori Antisari et al., 2015; Roba et al., 2016). Leaves samples were ground and sieved through a 0.5 mm sieve. All the samples were weighed before and after drying. The digestion method followed that developed by Roba et al. (2015, 2016). For each analysis, 3 g of sample was digested with 4 ml of nitric acid (65%) and 1 ml of perchloric acid (70%) until a transparent solution was obtained. The digested samples were then diluted to 50 ml volume and filtered. The clear supernatant was analyzed by FAAS. For each set of measures, one blank was prepared using the same procedure. The digestion was carried out in a well-ventilated fume hood.

**Statistical analysis**

A Pearson correlation analysis was conducted to evaluate the relationships between the different heavy metals in soils and leaves around the CIMTOGO factory.

**Determination of heavy metals in all samples**

In order to report the metal concentration as mg/kg in dried soil, the metal concentration from the soil extract was multiplied by the dilution and divided by the mass of dried soil/sediment as described by the equation [1]:

$$Metal\ concentration\ in\ soil\ \left(\frac{mg}{kg}\right) = \frac{metal\ concentration\ in\ extract\ \left(\frac{mg}{l}\right) \times 100\ ml}{soil\ mass\ (g)} \quad [1]$$

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### Heavy metal pollution assessment

Heavy metal pollution was assessed by indices including the contamination factor ($C_f$), the degree of pollution ($C_{deg}$), the potential ecological risk index (RI) and the pollution load index (PLI) (Swain, 2024; Devanesan et al., 2017; Mandeng et al., 2019). Contamination factor ($C_f$) concerned the amount of metal contamination in the soil, leaves or water and is given by the formula (equation [2]) and the degree of pollution characterizes the pollution status due to the different heavy metals (equation [3]). (Hakanson, 1980; Newaz et al., 2021).

$$C_f = \frac{C_i}{C_n} \qquad [2]$$

$$C_{\deg} = \sum C_f \qquad [3]$$

where, $C_i$ is the mean concentration of individual metal, and $C_n$ is the concentration of a reference value for individual metal. In this study, $C_n$ for soil and leaves were the limits values from WHO (WHO, 1998; FAO/WHO, 2018) and European Parliament and Council of the European Union (European Union, 2019). Ecological risk factor RI assesses the ecological risk of a heavy metal, and is related to the toxicity of metals and the response of the environment (equation [4]):

$$RI = \sum T_r C_f \qquad [4]$$

where $T_r$ represented the toxicity factor of heavy metal (Cd = 30, Ni = 5, Cu = 5, Pb = 5, Cr = 2 and Zn = 1).
Pollution load index (PLI) indicates the evolution of soil and plant pollution and is defined as (equation [5]) (Hakanson, 1980; Newaz et al., 2021):

$$PLI = \sqrt[n]{C_f^1 \times C_f^2 \times C_f^3 \times ......\times C_f^n} \qquad [5]$$

Geo-accumulation index (Igeo) is used to evaluate the degree of anthropogenic influence on the pollution levels and is defined as (equation [6]) (Olatunde et al., 2020).

$$I_{geo} = Log_2(\frac{C_i}{1.5C_n}) \qquad [6]$$

where $C_i$ is the concentration of the metal in the soil sample and $C_n$ is the concentration of a reference value for individual metal and the factor 1.5 related to the impact of changes in background values. Contamination classes are based on the increasing numerical value of this index (Huu et al., 2010). The values of these indices with their associated interpretations are presented in the Table 1 (Hakanson, 1980; Newaz et al., 2021 ; Calmuc et al., 2021).

**Table 1.** *Contamination factor, degree of contamination, potential ecological risk index, geo-accumulation index, and Pollution load index categories and interpretation*

| Indices | Values | Interpretation |
|---|---|---|
| $C_f$ | $C_f < 1$ | Low contamination |
| | $1<C_f<3$ | Moderate contamination |
| | $3< C_f <6$ | Considerable contamination |
| | $C_f > 6$ | Very high contamination |
| $C_{deg}$ | $C_{deg} < 8$ | Low degree of contamination |
| | $8< C_{deg} <16$ | Moderate degree of contamination |
| | $16 <C_{deg} <32$ | Considerable degree of contamination |
| | $C_{deg} > 32$ | Very high degree of contamination |
| RI | RI < 150 | Low potential ecological risk. |
| | 150 < RI < 300 | Moderate potential ecological risk. |
| | 300 < RI < 600 | Considerable potential ecological risk. |
| | RI > 600 | Very high ecological risk |
| PLI | PLI < 1 | Denote perfection |
| | PLI =1 | Only baseline levels of pollution |
| | PLI > 1 | Deterioration of soil quality |
| $I_{geo}$ | $I_{geo}< 0$ | unpolluted |
| | $0<I_{geo}<1$ | unpolluted to moderately polluted |
| | $1<I_{geo}<2$ | moderately polluted |
| | $2<I_{geo}<3$ | moderately to strongly polluted |
| | $3<I_{geo}<4$ | strongly polluted |
| | $4<I_{geo}<5$ | strongly to very strongly polluted |
| | $I_{geo} \geq 5$ | very strongly polluted |

### Health risk assessment

The hazard quotient characterizes the non carcino-gennic adverse effects that corresponds to the ratio of average daily intake (ADI) and reference dose (RfD) due to exposure to the heavy metal in the soil based on the method developed as follows (Yetesha et al.,

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2023; Gebreyohannes & Gebrekidan, 2018; IRIS, 2003; Silambarasan et al., 2012):

$$HQ = \frac{ADI}{RfD} \quad [7]$$

where RfD is the reference doses that correspond to an estimated exposure of heavy metal to the human body per day without harmful effect during life time (Yang and Liu, 2012).

The value of reference doses (RfD) (mg/kg/day) for the heavy metals used in the present work were those from references (Yetesha et al., 2023; Gebreyohannes & Gebrekidan, 2018) (Cr-1.50; Ni-0.02; Cu-0.04; Zn-0.30; Cd-0.001 and Pb-0.004). Human beings are safe for the hazard quotient less than 1(IRIS, 2003). Daily intake (ADI) of metals is calculated using the equation [8] (Yetesha et al., 2023):

$$ADI = \frac{C_i \times C_{factor} \times D}{BW} \quad [8]$$

where: $C_i$ is the heavy metal concentrations in plants (mg/kg), $C_{factor}$ is the conversion factor to convert fresh vegetable weight to dry weight (0.085), D is the daily intake of vegetables estimated at 0.2 kg/day (Gebreyohannes & Gebrekidan, 2018) and BW is an average body weight (65 kg) (Yetesha et al., 2023). The potential risk of adverse health effects from a mixture of chemical elements in the samples was assessed using the hazard index (HI) as the sum of HQ (Gebreyohannes & Gebrekidan, 2018):

$$HI = \sum HQ \quad [9]$$

## Results and discussion

### Heavy metals average concentration in the soil and leaf samples

The average amount of heavy metals analyzed in the soil and leaf samples from the study area is presented in table 2 with comparison with studies from other countries. The results are compared with the WHO standard limits (WHO, 1998; FAO/WHO, 2018) and European Union (EU) legislation (European Union, 2019) and with those from others areas in West Africa. The average content obtained for the metals in the samples at CIMTOGO followed the abundance Zn > Cr > Ni > Pb > Cu > Cd and Zn > Cu > Pb > Ni > Cr > Cd for soil and vegetation, respectively.

**Table 2:** *Comparison of heavy metals concentrations in the soil and leaf of CIMTOGO with studies from other countries*

| Samples | Locations | Zn | Cr | Cd | Ni | Pb | Cu | References |
|---|---|---|---|---|---|---|---|---|
| Soil (mg/kg) | CIMTOGO | 136.19 ±63.46 | 78.52 ±31.55 | 3.6 ±1.97 | 40.60 ±26.64 | 37.36 ±18.23 | 27.24 ±7.42 | Present study |
| | Nigeria | 213.64 | 35.6 | 0.76 | 5.13 | 35.43 | 41.63 | Olatunde et al., 2020; Laniyan & Adewumi, 2020 |
| | Ghana | 35.02 | 961.24 | - | 245.26 | 13.13 | 27.97 | Addo et al., 2012 |
| | Limits | 300 | 2 | 1.5 | 50 | 120 | 300 | FAO/WHO, 2018; Olatunde et al., 2020 |
| Leaf (mg/kg) | CIMTOGO | 48.65 ±13.43 | 3.71 ±1.43 | 1.01 ±0.12 | 3.15 ±0.92 | 6.71 ±1.45 | 10.85 ±2.55 | Present study |
| | Nigeria | 137.87 | 30.62 | 0.02 | 3.77 | 15.46 | 26.52 | Laniyan & Adewumi, 2020; Adejoh et al., 2016 |
| | Ghana | 66.77 | 238.75 | - | 11.67 | 6.02 | 23.8 | Addo et al., 2012 |
| | Limits | 100 | 0.19 | 0.2 | 50 | 0.3 | 100 | FAO/WHO, 2018; European Union, 2019 |

The average concentrations of zinc in the soil and leaves samples are found less than the permissible limit set by WHO (UNEP, 2001). Work performed by Laniyan and Adewumi, (2020) in the Cement Production of Ewekoro, Southwest Nigeria showed higher concentration of Zn than the values obtained in the soil and leaves at CIMTOGO. Addo et al., (2012) assessed the Zn content in the vicinity of a Cement Factory in the Volta Region (Ghana), which revealed higher concentrations for soil and vegetation.

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Chromium average concentrations in soil near CIMTOGO factory is found very much higher than the permissible limit set by European legislation (European Union, 2019). The average concentrations of chromium in the leaves collected from CIMTOGO is higher than the permissible limit set by WHO (WHO, 1988). High concentration of Cr was obtained by Laniyan and Adewumi, (2020) in their study for the soil and the leaves. Cadmium average concentrations in the soils of the CIMTOGO area is found exceeded the permitted limit set by European legislation (European Union, 2019). The average concentration in the leaves in the study area is of below the WHO permissible limit (FAO/WHO, 2018). The presence of the Cadmium in the soil and leaves constitutes a real danger for human health and the environment in this area. Crops and vegetables should be intensively monitored and agriculture must be forbidden in this area. The findings by Adejoh et al., (2016) for the cadmium in the soil and leaves in the vicinity of a cement factory in north central, Nigeria are lower than the values at CIMTOGO (Etim et al., 2021). Nickel average concentrations for soil and leaves in the CIMTOGO area are below the European legislation limits (European Union, 2019). Nevertheless, the monitoring of the level of this metal in Togo would be useful to avoid health and environmental issues. Laniyan and Adewumi, (2020) found in the Cement Production of Ewekoro (Nigeria) for Nickel lower values in the soil and leaves. The average concentrations of lead in the soil at CIMTOGO is found below the permissible limit of European legislation (European Union, 2019) and the one in the leaf samples is higher than the permissible limit of WHO (FAO/WHO, 2018). The monitoring of lead in a cement industry in Ghana by Addo et *al* .(2012) gave a lower value than the one found in the soil and in the leaf in the present study. The copper average concentrations in the soils and leaves in the CIMTOGO area are lower than the WHO permissible limit (WHO, 1991). Similar findings for copper were obtained in soil by Addo et *al.* (2012) while the copper amount in vegetation is slightly higher (Laniyan and Adewumi, 2020) compared to the results in the present study. From the average concentrations, the heavy metals presence could be associated with (i) the raw material, which storage is open air and its dusts can be deposited and retained in the soil and leaf, (ii) the cement production itself and (iii) attendant vehicular traffic and emissions (Olatunde et al., 2020; Adejoh, 2016; Adedeji et al., 2020). Also, CIMTOGO is closer to the Port of Lomé and to the international road $N_2$ (Lomé – Cotonou). Further accumulation of heavy metals such as Cr, Pb and Cd in the edible leaves in the area must be prevented through other investigations and regulations.

**Correlation between heavy metals within CIMTOGO samples**

The relationship between the investigated heavy metals in the soils and leaves around CIMTOGO is carried out and the correlation coefficients are presented in table 3. Positive coefficients are found for all pairs of heavy metals in the present study except between Zn and Cd. So, the content levels of these heavy metals in the samples are related one to another. It is also known that strong positive correlation coefficients would be obtained between heavy metals from the same sources, while poor or no correlation indicates that these metals are from different origins. Higher correlation with significance

| Soils | Zn | Cr | Cd | Ni | Pb | Cu |
|---|---|---|---|---|---|---|
| Zn | 1.0000 | 0.2236 | -0.1565 | 0.0826 | 0.2331 | 0.4283 |
| Cr | 0.6664 | 1.0000 | **0.8029** | **0.9296*** | **0.8109** | **0.6019** |
| Cd | 0.6856 | **0.9602**** | 1.0000 | **0.7617** | **0.8637** | 0.2463 |
| Ni | **0.7449** | **0.9145** | **0.8098** | 1.0000 | **0.8055** | **0.6774** |
| Pb | **0.8296** | **0.7813** | **0.7603** | **0.9043** | 1.0000 | **0.5006** |
| Cu | 0.6295 | 0.6120 | **0.7041** | 0.3974 | 0.3656 | 1.0000 |
| Leaves | Zn | Cr | Cd | Ni | Pb | Cu |

**Table 3**
*Correlation coefficients for metals in soils and leaves around CIMTOGO (Lomé)*

*Note:*
** Correlation is significant at the 0.00003 level (2-tailed)*
*** Correlation is significant at the 0.002 level (2-tailed)*

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($p < 0.00003$) (values in bold in table 3) were observed between most of heavy metals as Cr, Cd, Ni, Pb in the soil while the lowest one (-0.1565) was found between Zn and Cd. The concerned heavy metals in this study area would be from a common sources. But the weak correlation between Zn and other heavy metals indicated that Zn in soils would be from different source especially from natural sources. The presence of Cd in the soil could be related to the emissions from cement production because it has been reported that Cd is often released from the raw materials (Ogunkunle & Fatoba, 2014). The presence of Cr and Zn in the soil could be attributed to the long years of operation of CIMTOGO as this factory has been in operation since 1969 and is still in full operation (1,700,000 tons/year since 2021). But the poor correlation (0.2236) indicates that Cr and Zn are not from the same pollution source and these heavy metals could be supposed to be released from industrial activities. The presence of Pb could be related to automobile emissions and petrol engine discharges because many trucks are involved in transporting raw materials and finished cement products. The correlation analysis pointed out natural and external contributions for the presence of heavy metals in the environment of the study area (Olatunde et al., 2020). There exists strong correlations with-significance ($p < 0.002$) between heavy metal contents (Cr, Cd, Ni, Pb) in the leaves. The results show positive coefficients that indicates that the heavy metals would be from the same sources with the atmospheric deposition as important source.

**Heavy Metal Pollution Assessment – Pollution indices**

Pollution evaluation indices calculated are shown in table 4. The values of the contamination factor $C_f$ for Zn in soil and leaves are lower than 1, which correspond to low Zn contamination. The chromium contamination factor $C_f$ for soil and leaves are greater than 6 which corresponds to a very high chromium contamination. Regular monitoring to protect human health and the environment becomes crucial because the presence of this element in leaves in the study area poses a great health and environmental issues. The contamination factors of cadmium values correspond to a moderate contamination in the soil and considerable in leaves in the area. The contamination factors for Ni correspond to a low contamination of Nickel in the area. The lead contamination factors obtained are 0.31 in the soil and 22.37 in leaves. These values correspond to a low lead contamination in the soil and very high lead contamination in leaves of plants.

**Table 4.** *Pollution indices on CIMTOGO site*

| Samples | $C_{deg}$ | RI | PLI | | Zn | Cr | Cd | Ni | Pb | Cu |
|---|---|---|---|---|---|---|---|---|---|---|
| Soil | 43.36 | 157.35 | 1.02 | **Cf** | 0.45 | 39.27 | 2.41 | 0.81 | 0.31 | 0.11 |
| Leaf | 47.60 | 303.73 | 1.39 | **Cf** | 0.49 | 19.53 | 5.05 | 0.06 | 22.37 | 0.11 |
| Soil | | | | **Igeo** | -1.74 | **4.71** | **0.68** | -0.89 | -2.27 | -3.77 |
| Leaf | | | | **HQ** | 4.2E-2 | 6.5E-4 | 2.6E-1 | 4.1E-2 | 4.4E-1 | 7.1E-2 |
| Leaf | | | | **HI** | 0.86 | | | | | |

The high contamination in leaves may result from dust deposition from industries and traffics (Adejoh, 2016). The surrounding areas would not be used for farming leafy vegetables and the decision makers must monitor the lead contamination. The copper contamination factors for the area are lower than 1, corresponding to a low copper contamination in the area. The degree of pollution of heavy metals for the soil in the area is 43.36 higher than 32 corresponding to a very high degree of contamination. The potential ecological risk index is 157.26, ranges between 80 and 160 corresponding to a medium ecological risk potential of the area. The pollution load index is 1.02, greater than 1 showing a slightly polluted soil (Devanesan et al., 2017; Mandeng et al., 2019). For the leaves in the area the degree of pollution for heavy metals is 47.6 higher than 32 corresponding to a very high degree of contamination in the leaf samples. The potential ecological risk index is 303.73, a value between 160 and 320 corresponding to a very high potential ecological risk. The pollution load index is 1.39 greater than 1 and corresponding to a progressive deterioration of the quality of the plant leaf in the CIMTOGO area and its surroundings (Devanesan et

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al., 2017; Mandeng et al., 2019). I-geo results in this study presented negative indices (Table 4) indicate that the Cu, Pb, Ni and Zn are unpolluted metals. Igeo value of Cd (0.68) indicates that Cd is unpolluted to moderately polluted in the study area. However, Cr Igeo value (4.71) indicate strongly to very strongly contamination in the soil. The values of $C_f$ and Igeo are found greater for Cr that corresponds to a contamination related to anthropogenic origin and this metal is posing the most ecological risk. A considerable ecological risk exists in the study area based on the indices due to the presence of Cd, Cr, Pb and Zn in soils. The cement manufacture and anthropogenic activities associated with natural processes are responsible of the main presence of these heavy metals (Liu & Wang, 2024; Ogunkunle & Fatoba, 2014; Ismail et al., 2023).

**Health risk assessment of heavy metals in soil**

Tables 4 presents the Hazard quotient (HQ) and the Hazard Index (HI) estimated in the study area. The HQ and HI values are lower than the permissible limits of 1 and show that these heavy metals may not cause adverse health effects for adults. Hence, from these preliminary findings of assessment, of heavy metal contents must be more investigated in leaves in the vicinity of CIMTOGO or in other facto-ries for health risk assessment.

## Conclusions

In this study, heavy metals contents are investigated in soil and leaf samples from CIMTOGO industry in the capital of Togo, Lomé. Higher amounts for heavy metals in soil and plant leaves are obtained. The amount of Cr and Cd in the soil exceeded the permissible standard limit. In the leaves, the average concentrations of Cr, Cd and Pb are found above the permissible limit. This work show very high potential ecological risk in the soil and the leaves in the area. Studies are still needed to avoid adverse effects on health and the environment in the future because the hazard index obtained is closer to the limit. Pollution indices values showed that heavy metals may be originated from activities of the factory. Actions must be made to reduce the pollution status like to design an environmental plan of constant monitoring of heavy metals in the area. As new cement factoy were built in the country, CIMTOGO in Lomé must manage its production activities. The present findings are a useful information concerning the heavy metals pollution in Togo and the adverse effects of cement factories on human and environment

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that would influence this paper.

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## References

ABATEMI-USMAN S., AKINDELE O., AYANLADE A., PEREZ M., ATTAHIRU I., NORTON G., FELDMANN J., KRUPP E. (2023) Trace element concentrations in soil contaminate corn in the vicinity of a cement manufacturing plant: Potential health implications. Journal of Exposure. Science and Environmental Epidemiology, 33(5):813-823. https://doi.org/10.1038/s413 70-023-00548-8

ADDO M.A., DARKO E.O., GORDON C., NYARKO B.J.B, GBADAGO J.K., NYARKO E., AFFUM H.A., BOTWE B.O. (2012) Evaluation of Heavy Metals Contamination of Soil and Vegetation in the Vicinity of a Cement Factory in the Volta Region Ghana. International Journal of Science and Technology, 2(1):40-50.

ADEDEJI S.A. , KAKULU E. S., DAUDA S. M., AKANNAM O. P. (2020) Heavy Metal Pollution in Soil Samples obtained from some communities around a cement factory in Obajana Kogi State Nigeria. Journal of Environmental Science and Public Health, 4:161-174. https://doi.org/I:10.26502/ jesph.96120092

ADEJOH I.P. (2016) Assessment of heavy metal contamination of soil and cassava plants within the vicinity of a cement factory in north central Nigeria. Advances in Applied Science Research, 7(3):20-27.

ADUAYI-AKUE A.A., GNANDI K. (2014) Evaluation de la pollution par les métaux lourds des sols et de la variété locale du maïs Zea mays dans la zone de traitement des phosphates de Kpémé (Sud du Togo). International Journal of Biological and Chemical Science, 8(5):2347-2355. https://doi.org/10.4314/ijbcs.v8i5.37

DOI: 10.6092/issn.2281-4485/19712

ADUAYI-AKUE A.A., GNANDI K., TETE-BENISSAN A., DEGBE M., TANOUAYI G., GBEASSOR F. (2015) Evaluation des teneurs des métaux lourds dans le sang des sujets de la zone de traitement des phosphates au Sud du Togo. International Journal of Biological and Chemical Sciences, 9(4):1972-1982. https://doi.org/10.4314/ijbcs.v9i4.22

AKPAMBANG V. O. E., EBUZEME G. C., AKINOLA J. O. (2022) Heavy metal contamination of topsoil around a cement factory – A case study of Obajana Cement Plc. Environmental Pollutans and Bioavailability, 34(1):12–20. https://doi.org/ 10.1080/26395940.2021.2024090

AMIRI H., DANESHVAR E., AZADI S., AZADI S. (2022) Contamination level and risk assessment of heavy metals in the topsoil around cement factory: A case study. Environmental Engineering Research, 27(5):210313. https://doi.org/10. 4491/eer.2021.313

ANGON P. B. ISLAM M. S. KC S. DAS A. ANJUM N. POUDEL A. & SUCHI S. A. (2024). Sources effects and present perspectives of heavy metals contamination: Soil plants and human food chain. Heliyon, 10:e28357. https://doi.org/10.1016/j.heliyon.2024.e28357

ATAKPAMA W., KANDA M., FOLEGA F. LAMBONI D. T. BATAWILA K. AKPAGANA K. (2021) Agriculture urbaine et périurbaine dans la ville de Lomé et ses banlieues. Revue Marocaine des Sciences Agronomique and Vétérinaires., 9(2):205-211.

BADAMELI A., DUBREUIL V. Diagnosis of climate change in Togo through the evolution of temperature between 1961 and 2010. (2015) Proceedings of the XXVIII$^{th}$ Symposium of the International Association of Climatology Liège Belgium, 421-426.

BARBIZZI S., DE ZORZI P., BELLI M., PATI A. SANSONE U., STELLATO L., BARBINA M., DELUSA A., MENEGON S., COLETTI V. (2004) Characterization of reference site for quantifying uncertainties related to soil sampling. Environmental Pollution, 127:131–135. https://doi.org/10. 1016/S0269-7491(03)00236-7

CALMUC V.A., CALMUC M., ARSENI M., TOPA C.M., TIMOFTI M., BURADA A., ITICESCU C., GEORGESCU L.P. (2021) Assessment of Heavy Metal Pollution Levels in Sediments and of Ecological Risk by Quality Indices. Applying a Case Study: The Lower Danube River Romania. Water, 13(12):1801. https://doi.org/10. 3390/w13131801

CIMTOGO (2024) https://www.heidelbergcement.tg/fr/cimtogo Accessed on July 10$^{th}$, 2024.

DAS D., HASAN M., HOWLADAR M.F. (2023) Topsoil heavy metals status and potential risk assessment around the cement factories in Chhatak Bangladesh. Environment, Development and Sustainability, 25:5337–5362. https://doi.org/ 10.1007/s10668-022-02269-8

DE ZORZI P., BARBIZZI S., BELLI M., CICERI G., FAJGELJ A., MOORE D. , SANSONE U., VAN DER PERK M. (2005) Terminology in soil sampling (IUPAC Recommendation 2005). Pure and Applied Chemistry, 5(77):827–841. https://doi.org/10.1351/pac200577050827

DEVANESAN E., GANDHI S.M., SELVAPANDIYAN M., SENTHILKUMAR G., RAVISANKAR R. (2017) Heavy metal and potential ecological risk assessment in sediments collected from Poombuhar to Karaikal Coast of Tamilnadu using Energy Dispersive X-ray fluorescence (EDXRF) technique. Beni-Suef. University Journal of Basic and Applied Sciences, 6(3):285-292. https://doi.org/10. 1016/j.bjbas.2017.04.011

DZAGLI M.M., AMOUZOUVI Y.M., SESIME K., AFOUDJI K.B.R. (2022) Heavy metal pollution assessment in phosphate mining and processing sites Hahotoé and Kpémé in Togo. EQA-International Journal of Environmental Quality, 47:9–21. https://doi.org/10.6092/issn.2281-4485/13435

ETIM M.-A., BABAREMU K., LAZARUS J., OMOLE D. (2021) Health Risk and Environmental Assessment of Cement Production in Nigeria. Atmosphere, 12:1111. https://doi.org/10.3390/atmos12091111

EUROPEAN PARLIAMENT AND COUNCIL OF THE EUROPEAN UNION. (2019) Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilizing products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003. Official Journal of the European Union, L 170/1.

FAO/WHO (2018) Joint FAO/WHO Food Standards Programme Codex Committee on Contaminants in Foods 12th Session Utrecht, The Netherlands.

FIKADU T., MEKASSA B. (2022) Determination of Heavy Metals in Cement Dust Top Soil and Teff Around Habesha and Mugher Cement Factory Oromia Regional State Ethiopia. Bulletin of the Chemical Society of Ethiopia, 36(3):487-501. https://doi.org/10.4314/bcse.v36i3.1

GEBREYOHANNES F., GEBREKIDAN A. (2018) Health risk assessment of heavy metals via consumption of spinach vegetable grown in Elalla River. Bulletin of the Chemical Society of Ethiopia, 32(1):65-75. https://doi.org/10.4314/bcse.v32i1.6

HAKANSON L. (1980) Ecological risk index for aquatic pollution control. A sedimentological approach. Water Research, 14:975-1001. https://doi.org/10.1016/0043-1354(80)90143-8

DOI: 10.6092/issn.2281-4485/19712

HAZOU, E. ZORKO B., NEČEMER M., HALIBA E. M., AZIABLE E., GUEMBOU SHOUOP C.J., TCHAK PELE K.P. (2021) Heavy Metal Pollution Assessment Using Energy-Dispersive X-ray Fluorescence and Multivariate Statistical Approach of Soil from Phosphate Ore Sites Southern Region of Togo. Water, Air and Soil Pollution, 232:489. https://doi.org/10.1007/s11270-021-05439-y

HUU H.H., RUDY S., VAN DAMME A. (2010) Distribution and contamination status of heavy metals in estuarine sediments near Cau Ong harbor Ha Long Bay Vietnam. Geologica Belgica, 13:37-47.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (1995) Soil Quality –Extraction of trace elements soluble in aqua regia, ISO 11466, Geneva Switzerland.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (2006) Soil quality - Pretreatment of samples for physico-chemical analysis. ISO 11464, Geneva Switzerland.

IRIS - Integrated Risk Information System (2003) China via consumption of vegetables and fish. Science Database US Envrionmental Protection Agency, USA.

ISMAIL Z., ALI S., ZULFIQAR A., EL-SEREHY H. A. (2023) Impact of cement industries on potentially toxic elements' contamination and other characteristics of topsoil: A case study. Environmental Pollution and Bioavailability, 35(1):2271664. https://doi.org/10.1080/26395940.2023.2271664

JAFARI A., ASADYARI S., MOUTAB SAHIHAZAR Z., HAJAGHAZADEH M. (2023) Monte Carlo-based probabilistic risk assessment for cement workers exposed to heavy metals in cement dust. Environmental Geochemistry and Health, 45:5961–5979. https://doi.org/10.1007/s10653-023-01611-x

LANIYAN T.A., ADEWUMI A.J.P. (2020) Evaluation of Contamination and Ecological Risk of Heavy Metals Associated with Cement Production in Ewekoro Southwest Nigeria. Journal of Health and Pollution, 10(25):200306. https://doi.org/10.5696/2156-9614-10.25.200306

LIU T., WANG Z. (2024) Contamination and health risk assessment of heavy metals in soil surrounding an electroplating factory in JiaXing China. Scientific Reports, 14:4097. https://doi.org/10.1038/s41598-024-54620-w

MADHAV S., MISHRA R., KUMARI A., SRIVASTAV A. L. AHAMAD A., SINGH P., AHMED S., MISHRA P. K., SILLANPÄÄ M. (2024) A review on sources identification of heavy metals in soil and remediation measures by phytoremediation-induced methods. International Journal of Environmental Science and Technology, 21:1099–1120. https://doi.org/10.1007/s13762-023-04950-5

MALLONGI A., STANG S., ASTUTI R.D.P., RAUF A.U., NATSIR M.F. (2023) Risk assessment of fine particulate matter exposure attributed to the presence of the cement industry. Global Journal of. Environmental Science and Management, 9(1):43-58. https://doi.org/10.22034/gjesm.2023.01.05

MANDENG E.P.B., BIDJECK L.M.B., BESSA A.Z.E., NTOMB Y.D., WADJOU J.W., DOUMO E.P.E, BITOM DIEUDONNÉ L. (2019) Contamination and risk assessment of heavy metals and uranium of sediments in two watersheds in Abiete-Toko gold district Southern Cameroon. Heliyon, 5:e02591. https://doi.org/10.1016/j.heliyon.2019.e02591

MISHRA U.C., SARSAIYA S., GUPTA A. (2022) A systematic review on the impact of cement industries on the natural environment. Environmental Science and Pollution Research, 29:18440–18451. https://doi.org/10.1007/s11356 -022-18672-7

NEWAZ K.K., PAL S.K., HOSSAIN S., KARIM A. (2021) Evaluation of heavy metal pollution risk associated with road sediment. Environmental Engineering Research, 26(3):200239. https://doi.org/10.4491/eer.2020.239

OGUNKUNLE C.O., FATOBA P.O. (2014) Contamination and spatial distribution of heavy metals in topsoil surrounding a mega cement factory. Atmospheric Pollution Research, 5(2):270-282. https://doi.org/10.5094/APR.2014.033

OLATUNDE K.A., SOSANYA P.A., BADA B.S., OJEKUNLE Z.O., ABDUSSALAAM S.A. (2020) Distribution and ecological risk assessment of heavy metals in soils around a major cement factory Ibese Nigeria. Scientific African, 9:e00496. https://doi.org/10.1016/j.sciaf.2020.e00496

PARK E. J., YANG M. J., KANG M. S., JO Y. M., YOON C., LEE Y., KIM D. W., LEE G. H., KWON I. H., KIM J. B. (2023) Subchronic pulmonary toxicity of ambient particles containing cement production-related elements. Toxicology Reports, 11:116-128. https://doi.org/10.1016/j.toxrep.2023.07.002

PARLAK M., EVEREST T., TUNÇAY T. (2023) Spatial distribution of heavy metals in soils around cement factory and health risk assessment: a case study of Canakkale-Ezine (NW Turkey). Environmental Geochemistry and Health, 45(7):5163–5179. https://doi.org/10.1007/s10653-023-01578-9

ROBA C., ROŞU C., PIŞTEA I. OZUNU A., BACIU C. (2016) Heavy metal content in vegetables and fruits cultivated in Baia Mare mining area (Romania) and health risk assessment. Environmental Science and Pollution Research, 23:6062–6073. https://doi.org/10.1007/s11356-015-4799-6

DOI: 10.6092/issn.2281-4485/19712

ROBA C., ROŞU C., PIŞTEA I., BACIU C., COSTIN D., OZUNU A. (2015) Transfer of Heavy Metals from Soil to Vegetables in a Mining/Smelting Influenced Area (Baia Mare – Ferneziu, Romania). Journal of Environmental Protection and Ecology, 16(3):891–898

SILAMBARASAN K., SENTHILKUMAAR P., VELMURUGAN K. (2012) Studies on the distribution of heavy metal concentrations in River Adyar Chennai Tamil Nadu. European Journal of Experimental Biology, 2:2192-2198.

SWAIN C.K. (2024) Environmental pollution indices: a review on concentration of heavy metals in air water and soil near industrialization and urbanisation. Discover Environment, 2:5. https://doi.org/10.1007/s44274-024-00030-8

UDDIN A.H., KHALID R.S., ALAAMA M., ABDUALKADER A. M., KASMURI, A., ABBAS S.A. (2016) Comparative study of three digestion methods for elemental analysis in traditional medicine products using atomic absorption spectrometry. Journal of Analytical Science and Technology, 7:6. https://doi.org/10.1186/s40543-016-0085-6

UNITED NATIONS ENVIRONMENT PROGRAM. (2001) World Health Organization and International Labour Organization. Zinc-Environmental Health Criteria 221, Geneva.

VITTORI ANTISARI L., BIANCHINI G., DINELLI E., FALSONE G., GARDINI A., SIMONI A., TASSINARI R., VIANELLO G. (2014) Critical evaluation of an intercalation project focused on the definition of new multi-element soil reference materials (AMS-MO1 and AMS-ML1). EQA-International Journal of Environmental Quality, 15:41-60. https://doi.org/10.6092/issn.2281-4485/4553

VITTORI ANTISARI L., ORSINI F., MARCHETTI L., VIANELLO G., GIANQUINTO G. (2015) Heavy metal accumulation in vegetables grown in urban gardens. Agronomy for Sustainable Development, 35(3):1139-1147. https://doi.org/10.1007/s13593-015-0308-z

WAN Y., LIU J., ZHUANG Z., WANG Q., LI H. (2024) Heavy Metals in Agricultural Soils: Sources Influencing Factors and Remediation Strategies. Toxics., 12(1):63. https://doi.org/10.3390/toxics12010063

WHO - WORLD HEALTH ORGANIZATION (1988) Chromium-Environmental Health Criteria 61, Geneva

WHO - WORLD HEALTH ORGANIZATION (1991) Environmental Health Criteria 108. Nickel, Prepared as a Part of WHO's International Programme on Chemical Safety, World Health Organization: Geneva Switzerland, p. 383.

WHO – WORLD HEALTH ORGANIZATION (1998) Copper Environmental Health Criteria 200. International Program on Chemical Safety, Geneva

WOROU K. (2002) Sols dominants du Togo – corrélation avec la Base de référence mondiale. In Quatorzième Réunion du Sous-Comité Ouest et Centre Africain de Corrélation des Sols pour la Mise en Valeur des Terres (Abomey, Bénin, 9-13 octobre 2000), Rapport sur les ressources en sols du monde, FAO, 98,105-120.

WOROU K., GOOSSE H., FICHEFET T., GUICHARD F., DIAKHATE M. (2020) Interannual variability of rainfall in the Guinean Coast region and its links with sea surface temperature changes over the twentieth century for the different seasons. Climate Dynamics, 55:449–470. https://doi.org/ 10.1007/s00382-020-05276-5

YANG T., LIU J. (2012) Health risk assessment and spatial distribution characteristic on heavy metals pollution of Haihe River Basin. Journal of Environmental and Analytical Toxicology, 2:152. https://doi.org/10.4172/2161-0525.1000152

YETESHA A., CHANDRAVANSHI B. S., YOHANNES W. (2023) Major and Heavy Metals Contents and Health Risk Assessment of Pumpkin Peel Flesh and Seed by Microwave Plasma-Atomic Emission Spectroscopy Bulletin of the Chemical Society of Ethiopia, 37(3):533-551. https://doi.org/10. 4314/bcse.v37i3.1