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# Health Risks Assessment of Heavy Metals in Indoor and Outdoor Air Measured with x-ray Fluorescence

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**Abstract**

There are many growing concerns about environmental pollution and public health issues associated with surrounding heavy metals. Heavy metals are constantly emitted into the environment (indoor and outdoor) and pose a major threat to human health, the threat is linked to the presence of Cr, Cu, Ni, Pb, Cd, and Zn in dust, which consists of mineral and organic particles originating from the soil, industrial emitters, motor vehicles, and fuel consumption or other sources indoor like cooking, cigarettes etc. The present study aimed to investigate the potentially toxic metal (Zn, Fe, Cr, Ni, and Cu). Air dust samples were collected from indoor and outdoor air at El-Minia City, Egypt. Heavy metals concentrations were performed using X-ray fluorescence (WDX). Human health risk of the measured heavy metals concentration was evaluated. The concentrations of heavy metals were found higher outdoor than indoor except Cu concentration was higher in indoor (25010±3751.5 mg $kg^{-1}$) compared to outdoor (50±7.5 mg $kg^{-1}$). The results show a widespread heavy metal contamination, especially Cu and Fe, which were present as the highest values in indoor and outdoor dust, while Sr was the lowest content. Indoor and outdoor concentration ratios varied widely from one metal to another. A contamination factor is used to explain the originality of the measured heavy metals. The non-carcinogenic risk was assessed for adults and children via dermal contact route with order. In addition, non-cancerogenic risk values for heavy metals in El-Minia are not significant. Where, the calculated Hazard quotient ($HQ_{dermal}$) value was lower than the acceptable $HQ_{dermal}$ value of 1 indicating no significant non-cancer risk to the people from exposure to these heavy metals at present.

*Keywords:* Public health; WDX; toxic metal; Hazard quotient

## 1. Introduction

As a result of rapid population growth and major infrastructure development, the urban environment has been subjected to significant stress, especially chemical contamination of certain components of the urban landscape. In recent years, dust of roofs of buildings, roads and driveways have attracted considerable attention due to the ease of sampling of sedimentary material and its ability to act as an indicator of urban pollution levels [1–3]. Potentially harmful elements (PHEs) are considered one of the most dangerous pollutants that pose a threat for public health [4–7]. Several studies were conducted on the health risk assessment either non-carcinogenic or carcinogenic[8,9]. Human can be exposed to the PHEs in the dust through ingestion, inhalation and direct dermal contact [9]. The ingestion is the most important pathway that can cause health problems in the human body [10–12]. The exposure to dust can be associated with health risk that depends on various variables including toxicity and concentration of certain PHE, the time of year and human age [12–14]. Children are particularly sensitive to the effects of environmental pollution as a result of intensive body growth and relatively weak metabolic and elimination capabilities [15].

The present study aimed to investigate the potentially toxic metal (Zn, Fe, Cr, Ni, and Cu) in indoor and outdoor air at El-Minia City, Egypt. Heavy metals concentrations were performed using X-ray fluorescence (WDX). Human health risk of the measured heavy metals concentration was evaluated.

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## 2. Materials and methods

The study includes both outdoor and indoor measurements in El-Minia Governorate, Egypt. Fig. 1 shows El-Minia Governorate map. Indoor measurements were performed in El-Minia University, 10 meter above the ground level (environmental radiation Lab) at physics department. The surface area of the Lab is about 50 $m^2$. The sampling time is six hour. The university is located in the middle of El-Minia city in Upper Egypt [16,17].

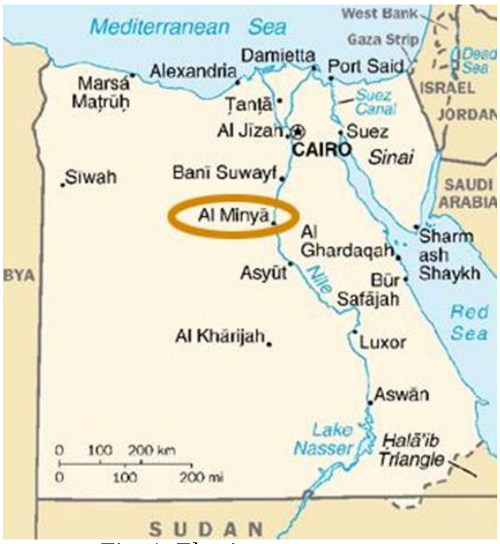

Fig. 1. El-mina governorate map.

### *2.1. Sampling and analysis*

Total particulate suspended matter has been sampled with high volume impactor (General Metal Works, Sierra Impactor Sibata, model HVC1000) operating at a flow rate of about 78 $m^3$/h through Whitman 41 cellulose filters of 16 x 20 cm in size for Sierra Impactor (**Fig.2**). At least 3 runs were performed for each measurement in outdoor air at different points. Each run can give 3 samples with diameter 5 cm for analysis. The sampling time of each run was 6 h.

Gravimetric analysis of the samples was conducted by Mettler analytical AE240 Dual Range Balance to get the collected mass of the aerosol particles on the substrates. Knowing the mass of the collected particles, the flow rate of the impactor and the sampling time, the concentration can be calculated [18].

$$c = \frac{m}{ft}\left(\frac{\mu g}{m^3}\right)$$

where c is the specific concentration, m (µg) is the relative mass of element on the measured substrate, F ($m^3$/h) is flowrate and t (h) is the time of sampling.

Fig. 2. High volume Sierra Impactor and Schematic design of WDXRF system.

The collected sampled were analyzed using X-ray Fluorescence. In wavelength dispersive spectrometers, fluorescence X-ray photons are separated by diffraction on a single crystal before being detected. Although wavelength dispersive spectrometers are occasionally used to scan a wide range of wavelengths, producing a spectrum plot as in EDXRF, they are usually set up to make measurements only at the wavelength of the emission lines of the elements of interest, one element at a time. Collimation becomes even more important in WXRF to focus the incident X-rays on the analyzing crystal at the appropriated Bragg angle. Eight elements (Cr, Fe, Ni, Zn, Sr, Ba, Mo, and Cu) were detected in the investigated samples of dust.

### *2.2. Contamination factor*

The contamination factor (CF) is a simplistic and useful tool for observing the contamination of heavy metal [19,20]. The CF is a geochemical indicator applied to define the contamination level from the heavy metals. Contamination factor (CF) is the ratio of metals concentration in the dust sample and in the Earth's crust (background), respectively. The values of background were possessed from Kabata-pendis, [21] and Loska et al, [22].

$$\mathrm{CF} = \frac{\text{Concentration of metals in dust sample}}{\text{Concentration of metals in background}}$$

CF values are categorized into 4 classes as follows [23]:

(i) Low contamination, CF < 1
(ii) Moderate contamination, 1 < CF < 3
(iii) Considerable contamination, 3 < CF <6
(iv) Very high contamination, CF > 6

*2.3. Health risk assessment*

In the urban environment, three main pathways of human exposure to heavy metal [24–26]; (1) ingestion (*Ding*), (2) inhalation (*Dinh*) and (3) dermal contact [27,28]. In the present study the health risks via the dermal contact pathway can be detected using Equation (1):

$$D_{dermal} = \frac{C\times AF\times SA\times ED\times EF\times ABS}{AT\times BW} \times 10^{-6} \qquad (1)$$

The parameters value of equation 1 are listed in Table 1, , ED is the exposure duration (years), EF is the exposure frequency (days/year), AT is the averaging time, BW is the average body weight (kg), (days), , , AF is the skin adherence factor for soil (mg/cm$^2$-day), SA is the surface area of the exposed skin that is in contact with the sample (cm$^2$), and ABS is the dermal absorption factor (unitless). C is the measured concentration of heavy metal (mg/kg).

Table 1: Exposure variables used in non-carcinogenic exposure $d_{dermal}$ assessment [29].

| | |
|---|---|
| **EF** | 180 days |
| **ED** | 24 years (adult), 6 years (children) |
| **BW** | 70 kg (adult), 15 kg (children) |
| **AT** | 365 × ED adult/children |
| **SA** | 2145 cm$^2$ event$^{-1}$ (adult), 1150 cm$^2$ event$^{-1}$ (child) |
| **AF$_{soil}$** | 0.07 mg cm$^{-2}$ day$^{-}$12 (adult), 0.2 mg cm$^{-2}$ day$^{-1}$ (child) |
| **ABS** | Fe, Cu, Zn, Sr, Mo, and Ba 0.03; Cr 0.02; Ni 0.04 |

*2.4. Non-carcinogenic risk assessment*

The concentrations of heavy metal were applied to assess the adult and children's health risks both carcinogenic and non-carcinogenic. Hazard quotient (HQ) calculated to determine non-carcinogenic health risk for each individual heavy metal element as described in Eq (2) [24]:

$$HQ = \frac{D}{RFD} \qquad (2)$$

where, RFD reflects the chronic reference dose for each heavy metal (mg/kg-day) as given in Table (2) [30]. The values of $HQ_{dermal}$ are classified into two categories; $HQ_{dermal}$ < 1 indicates that there is no harmful effect to the health and $HQ_{dermal}$ >1 indicates that there is no potential for adverse effects on health.

Table 2: Reference dose RFD (mg/kg-day) for each heavy metal within the dermal contact pathway [30].

| Heavy metal | RfD (mg/kg/day) |
|---|---|
| Cr | 6.00E-05 |
| Fe | 0.07 |
| Ni | 5.40E-03 |
| Zn | 0.06 |
| Sr | 0.06 |
| Ba | 0.014 |
| Mo | 5.00E-04 |
| Cu | 1.20E-02 |

## 3. Results and discussion

The heavy metals (Cr, Fe, Ni, Zn, Sr, Ba, Mo and Cu) are detected in indoor and outdoor urban dust of the studied area in Minia, Egypt. The obtained results of metals concentration in the urban dust are presented in Table 3 and are illustrated in **Fig. 3**. It was found that the cu has a higher metal concentration (25010 mg kg$^{-1}$) than other metals in the indoor exposure which ordered in the following sequences Ba > Fe > Zn > Cr >Ni > Sr > Mo. This may be linked to industrial application, vehicles emission, wood production, iron and steel production and phosphate fertilizer manufacture [31]. While the Fe has the maximum concentration in the outdoor exposure. This may be due to the contribution of natural and anthropogenic sources for the emission of Fe element.

The heavy metal contamination in the urban dust was assessed with the determination of the CF in indoor and outdoor (Table 4). On one hand, in case of the indoor exposure, the mean CF values illustrate the contamination varies in between low and very high. The mean Cu and Mo values represent the very high contamination (Cu= 642.9 and Mo = 9.09) while Zn (1.57) and Ba (1.28) are moderate contamination as well as Cr, Fe, and Sr described the low contaminated. The high contamination is owing to anthropogenic emissions of copper include vehicles emission, iron and steel production, wood production, coal combustion, nonferrous metal production, industrial application, and phosphate fertilizer manufacture [31]. On the other hand, the very high contamination values are registered in the outdoor for Zn and Mo, respectively. This is due to human activities and may also be traced to vehicles emissions. Primary, the anthropogenic sources of zinc in the urban environment (air, soil, and water) include the released materials from mining and metallurgic operations and use of commercial products involving zinc such as fertilizers [31] while the considerable contamination for Cr, Fe, Ni, Ba and Cu. Moreover, the urban dust was low contaminated with the Sr. ++++

Table 3: The descriptive statistics (concentration) with mean and standard deviation (SD) of the heavy metals are detected in the air dust collected in indoor and outdoor.

| Desc-sta | Cr | Fe | Ni | Zn | Sr | Ba | Mo | Cu |
|---|---|---|---|---|---|---|---|---|
| Indoor Mean | 30 | 210 | 20 | 110 | 10 | 590 | 10 | 25010 |
| SD | 4.5 | 31.5 | 3 | 16 | 1.5 | 88 | 1.5 | 3751 |
| Outdoor Mean | 330 | 10150 | 110 | 420 | 10.2 | 2130 | 330 | 50 |
| SD | 49.5 | 1522 | 16.5 | 63 | 1.5 | 319.5 | 49.5 | 7.5 |

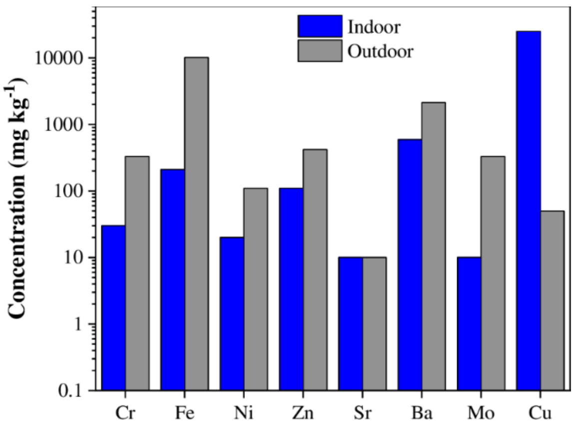


Fig. 3. outdoor and indoor elements concentration in air dust.

In the present study, the appreciation of human hazard risk induced by heavy metals in the examined area including indoor and outdoor through dermal contact route was performed for both adults and children. The values of reference dose are listed in Table 2. The non-cancerogenic risk from the heavy metals are attributed from the hazard quotients (HQ) for dermal contact pathway. Based on the results of average daily metal intake by dermal contact which tabulated in Table 5. the values of $HQ_{dermal}$ for adult and children are calculated and presented in Tables 6 and 7 in indoor and outdoor, respectively. The $HQ_{dermal}$ values for children and adult in the indoor are lower than the recommended limit ($HQ_{dermal}$<1). Thus, no significant non-cancerogenic risk for all targeted populations. However, the $HQ_{dermal}$ values in the outdoor are found higher than the recommended limit ($HQ_{dermal}$ < 1) for the children which can be indicated the children more exposed to the heavy metal risk than adult. Herein, the chromium represents the higher contribution of non-cancerogenic risk followed Mo, Ba, Fe, Ni, Zn, Cu and Sr, respectively. The source of chromium is the industrial compartments include chromate production, ferrochrome and chrome pigment production, metal processing, tannery facilities, and stainless-steel welding. The chromium released from the air and wastewater is contributed from metallurgical, chemical industries and refractory [31].

Table 4: The contamination factor (CF) which calculated in the air dust for heavy metal in the indoor and outdoor.

| | Cr | Fe | Ni | Zn | Sr | Ba | Mo | Cu |
|---|---|---|---|---|---|---|---|---|
| **Indoor** | 0.5 | 0.1 | 0.69 | 1.57 | 0.06 | 1.28 | 9.09 | 642.9 |
| **Outdoor** | 5.6 | 4.2 | 3.8 | 6.0 | 0.06 | 4.6 | 300.0 | 1.29 |

Table 5: The average daily metal intake for adults and children through dermal contact pathway in the indoor and outdoor of the studied area.

| Heavy metal | Indoor | | Outdoor | |
|---|---|---|---|---|
| | Adult | Children | Adult | Children |
| Cr | 3.04E-06 | 5.46E-06 | 3.34E-05 | 6.01E-05 |
| Fe | 3.19E-05 | 3.82E-05 | 1.03E-03 | 1.85E-03 |
| Ni | 4.05E-06 | 3.64E-06 | 1.11E-05 | 2.00E-05 |
| Zn | 1.67E-05 | 2.00E-05 | 4.25E-05 | 7.65E-05 |
| Sr | 1.01E-06 | 1.82E-06 | 1.01E-06 | 1.82E-06 |
| Ba | 1.52E-06 | 1.82E-06 | 2.16E-04 | 3.88E-04 |
| Mo | 8.96E-05 | 1.07E-04 | 3.34E-05 | 6.01E-05 |
| Cu | 1.01E-06 | 1.82E-06 | 5.06E-06 | 9.10E-06 |

Table 6: Hazard quotient (HQ) of the metals for children and adults through dermal contact pathway in the indoor of studied area.

| | **Cr** | **Fe** | **Ni** | **Zn** |
|---|---|---|---|---|
| **Children** | 9.1E-02 | 5.5E-04 | 6.7E-04 | 3.3E-04 |
| **Adult** | 5.1E-02 | 4.6E-04 | 7.5E-04 | 2.8E-04 |
| | **Sr** | **Ba** | **Mo** | **Cu** |
| **Children** | 3.1E-05 | 7.7E-03 | 3.64E-03 | 3.8E-01 |
| **Adult** | 2.5E-05 | 6.4E-03 | 2.02E-03 | 3.2E-01 |
| | **Total** | | | |
| **Children** | 4.8E-01 | | | |
| **Adult** | 5.0E-02 | | | |

Table 7: Hazard quotient (HQ) of the metals for children and adults through dermal contact pathway in the outdoor of studied area.

| | **Cr** | **Fe** | **Ni** | **Zn** |
|---|---|---|---|---|
| **Children** | 1.00E+00 | 2.64E-02 | 3.71E-03 | 1.27E-03 |
| **Adult** | 5.57E-01 | 1.47E-02 | 2.06E-03 | 7.09E-04 |
| | **Sr** | **Ba** | **Mo** | **Cu** |
| **Children** | 3.03E-05 | 2.77E-02 | 1.20E-01 | 7.58E-04 |
| **Adult** | 1.69E-05 | 1.54E-02 | 6.68E-02 | 4.22E-04 |
| | **Total** | | | |
| **Children** | 1.18E+00 | | | |
| **Adult** | 6.57E-01 | | | |

## 4. CONCLUSION

The heavy metals are detected in the urban dust in indoor and outdoor. The copper has the higher concentration than other detected metals in the indoor. While the outdoor the Fe represents the maximum concentration. Moreover, the contamination with the heavy metals in the urban dust are observed vary in between low contaminated (Cr, Fe, and Sr) and very high contaminated (Cu and Mo) in the indoor while in the outdoor the Sr is described the low contaminated and very high contaminated with Zn and Mo. No significant non-cancerogenic health risk was detected in urban dust which collected from the indoor and outdoor for children and adult.

## 5. Conflicts of interest

"There are no conflicts to declare".

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