



Evaluation of Environmental Impact of Iron and Steel Industry in Egypt; Radiological and Heavy Metals Contribution

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ABSTRACT

This study is established to evaluate the impact of iron and steel industry in Egypt on the public and environment. The study involved five companies for iron and steel production. Forty-two raw materials samples, eight waste samples were collected from the selected companies as well as sixty-eight soil samples were collected inside and around the companies.

The activity concentrations of ^{226}Ra , ^{232}Th , ^{40}K and ^{137}Cs were determined applying Hyper-Pure Germanium (HPGe) detector. Radiological health parameters such as radium equivalent, annual gonadal equivalent dose and excess lifetime cancer risk were estimated to assess health implication of exposure to the general public and workers to the studied samples. Heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, and As) were determined by ICP- OES. Contamination factor, contamination degree and pollution load index of heavy metals were estimated; in addition pollution load index (PLI) of zones was used to compare the pollution levels between the studied companies.

The activity concentration of ^{226}Ra , ^{232}Th , ^{40}K , and ^{137}Cs in soil samples ranged from < 0.7 to 257.5 , < 0.6 to 25.4 , 3.63 to 1578 , and < 0.04 to 18.6 Bqkg⁻¹ respectively. Soil samples have hazard indices within safe limit and don't pose a significant health hazard except some soil samples around the first company. Concentration of Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, and As ranged from (0.038 to 57), (2.265 to 922.65), (3.97 to 774.2),

KEYWORDS

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(5184.3 to 99669.2), (94.2 to 17299), (4.00 to 129.5), (6.0 to 1322.7), (43.2 to 2716.1), and (0.025 to 22.3) ppm respectively. The most polluted zone is the third company showing $PLI = 3.3$ and the most contributed site is S50 beside the electric arc furnace as a result of its elevated concentrations of Cd, Zn, and Pb.

The obtained results are used as a baseline data for monitoring possible radioactivity and heavy metals pollutions in the future around the iron and steel industry in Egypt. Some recommendation should be carried out such as Erasing contaminated soil and monitoring the accumulation of heavy metals in soil samples is very important.

INTRODUCTION

The earth's natural radioactivity can be broadly classified into two categories: high energy cosmic rays incident on the Earth's atmosphere, commonly termed cosmic radiation, and radioactive nuclides generated during the formation of the Earth and still present in the Earth's crust, commonly termed terrestrial radiation. Terrestrial radioactivity is mostly produced by ^{238}U , ^{232}Th series radionuclides, as well as ^{40}K (EC, 2015).

The naturally occurring radioactive materials (NORMs) are found in various geological formations such as soil, rocks, water, air as well as building materials (Avwiri et al., 2014) also in houses with varying degree of concentrations depending on the geographical conditions and geologic formations (Zivanovic et al., 2012 ; Huang et al., 2015). Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. When rocks are disintegrated through natural process, radionuclides are carried to soil by rain and flows (Taskin et al., 2009). In addition to the natural sources, soil radioactivity is also affected by human-made activities. The radioactivity concentrations in soil give information on both natural and man-made

sources which is important in radiological monitoring and assessment of radiation dose for public (EPA, 2007). Studies of natural radioactivity are necessary not only for their radiological impact but also for their ability to act as excellent biochemical and geochemical traces in the environment (Surinder Singh et al., 2003). Natural sources contribute almost 80% of the collective radiation exposure of the world's population (Kaleel and Mohanad 2012).

Soils vary across the landscape; therefore, each soil sample contains unique trace element concentrations based on its parent material and other soil-forming factors that may have added or removed these elements from the soil. High background concentrations of trace elements, whether natural or anthropogenic, could result in mobilization and release into surface and subsurface waters also subsequent incorporation into the food chain. The high levels of heavy metals and other pollutants in the soil samples have been attributed to metal rich source rocks, atmospheric pollution from motor vehicles, combustion of fossil fuels, agricultural fertilizers and pesticides, organic manures, disposal of urban and industrial wastes, as well as mining and smelting processes (Alloway 1990; Brumelis et al., 1999).

The steel industry uses the same raw materials in different production process as a source of steel, where the production of steel carried out by two methods: (1) The blast furnace method in which iron oxide ore is the major raw material for steel production (The First Environmental Conference, 2004), (2) The electric arc method in which the main source of steel is scrap (Integrated Management System Manual, 2005).

Steel is an alloy that contains more than 50% of iron and 0.03-1.5% of carbon and to obtain the properties described for different purposes, other metals are usually added (Umland and Bellama, 1996). Some of these metals include; Mn, Zn, Ni, Cr and V. Mn is the only metal without any substitute that is used as a deoxidizing and desulfuring agent in

the manufacture of steel. Zn is used in galvanizing steel to give a protective coating against corrosion. Ni and Cr are used for producing stainless steel and high temperature alloys of steel (**Leet *et al.*, 1982**). V used in the manufacture of steel makes the metal more ductile and resistant to shock. On the other hand during the manufacture of steel by electric arc furnace (EAF) method, the result dust is hazardous and toxic, since it contains soluble oxides such as Cd, Pb, As, and Cr which are formed at high temperature above the steel bath and in the off-gas systems of the EAF (**Lopez *et al.*, 1996**). After disposal of flue dust in landfills, these soluble oxides find their way into the water Table, causing pollution. The EAFD is produced in large quantities (15 kg/t) during manufacture of steel (**Lopez *et al.*, 1996**). We must mention that many studies detected ^{137}Cs in the EAFD (**Keck *et al.*, 1994**; **Kugeler and Thierfeldt, 1999**; **Tahir *et al.*, 2010**) and United States Environmental Protection Agency (EPA) categorized it as hazard waste (**Nadeem *et al.*, 2016**). Iron and steel industry is significant source for atmospheric emission pollutants (**IPPC, 2001**).

Soil is a great geochemical reservoir for contaminant as well as a natural buffer for transportation of chemical materials and elements in the atmosphere, hydrosphere, and biomass. So, it is the most important component of the human biosphere. As soil is an important constituent of the human biosphere, any harmful change to this segment of the environment seriously affects the overall quality of human life. The most adverse effect of heavy metals is that they can be introduced into the food chain and threaten human health.

According to **Udosen *et al.* (1990)**, heavy metals in soil are associated with geometrical cycles and biological processes and could be greatly influenced by industrial activities. In particular, heavy metal pollution of soils due to intense industrialization and urbanization has become a serious concern in many developing countries (**Wei and Yang, 2010**; **Yaylali-**

Abanuz, 2011), and worldwide (**Alloway, 1995**).

The main objective of this work is to measure the activity concentration levels of ^{226}Ra , ^{232}Th , ^{40}K and ^{137}Cs in raw materials (such as Dolomite, flour spare, lime and coke), waste (slag and EAFD) and soil samples. These measurements are aimed to estimate hazard indices (Absorbed dose rate, annual effective dose, external radiation hazard index, radioactivity level index, annual gonadal equivalent dose and excess lifetime cancer risk). Also the concentration of heavy metals was measured; in addition to calculate pollution indices (contamination factor, contamination degree and pollution load index and pollution load index of zone). This type of measurements is of great importance in drawing a clear picture about the radiological and chemical implications of iron and steel industry on its workers, public and the surrounding environment.

MATERIALS AND METHODS

Sampling Locations

The present study involved five factories of iron and steel production in Egypt located in Cairo, Alexandria, El Sadat city and El Suez as indicated in Figure 1.

A total of 118 samples namely; forty-two raw materials and eight waste samples included slag, scale, dust from EAF, brick from EAF and dust beside direct reduced plant (DRP) were collected from companies in addition to sixty-eight soil samples were collected from inside and around the five factories. Twenty soil samples were collected around the first company which located in Cairo. Thirteen raw materials, two waste samples (slag and dust beside DRP) and twenty soil samples were collected inside and around the second company which located in Alexandria. Twelve raw materials, two waste (slag and brick from EAF) and nine soil samples were collected inside and around the third company which located in El Sadat city. Eight raw materials, three

waste (slag, scale and dust from EAF) and nine soil samples were collected inside and around the fourth company which located in El Sadat city. Nine raw materials, one waste (scale) and eight soil samples were collected inside and around the fifth company-

which located in El Suez city. The coordinates of all sampling points were identified by the Global Positioning System device (GPS, eTrex, Personal Navigator, Garmin Ltd).

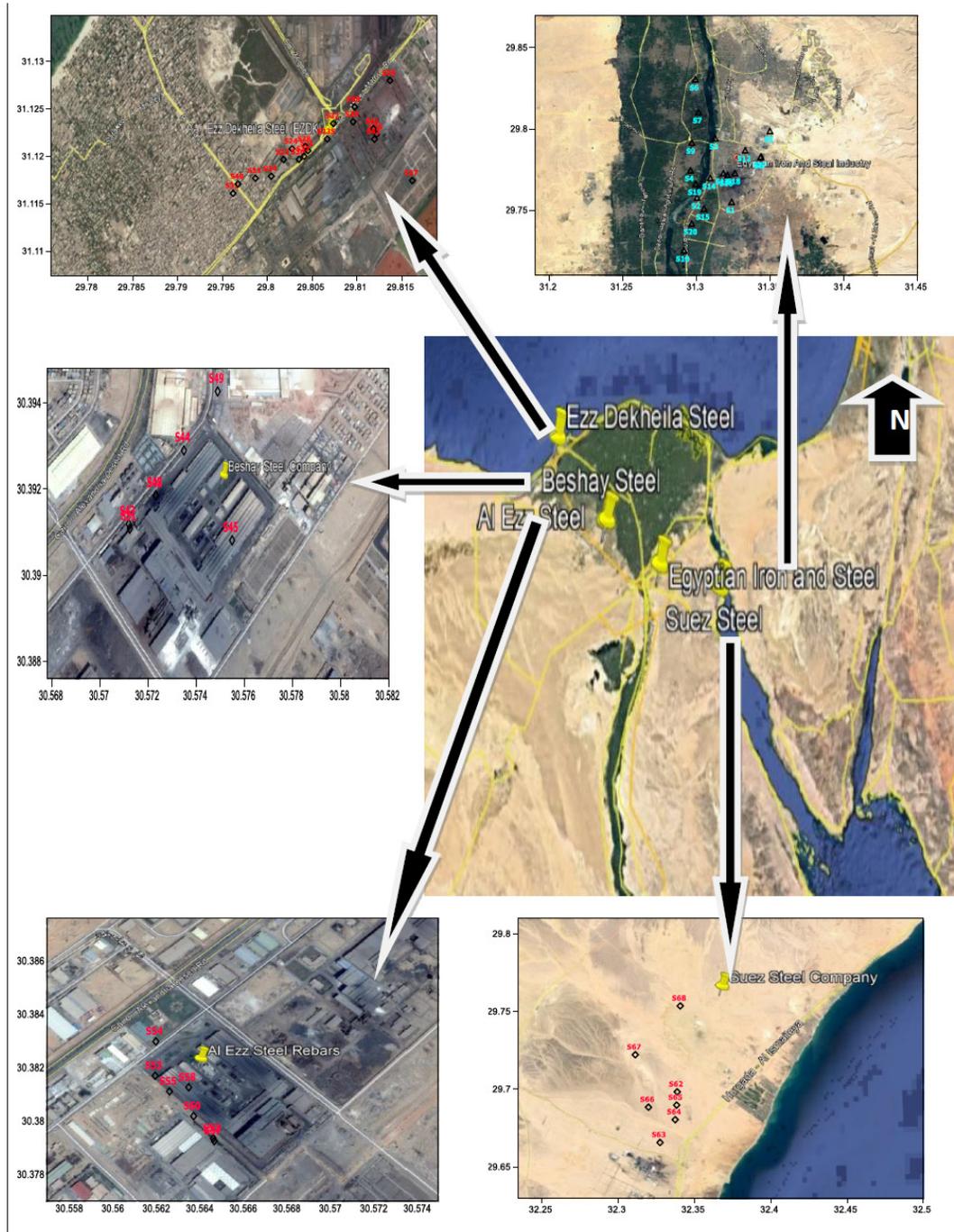


Fig. (1): Location map of the studied area indicating sampling points.

Samples preparation for gamma measurement

Samples were oven dried at a temperature of 110°C for about 24 hours to insure removal of moisture (Alam *et al.*, 1997). Then mixed homogeneously and passed through a 1mm sieve (Tufail *et al.*, 2006). 100ml of samples was weighed by an electrical balance and transferred into polyethylene container that marked individually with identification parameters e.g., name and location of the sample, date of preparation and net weight. The polyethylene container was sealed tightly with insulating tape to prevent the escape of radon daughters. The samples were stored and kept for a period of 1 month to attain secular radioactive equilibrium between ²³²Th series and ²²⁶Ra- contents of the sample and their daughters (Kurnaz *et al.*, 2007; Samad *et al.*, 2012).

Soil preparation for ICP-OES

All soil samples were digested according to method 3050B (EPA, 1996). The digested samples were diluted to 100 ml with deionized water, filtrated into polyethylene bottles and introduced for heavy metal analysis using ICP-OES.

Radioactive Measurements

The detection and measurement of radionuclides in the samples were carried out by gamma spectrometry system based on high purity germanium (HPGe) detector with 40% relative efficiency. The p-type HPGe detector supplied by CANBERRA had a resolution of 1.9 keV at 1332 keV of Cobalt-60 gamma-ray line. The device was calibrated for efficiency using standard method described in El-Tahawy *et al.* (1992). Depending on sample activity, spectra were recorded for time 82000 s, and analyzed using the GENIE 2000 CANBERRA software. The background was used to determine the limit of detection and minimum detectable activity (MDA) according to Currie (1968). The minimum detectable activities at 95% confidence level for the detecting system were 0.7, 0.6, 3.0, and 0.04 Bqkg⁻¹ for ²²⁶Ra, ²³²Th, ⁴⁰K, and ¹³⁷Cs, respectively. The ²³²Th

was determined from the average concentrations of ²²⁸Ac (338.32 keV, 911 keV, 968.97 keV) and ²⁰⁸Tl (583.19 keV) in the samples and the ²²⁶Ra was determined from the average concentration of the ²¹⁴Pb (351.9 keV) and ²¹⁴Bi (609.3, 1120, and 1764.5 keV) decay products. The ⁴⁰K and ¹³⁷Cs were determined directly from 1460.8 keV and 661.6 keV, respectively (Roessier *et al.*, 1970; IAEA, 1989).

The activity concentration of a certain radionuclide, A(Bqkg⁻¹), in the samples was calculated using the following equation (Knoll, 1998; Abdel-Ghany, 2010).

$$A (\text{Bqkg}^{-1}) = \frac{C_a}{(\varepsilon \cdot I_{eff} \cdot M_s)} \quad (1)$$

Where C_a is the net gamma counting rate (counts per second) for a peak at energy E , ε is the detected efficiency of a specific γ -ray, I_{eff} is the intensity of the γ -line in radionuclides, and M_s is the mass of the sample in kilograms.

RADIOLOGICAL HAZARD INDICES CALCULATIONS

Radium Equivalent (Ra_{eq})

Ra_{eq} is weighted sum of specific activities ²²⁶Ra, ²³²Th and ⁴⁰K based on the estimation that 370 Bqkg⁻¹ of ²²⁶Ra, 259 Bqkg⁻¹ of ²³²Th and 4810 Bqkg⁻¹ of ⁴⁰K generate the same gamma dose rate (Beretka and Mathew, 1985; Ndontchueng *et al.*, 2014). The calculation of Ra_{eq} is based on the following relation:

$$Ra_{eq} (\text{Bqkg}^{-1}) = A_{Ra} + 1.43A_{Th} + 0.077A_k \quad (2)$$

Where A_{Ra} , A_{Th} and A_k are activity concentrations of ²²⁶Ra, ²³²Th and ⁴⁰K in Bqkg⁻¹ respectively.

Absorbed Gamma Dose Rate D_r (nGy/h)

The absorbed gamma dose rate was assessed utilizing the activities concentrations of the ²²⁶Ra, ²³²Th and ⁴⁰K measured for samples and using dose coefficients 0.462, 0.604 and 0.0417 for ²²⁶Ra, ²³²Th and ⁴⁰K respectively, the following equation has been

used for calculate absorbed gamma dose rate (UNSCEAR, 2000):

$$D_r \text{ (nGy/h)} = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_k \quad (3)$$

Where A_{Ra} , A_{Th} and A_k are activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K respectively in Bqkg^{-1} .

Annual Effective Dose Equivalent (AEDE)

Applying the conversion factor of 0.7 (Sv/Gy), which converts absorbed dose D_r in air to human effective dose and using an outdoor occupancy factor of 0.2 as recommended by UNSCEAR (2000). The annual effective dose equivalent was calculated from following relation:

$$AEDE \text{ (}\mu\text{Sv/y)} = D_r \text{ (nGyh}^{-1}\text{)} \times 8760 \text{ h} \times 0.7 \text{ (Sv/Gy)} \times 0.2 \times 10^{-3} \text{ (4)}$$

Gamma Radiation Representative Level Index (I_γ)

Gamma radiation representative level index is another radiation hazard index used for the evaluation of the external exposure to γ -ray associated with the natural radionuclides (^{226}Ra , ^{232}Th and ^{40}K), it is calculated according to the following equation (NEA-OECD, 1979; UNSCEAR, 2000; Shanthi et al., 2010):

$$I_\gamma = (A_{Ra}/150) + (A_{Th}/100) + (A_K/1500) \leq 1 \text{ (5)}$$

Where A_{Ra} , A_{Th} and A_k are activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in Bqkg^{-1} respectively.

Annual Gonadal Equivalent Dose (AGED)

The annual gonadal equivalent dose is a measure of the genetic significance of the yearly dose received by the population's reproductive organs (Ravisankar et al., 2014). Organs with rapidly dividing cells such as gonads, and the active bone marrow and bone surface cells are considered as organs of interest by UNSCEAR, (2000). The increase in AGED has been known to affect the bone marrow, causing destruction of the red blood cells that are then replaced by white blood cells. This situation results in a blood cancer called leukemia which is fatal.

AGED due to specific activities of ^{226}Ra , ^{232}Th and ^{40}K was estimated using the following formula (Mamont - Ciesla et al., 1982; Vohra et al., 1982; Avwiri et al., 2014).

$$AGED \text{ (mSvy}^{-1}\text{)} = 3.09A_{Ra} + 4.18A_{Th} + 0.314A_k \text{ (6)}$$

Where A_{Ra} , A_{Th} and A_k are activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in Bqkg^{-1} respectively.

Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk (ELCR) gives the probability of developing cancer over a lifetime at a given exposure level, considering 70 years as the average duration of life for human being (Taskin et al., 2009). Radioactivity in building materials are known to produce carcinogenic effects due to accumulation of radon and its progenies in air that emanate from the wall and floor of a room. The excess lifetime cancer risk (ELCR) gives the probability of developing cancer over a lifetime at a given exposure level, considering 70 years as the average duration of life for human being (Taskin et al., 2009).

Based upon calculated values of annual effective dose (AEDE), ELCR was estimated using the following formula (Taskin et al., 2009; Ramasamy, 2011; Qureshi et al., 2014):

$$ELCER = AEDE \times DL \times RF \quad (7)$$

AEDE is the annual effective dose equivalent, DL is duration of life (estimated to be 70 years) and RF is risk factor (Sv^{-1}) which reflects the fatal cancer risk per Sievert. For stochastic effects, ICRP-106 (ICRP, 2008) uses RF as 0.05 Sv^{-1} for the general public.

ASSESSMENT OF HEAVY METAL POLLUTION

Contamination Factor and Degree of Contamination

The assessment of soil contamination was carried out using the contamination factor. Contamina-

tion factors (C_f^i) were calculated to evaluate the level of contamination of each element, according to the following equation (Tippie, 1984).

$$C_f^i = \frac{C_{0-1}^i}{C_n^i} \quad (8)$$

Where C_{0-1}^i is the measured concentration of the examined metal i in the soil sample, and C_n^i is the background concentration of individual metal. In the present study a modification has applied the factor as indicated by Krzysztof *et al.*, (2003) where the concentration of elements in the earth's crust is used as a reference value, used as C_n^i .

Four contamination categories are documented on the basis of the contamination factor (Hakanson, 1980). $C_f^i < 1$ low contamination; $1 \leq C_f^i < 3$ moderate contamination; $3 \leq C_f^i < 6$ considerable contamination; $C_f^i > 6$ very high contamination.

The sum of contamination factors for all elements examined represents the degree of contamination (C_{deg}) of the site and all four classes were recognized (Hakanson, 1980).

$$C_{deg} = \sum C_f^i \quad (9)$$

Where, C_{deg} is the degree of contamination in a particular sampling site and C_f^i is contamination factor. The following terms is adopted to illustrate the degree of Contamination: $C_{deg} < 8$: low degree of Contamination; $8 \leq C_{deg} < 16$: moderate degree of contamination; $16 \leq C_{deg} < 32$: considerable degree of contamination; $C_{deg} > 32$: very high degree of contamination indicating serious anthropogenic pollution (Hakanson, 1980).

Pollution Load Index

The pollution load index (PLI) was proposed by Tomlinson *et al.* (1980) for detecting pollution which permits a comparison of pollution levels between sites. The PLI was obtained as a concentration factor of each heavy metal with respect to the background value in the soil.

A $PLI < 1$ indicates perfection pollution; a $PLI = 1$ indicates Base line level of pollution and $PLI > 1$ indicates deterioration of site quality (Usero and Garcia, 2000). The PLI has been calculated according to the following equation (Tomlinson *et al.*, 1980):

$$PLI = (C_{f_1}^i \times C_{f_2}^i \times C_{f_3}^i \times C_{f_n}^i)^{1/n} \quad (10)$$

Where, n is the number of metals studied and C_f^i is the contamination factor as mentioned above.

Site indices can be treated in exactly the same way to give a pollution load index for zone.

$$PLI \text{ for zone} = \sqrt[n]{PLI_1 \cdot PLI_2 \cdot \dots \cdot PLI_n} \quad (11)$$

Where, PLI is pollution load index and n equals the number of sites.

RESULTS

Activity Concentrations

The results for the activity concentrations (dry weight) of ^{226}Ra , ^{232}Th , ^{40}K and ^{137}Cs in soil samples of companies were reported in Table 1, and reported as Bqkg^{-1} dry weight. Soil samples of the first company show activity concentrations ranged from 6.8 to 227.5 Bqkg^{-1} (32.9 Bqkg^{-1} , in average) for ^{226}Ra , ranged from 6.7 to 19.3 Bqkg^{-1} (9.8 Bqkg^{-1} , in average) for ^{232}Th and ranged from 54.5 to 1578.9 Bqkg^{-1} (216.7 Bqkg^{-1} , in average) for ^{40}K . Soil samples of the second company show activity concentrations ranged from 11.6 to 28.2 Bqkg^{-1} (20.2 Bqkg^{-1} , in average) for ^{226}Ra , ranged from 6.2 to 25.4 Bqkg^{-1} (13.6 Bqkg^{-1} , in average) for ^{232}Th and ranged from 16.4 to 245.3 Bqkg^{-1} (154.2 Bqkg^{-1} , in average) for ^{40}K . Soil samples of the third company show activity concentrations ranged from 10.8 to 21.4 Bqkg^{-1} (5.6 Bqkg^{-1} , in average) for ^{226}Ra , ranged from 7.1 to 13.5 Bqkg^{-1} (11.1 Bqkg^{-1} , in average) for ^{232}Th , ranged from 59.9 to 221.5 Bqkg^{-1} (177.3 Bqkg^{-1} , in average) for ^{40}K and ranged from 0.43 to 18.6 Bqkg^{-1} (8.1 Bqkg^{-1} , in average) for ^{137}Cs . Soil samples of the fourth company show activity concentrations ranged from 5.7 to 15.9 Bqkg^{-1} (12.3 Bqkg^{-1} , in average) for ^{226}Ra ,

ranged from 5.7 to 16.4 Bqkg⁻¹ (12.1 Bqkg⁻¹, in average) for ²³²Th and ranged from 112.2 to 202.2 Bqkg⁻¹ (165.2 Bqkg⁻¹, in average) for ⁴⁰K. Soil samples of the fifth company show activity concentrations ranged from 1.7 to 25.4Bqkg⁻¹ (13.0 Bqkg⁻¹, in average) for ²²⁶Ra, ranged from 1.2 to 11.3 Bqkg⁻¹ (6.5 Bqkg⁻¹, in average) for ²³²Th and ranged from 3.6 to 135.2 Bqkg⁻¹ (58.5 Bqkg⁻¹, in average) for ⁴⁰K.

Table 3 and Table 4 shows the activity concentrations for ²²⁶Ra, ²³²Th, ⁴⁰K and ¹³⁷Cs of raw materials and waste respectively. The activity concentration of ²²⁶Ra ranged from 2.9 Bqkg⁻¹ (Si-Mn and Mn) to 85.9 Bqkg⁻¹ (Fluorspar) in the second company; from <0.7 Bqkg⁻¹ (Fe-Si-Mn and FeMn) to 82.6 Bqkg⁻¹ (Fluorspar) in the third company; ranged from <0.7 Bqkg⁻¹ (Si-Mn and olivine sand filter) to 84.0 Bqkg⁻¹ (Fluorspar) in the fourth company and from <0.7 Bqkg⁻¹ (Fe-Mn) to 391.6Bqkg⁻¹ (Bauxite) in the fifth

company. ²³²Th ranged from <0.6 Bqkg⁻¹ (Fluorspar and Mn) to 13.1 Bqkg⁻¹ (Calcium aluminates) in the second company; ranged from <0.6 Bqkg⁻¹ (Calcium oxide, Fe-Si-Mn and Fe-Mn) to 11.8 Bqkg⁻¹ (Fluorspar) the third company; ranged from <0.6 Bqkg⁻¹ (Si-Mn) to 16.2 Bqkg⁻¹ (coke) in the fourth company and ranged from <0.6 Bqkg⁻¹ (Fe-Mn and Dolomite) to 426.9 Bqkg⁻¹ (Bauxite) in the fifth company. ⁴⁰K ranged from <3.0 Bqkg⁻¹ (coal and lime) to 127.5 Bqkg⁻¹ (Anthracite powder) in the second company; ranged from < 3.0 Bqkg⁻¹ (Ca-Si, Calcium oxide, Dolomite and Fe-Si-Mn, lime and Fe-Mn) to 897.6 Bqkg⁻¹ (Fluorspar) the third company; ranged from <3.0Bqkg⁻¹ (Fluorspar) to 59.2 Bqkg⁻¹ (coke) in the fourth company and ranged from < 3.0 Bqkg⁻¹ (Fe-Mn) to 118.9 Bqkg⁻¹ (lime) in the fifth company. In all raw materials samples ¹³⁷Cs is under the detection limit.

Table (1) : Specific activity concentrations (dry weight) of ²²⁶Ra, ²³²Th, ⁴⁰K and ¹³⁷Cs in soil samples.

Site	SamplesNo.	Activity Concentrations of Soil Samples (Bqkg ⁻¹)			
		²²⁶ Ra	²³² Th	⁴⁰ K	¹³⁷ Cs
The first company	S1	13.1±1.5	14.2±1.5	179.35±7.8	<0.04
	S2	32.0±1.3	10.8±1.0	204.5±6.3	<0.04
	S3	8.9±1.3	7.1±1.02	1578.9±8.3	<0.04
	S4	9.8±0.78	7.6±0.81	119.5±6.5	<0.04
	S5	26.7±0.7	9.39±1.3	54.51±5.6	<0.04
	S6	6.8±0.85	7.3±0.69	165.5±5.7	<0.04
	S7	15.6±1.6	11.5±1.6	151.1±9.21	<0.04
	S8	10.9±1.4	10.8±1.4	188.0±7.2	<0.04
	S9	11.6±1.3	7.7±1.1	175.2±5.9	<0.04
	S10	15.2±1.2	7.0±1.00	169.7±6.7	<0.04
	S11	13.09±2.7	11.3±1.8	187.9±8.5	<0.04
	S12	41.8±2.0	6.9±1.1	60.11±4.8	<0.04
	S13	65.8±2.3	11.1±0.9	91.91±5.9	<0.04
	S14	15.1±1.4	7.9±1.1	216.3±7.3	<0.04
	S15	50.2±2.0	9.5±1.2	93.32±7.3	<0.04
	S16	45.8±1.6	11.4±1.3	132.1±7.0	<0.04
	S17	22.5±1.2	12.9±1.1	206.6±6.9	<0.04
	S18	26.7±0.62	7.9±0.94	12.31±3.6	<0.04
	S19	227.5±2.7	19.3±1.8	90.13±5.4	<0.04
	S20	12.1±1.6	6.7±1.0	191.3±8.3	<0.04

The second company	S21	28.2±1.3	25.4±2.0	210.9±5.9	<0.04
	S22	25.6±1.5	14.7±1.4	193.3±6.5	<0.04
	S23	17.8±1.3	11.9±1.1	142.6±5.3	<0.04
	S24	26.3±1.7	13.3±1.6	165.0±6.4	<0.04
	S25	20.5±1.1	11.5±1.4	113.3±8.0	<0.04
	S26	27.4±1.3	17.5±1.7	114.3±5.5	<0.04
	S27	21.5±1.2	13.3±1.6	184.5±10	<0.04
	S28	22.5±1.6	14.9±1.5	158.2±6.3	<0.04
	S29	17.4±1.5	13.5±1.3	120.5±5.5	<0.04
	S30	16.3±1.6	13.2±1.6	175.6±6.2	<0.04
	S31	22.7±1.4	12.6±1.5	135.4±6.7	<0.04
	S32	20.8±1.3	11.9±1.5	139.3±6.3	<0.04
	S33	20.0±1.1	12.4±1.9	154.7±9.1	<0.04
	S34	16.2±0.9	11.7±1.6	137.9±8.8	<0.04
	S35	17.8±1.0	12.8±1.3	139.5±4.6	<0.04
	S36	23.0±0.85	19.3±1.5	245.3±6.4	<0.04
	S37	22.0±1.5	14.7±1.2	79.51±5.6	<0.04
	S38	14.1±0.72	13.8±1.3	164.8±8.3	<0.04
	S39	17.3±1.0	10.5±1.2	117.2±5.3	<0.04
	S40	22.2±1.5	11.6±1.4	136.4±6.1	<0.04
The third company	S41	11.6±0.59	6.5±0.81	16.41±3.0	<0.04
	S42	12.4±0.67	12.8±1.3	149.6±8.4	<0.04
	S43	11.97±1.1	10.7±1.3	221.5±6.3	<0.04
	S44	19.1±1.25	13.5±1.52	203.3±6.5	<0.04
	S45	10.8±0.91	7.51±1.16	146.2±4.8	<0.04
	S46	20.3±1.59	7.06±1.43	59.9±6.42	12.0±0.69
	S47	12.1±1.15	13.2±1.17	170.1±6.3	0.43±0.17
	S48	13.65±1.5	13.3±1.55	220.2±6.7	1.71±0.34
	S49	21.4±1.27	12.31±1.8	208.9±11	<0.04
	S50	20.2±0.71	10.5±1.16	164.8±5.2	18.6±0.48
The fourth company	S51	11.51±1.1	11.91±1.2	200.5±5.5	<0.04
	S52	14.52±1.2	11.81±1.4	140.4±4.9	<0.04
	S53	13.23±1.3	12.61±1.3	173.9±5.5	<0.04
	S54	15.32±1.2	14.51±1.4	196.5±6.3	<0.04
	S55	10.22±1.0	10.11±1.3	182.2±5.7	<0.04
	S56	5.74±0.48	5.71±0.99	118.5±4.2	<0.04
	S57	12.2±1.13	7.92±1.21	112.2±4.7	<0.04
	S58	15.9±1.31	15.1±1.40	191.8±5.9	<0.04
	S59	10.0±1.00	9.61±1.30	169.2±5.8	<0.04
The fifth company	S60	13.9±1.23	16.4±1.30	202.2±5.7	<0.04
	S61	1.71±0.74	2.81±0.80	13.2±0.90	<0.04
	S62	19.4±0.82	11.3±1.49	135.2 ±5.8	<0.04
	S63	<0.7	<0.6	4.84±1.50	<0.04
	S64	2.00±0.5	1.21±0.5	3.63±1.60	<0.04
	S65	15.21±1.1	9.51±1.4	99.1±4.80	<0.04
	S66	15.01±1.0	8.0±1.11	103.2±4.4	<0.04
	S67	12.32±1.1	6.0±1.21	87.6±3.70	<0.04
S68	25.4±2.2	<0.6	21.6±10.3	<0.04	

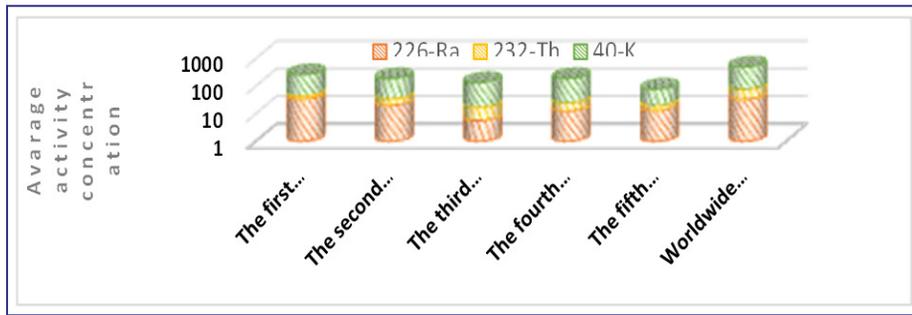


Fig. (2): The average activity concentrations for ^{226}Ra , ^{232}Th and ^{40}K in soil.

Table (2) : Comparison of ^{226}Ra and ^{232}Th ^{40}K average specific activity of soil samples for various countries.

Name of country	An average specific activity (Bqkg ⁻¹)		
	^{226}Ra	^{232}Th	^{40}K
United State *	40	35	370
Egypt*	17	18	320
China*	32	41	440
India*	29	64	400
Japan*	33	28	310
Iran*	28	22	640
Denmark*	17	19	460
Belgium*	26	27	380
Switzerland*	40	25	370
Poland*	26	21	410
Romania*	32	38	490
Greece*	25	21	360
Portugal*	44	51	840
Worldwide an average value of **	33	45	412

*(UNSCEAR, 2000)** (UNSCEAR, 2008)

The radiological hazard indices

The average values of all the studied radiological hazard indices for soil samples are presented in Table 5. The calculated Ra_{eq} , I_γ , D_r , AEDE, AGED, and ELCR values of the soil samples ranged from (0.37 to 262.0 Bqkg⁻¹), (0.003 to 1.77), (0.20 to 120.5 nGyh⁻¹) (0.25 to 147.8 μSvy^{-1}), (0.002 to 0.81 mSvy⁻¹), and (0.001×10^{-3} to 0.517×10^{-3}) with averages values of 51.0 Bqkg⁻¹, 0.39, 25.5 nGyh⁻¹, 31.3 μSvy^{-1} , 0.16 mSvy⁻¹ and 0.11×10^{-3} respectively.

The average values of all the studied hazard indices for raw materials are presented in Table 6. The calculated Ra_{eq} , I_γ , D_r , AEDE, AGED, and ELCR values of the raw materials ranged from (0.50 to 1009.36 Bqkg⁻¹), (0.004 to 6.9), (0.27 to 442.7 nGyh⁻¹), (0.33 to 542.9 μSvy^{-1}), (0.002 to 3.02 mSvy⁻¹) and (0.001×10^{-3} to 1.90×10^{-3}) with averages values of 56.3 Bqkg⁻¹, 0.39, 25.5 nGyh⁻¹, 31.2 μSvy^{-1} , 0.18 mSvy⁻¹ and 0.108×10^{-3} respectively.

Table (3) : Specific activity of ^{226}Ra , ^{232}Th , ^{40}K and ^{137}Cs in raw materials.

Site	Raw Materials	Specific activity of raw materials (Bqkg^{-1})			
		^{226}Ra	^{232}Th	^{40}K	^{137}Cs
The second company	Fe-Si	16.8±1.20	11.4±2.0	117.9±6.8	<0.04
	Fe-Si (lambo)	5.8±0.86	4.3±0.8	30.7±2.2	<0.04
	Si-Mn	2.9±0.50	1.9±0.4	25.1±1.6	<0.04
	Silicon	14.2±1.50	8.7±1.7	10.8±3.8	<0.04
	Mn	2.6±0.58	<0.6	5.6±1.4	<0.04
	Calcium aluminates	21.6±1.6	13.1±1.5	56.0±4.4	<0.04
	Oxide billets	13.1±0.9	11.7±0.8	6.3±0.9	<0.04
	Anthracite powder	19.1±1.5	8.93±1.8	127.5±6.9	<0.04
	Dolomite	49.2±1.7	3.0±1.4	48.9±3.7	<0.04
	Fluorspar	85.9±1.6	<0.6	8.6±3.8	<0.04
	Coal	8.5±1.6	4.4±0.9	<3.0	<0.04
	Limestone	13.5±1.4	4.1±1.2	<3.0	<0.04
main ore in steel	10.3±0.8	7.5±0.8	61.9±2.6	<0.04	
The third company	Ca-Si	16.2±0.8	4.0±0.7	<3.0	<0.04
	Fe-Si	2.3±0.5	1.9±0.7	3.5±1.8	<0.04
	Fe-Mn	<0.7	<0.6	<3.0	<0.04
	Fe-Si-Mn	<0.7	<0.6	<3.0	<0.04
	CaO	46.7±1.6	<0.6	<3.0	<0.04
	Dolomite	34.4±1.6	1.2±0.5	<3.0	<0.04
	Fluorspar	53.7±1.8	11.8±1.6	897.6±10	<0.04
	Coke	11.9±1.3	6.5±1.5	36.2±8.4	<0.04
	Limestone	5.3±0.8	<0.6	<3.0	<0.04
	carbon (1-4)mm	14.5±1.9	9.3±1.9	81.2±7.2	<0.04
	carbon (15-40)mm	3.5±1.1	3.7±1.6	14.2±6.2	<0.04
powder release from scrap	17.3±1.2	6.6±1.2	18.1±4.3	<0.04	
The fourth company	Fe-Si (imported)	13.7±1.0	9.8±1.0	6.1±2.8	<0.04
	Fe-Si (local)	4.5±0.8	3.5±0.8	7.8±2.6	<0.04
	Si-Mn	<0.7	<0.6	6.5±1.5	<0.04
	Dolomite	54.2±1.7	1.8±0.9	16.3±3.6	<0.04
	Olivine sand filter	<0.7	2.0±0.8	10.9±3.6	<0.04
	Fluorspar	84.0±1.6	3.5±1.2	<3.0	<0.04
	Limestone	36.8±1.4	1.4±0.9	18.7±3.9	<0.04
Coke	13.7±1.6	16.2±1.9	59.2±7.2	<0.04	
The fifth company	Si-Mn	11.4±1.1	6.7±1.2	108.9±4.8	<0.04
	Fe-Si	5.2±0.8	7.4±0.9	14.3±2.6	<0.04
	Fe-Mn	<0.7	<0.6	<3.0	<0.04
	Mn high carbon	14.8±1.1	6.4±2.4	92.6±10	<0.04
	Dolomite	54.2±1.9	<0.6	21.5±4.8	<0.04
	Limestone	20.2±1.1	11.1±1.4	118.9±4.9	<0.04
	Fluorspar	17.2±1.0	11.5±1.3	117.7±4.8	<0.04
	Bauxite	391.6±3.0	426.9±3.1	94.8±8.8	<0.04
Coke	18.7±1.8	10.8±1.8	76.1±7.0	<0.04	

Table (4) : Specific activity of ^{226}Ra , ^{232}Th , ^{40}K and ^{137}Cs in waste samples.

Waste samples	Specific activity (Bqkg^{-1})			
	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
Slag (the second company)	50.9±1.2	14.6±1.7	9.3±3.4	<0.04
dust beside DRP (the second company)	13.0±1.0	6.7±0.9	10.1±2.9	<0.04
brick from EAF (the third company)	82.6±1.6	85.1±2.2	129.5±5.5	4.12±0.2
Slag (the third company)	17.8±0.9	5.3±1.1	15.3±3.3	<0.04
Scale (the fourth company)	4.11±0.7	2.8±0.7	7.6±2.3	<0.04
Slag (the fourth company)	18.0±1.2	7.2±0.8	10.3±2.9	<0.04
EAF dust (the fourth company)	13.5±2.4	7.0±2.7	656.7±14	1.5±0.6
Scale (the fifth company)	<0.7	1.5±0.1	1.2±0.1	<0.04

Table (5) : The average of radiation hazard parameters for soil samples.

Site	Ra_{eq} (Bqkg^{-1})			I_7			D (nGyh^{-1})			$AEDE$ (μSvy^{-1})			$AGED$ (mSvy^{-1})			$ELCR \times 10^{-3}$		
	Min	Max	Aver.	Min	Max	Aver.	Min	Max	Aver.	Min	Max	Aver.	Min	Max	Aver.	Min	Max	Aver.
The first Co.	29.8	262.0	64.2	0.22	1.70	0.47	14.1	120.5	30.3	17.2	147.8	37.2	0.10	0.8	0.21	0.06	0.51	0.13
The second Co.	22.1	80.7	50.0	0.15	0.58	0.36	9.9	37.1	23.2	12.2	45.5	28.5	0.06	0.26	0.16	0.04	0.16	0.10
The third Co.	32.7	55.0	45.2	0.24	0.40	0.33	15.6	26.0	21.3	19.1	31.9	26.1	0.11	0.18	0.15	0.06	0.11	0.09
The forth Co.	22.9	52.9	41.5	0.17	0.39	0.31	11.0	24.7	19.5	13.5	30.3	23.9	0.07	0.17	0.14	0.04	0.10	0.08
The fifth Co.	0.3	45.9	22.8	0.003	0.33	0.16	0.2	21.4	10.6	0.25	26.2	13.0	0.002	0.15	0.07	0.001	0.09	0.05

Table (6) : Radiation Hazard Parameters for raw materials Samples.

<i>SITE</i>	<i>Raw materials</i>	<i>Ra_{eq}</i> (<i>Bqkg⁻¹</i>)	<i>I₇</i>	<i>D</i> (<i>nGyh⁻¹</i>)	<i>AEDE</i> (<i>μSvy⁻¹</i>)	<i>AGED</i> (<i>mSvy⁻¹</i>)	<i>ELCR</i> × 10 ⁻³
The second company	Fe-Si	42.18	0.301	19.56	23.99	0.137	0.084
	Fe-Si (lambo)	14.31	0.102	6.56	8.15	0.046	0.028
	Si-Mn	7.54	0.055	3.53	4.37	0.025	0.015
	Silicon	27.47	0.188	12.27	15.04	0.084	0.053
	Mn	3.03	0.021	1.43	1.76	0.010	0.006
	Calcium aluminates	44.95	0.314	20.23	24.80	0.139	0.087
	Oxide billets	30.32	0.208	13.38	16.40	0.091	0.057
	Anthracite powder	41.64	0.301	19.52	23.92	0.136	0.084
	Dolomite	57.25	0.391	26.58	32.60	0.180	0.114
	Fluorspar	86.56	0.578	40.04	49.11	0.268	0.172
	Coal	14.79	0.101	6.58	8.08	0.045	0.028
	Limestone	19.36	0.131	8.71	10.69	0.059	0.037
main ore in steel	25.79	0.184	11.87	14.56	0.083	0.051	
The third company	Ca-Si	21.92	0.148	9.90	12.14	0.067	0.042
	Fe-Si	5.37	0.037	2.39	2.93	0.016	0.010
	Fe-Mn	ND	ND	ND	ND	ND	ND
	Fe-Si-Mn	ND	ND	ND	ND	ND	ND
	CaO	46.73	0.311	21.58	26.46	0.144	0.093
	Dolomite	36.22	0.242	16.66	20.43	0.112	0.072
	Fluorspar	139.60	1.074	69.37	85.07	0.497	0.298
	Coke	23.98	0.168	10.93	13.41	0.075	0.047
	Limestone	5.32	0.035	2.45	3.0	0.016	0.011
	carbon (1-4) mm	34.04	0.243	15.70	19.26	0.109	0.067
	carbon (15-40) mm	9.88	0.070	4.44	5.45	0.031	0.019
	powder release from scrap	28.13	0.193	12.73	15.62	0.087	0.055
The fourth company	Fe-Si (imported)	28.18	0.193	12.50	15.33	0.085	0.054
	Fe-Si (local)	10.10	0.070	4.52	5.54	0.031	0.019
	Si-Mn	0.50	0.004	0.27	0.33	0.002	0.001
	Dolomite	58.02	0.390	26.81	32.88	0.180	0.115
	Olivine sand filter	3.69	0.027	1.66	2.04	0.012	0.007
	Fluorspar	89.01	0.595	40.92	50.19	0.274	0.176
	Limestone	40.24	0.271	18.63	22.84	0.125	0.080
	Coke	41.42	0.292	18.58	22.79	0.129	0.080
The fifth company	Si-Mn	29.37	0.216	13.85	16.99	0.097	0.059
	Fe-Si	16.88	0.118	7.47	9.16	0.051	0.032
	Fe-Mn	ND	ND	ND	ND	ND	ND
	Mn high carbon	31.08	0.224	14.50	17.86	0.102	0.063
	Dolomite	55.85	0.376	25.90	31.81	0.174	0.111
	Limestone	45.23	0.325	20.90	25.75	0.146	0.090
	Fluorspar	42.70	0.308	19.80	24.28	0.138	0.085
	Bauxite	1009.30	6.942	442.70	542.95	3.024	1.900
Coke	40.00	0.283	18.34	22.49	0.127	0.079	

Heavy Metals analysis

The concentration of heavy metals (ppm) for some of the collected soil samples is presented in Table 7.

Concentration of Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, and As ranged from (0.037 to 56.5), (2.26 to

922.6), (3.9 to 774.2), (5184.2 to 99669.2), (94.1 to 17299.1), (4.1 to 129.5), (6.0 to 1322.6), (34.2 to 2716.1), (0.03 to 22.3) ppm, with an average values of 4.4 ,127.1, 87.3 , 29034.0 , 2995.1, 19.1, 113.1, 588.5, and 5.5 ppm respectively.

Table (7) : Heavy metals concentrations (ppm) for soil samples.

Site	Sample No.	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	As
The first company	S2	ND	29.15	26.25	11389.3	1229.8	9.8625	11.99	100.37	0.97
	S5	ND	303.2	32.15	53594.3	17299.1	9.6125	13.24	156.09	2.05
	S13	0.513	139.0	6.50	74719.3	10846.6	12.0875	15.79	229.62	19.03
	S14	0.538	2.9	6.62	61444.3	10386.6	15.7125	19.04	441.64	12.08
	S16	4.638	106.7	24.25	58844.3	8936.6	12.8625	75.04	2297.40	18.45
The second company	S22	0.638	49.80	49.53	18729.3	439.07	15.76	40.49	403.39	2.65
	S25	0.213	26.73	23.70	6176.8	542.07	8.04	16.42	140.92	22.33
	S34	0.313	31.13	27.50	8479.3	273.57	8.31	28.59	160.67	3.12
	S36	ND	108.48	ND	99669.3	315.32	17.41	40.74	49.96	ND
	S37	1.863	4.65	60.50	44269.3	1598.60	23.29	100.70	813.64	0.025
The third company	S44	2.863	102.0	89.25	17336.8	960.32	27.04	162.9	981.89	7.675
	S45	3.463	147.3	398.30	23869.3	1318.80	40.66	148.5	886.39	3.975
	S49	1.363	65.05	75.15	15151.8	541.32	17.99	67.67	624.39	0.925
	S50	56.58	922.65	774.25	61694.3	5389.10	129.50	1322.70	2716.10	3.325
The fourth company	S52	4.633	530.10	112.10	32119.3	3849.10	24.34	186.2	1280.40	1.285
	S54	1.193	40.65	24.68	9081.8	219.79	9.27	46.9	272.89	3.548
	S56	2.138	67.38	38.03	8264.2	722.32	7.98	91.0	700.39	0.550
	S59	1.280	57.03	40.55	9294.2	483.82	10.12	66.1	443.14	0.715
The fifth company	S61	0.313	2.27	8.24	6829.2	145.17	4.78	6.65	43.21	1.273
	S62	0.413	23.05	8.20	5744.2	163.67	4.88	13.87	110.19	1.325
	S63	0.038	18.10	4.38	5184.2	94.16	5.51	6.02	47.27	1.250
	S67	0.163	19.28	3.98	6876.7	138.54	4.08	6.62	46.94	1.875
	Max	56.58	922.6	774.2	99669.2	17299.1	129.51	1322.69	2716.14	22.320
	Min	0.04	2.26	3.97	5184.2	94.16	4.08	6.02	43.21	0.025
	Average	4.40	127.10	87.30	29034.0	2995.1	19.1	113.10	588.50	5.500
	B	0.15	100	55	56300	850	75	12.50	70	1.500
B: is the average concentrations of elements in the Earth's crust										

Assessment of heavy metal pollution

The C_f^i , C_{deg} , PLI and PLI for zone values of the heavy metals in soil samples are presented in Table 8. Soil at the first company was classified as very high contamination with Cd, Mn, Zn and As (average C_f^i =12.6, 11.4, 9.2 and 7.0 respectively), moderate contamination with Cr and Pb (average C_f^i =1.1 and 2.2

respectively) and low contamination with Cu, Fe and Ni (average C_f^i =0.34, 0.92 and 0.1 respectively). Soil at the second company was classified as considerable contamination with Cd, Pb, Zn and As (average C_f^i =5.0, 3.7, 4.4 and 4.6 respectively) and low contamination with Cr, Cu, Fe, Mn and Ni (average C_f^i =0.4, 0.7, 0.6, 0.7 and 0.1 respectively).

Table (8) : The values of the heavy metals C_f^i , C_{deg} , PLI and PLI for zone and in soil samples.

		Contamination Factors (C_f^i)									C_{deg}	PLI	PLI for Zone
Site	Sample No.	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	As			
The first company	S2	—	0.29	0.48	0.2	1.45	0.13	0.98	1.43	0.65	5.62	0.51	1.26
	S5	—	3.03	0.58	0.95	20.4	0.13	1.09	2.23	1.37	29.7	1.0	
	S13	3.42	1.39	0.12	1.33	12.8	0.16	1.29	3.28	12.6	36.4	1.63	
	S14	3.58	0.03	0.12	1.09	12.2	0.21	1.56	6.31	8.05	33.1	1.12	
	S16	30.9	1.07	0.44	1.05	10.5	0.17	6.15	32.8	12.3	95.4	3.44	
	Average	12.6	1.16	0.35	0.92	11.5	0.16	2.2	9.2	7.0	40.1	1.5	
The second company	S22	4.25	0.5	0.9	0.33	0.52	0.21	3.32	5.76	1.77	17.5	1.1	0.83
	S25	1.42	0.27	0.43	0.11	0.64	0.11	1.35	2.01	14.8	21.2	0.72	
	S34	2.08	0.31	0.5	0.15	0.32	0.11	2.34	2.3	2.08	10.2	0.65	
	S36	—	1.08	—	1.77	0.37	0.23	3.34	0.71	—	7.51	0.85	
	S37	12.4	0.05	1.1	0.79	1.88	0.31	8.26	11.6	0.02	36.4	0.92	
	Average	5.0	0.44	0.73	0.63	0.75	0.19	3.7	4.5	4.6	18.5	0.85	
The third company	S44	19.0	1.02	1.62	0.31	1.13	0.36	13.4	14.0	5.12	56.0	2.5	3.34
	S45	23.0	1.47	7.24	0.42	1.55	0.54	12.2	12.6	2.65	61.8	3.21	
	S49	9.08	0.65	1.37	0.27	0.64	0.24	5.55	8.92	0.62	27.3	1.29	
	S50	377	9.2	14.0	1.1	6.3	1.73	108	38.8	2.22	559	12.0	
	Average	107.1	3.1	6.1	0.52	2.4	0.72	34.9	18.6	2.6	176	4.7	
The fourth company	S52	30.88	5.3	2.04	0.57	4.53	0.32	15.2	18.2	0.86	78.0	3.44	1.33
	S54	7.95	0.41	0.45	0.16	0.26	0.12	3.85	3.9	2.3	19.4	0.86	
	S56	14.25	0.67	0.69	0.15	0.85	0.11	7.46	10.0	0.37	34.5	1.1	
	S59	8.53	0.57	0.74	0.17	0.57	0.13	5.42	6.33	0.48	22.9	0.97	
	Average	15.4	1.7	0.98	0.26	1.5	0.17	8.0	9.6	1.02	38.7	1.5	
The fifth company	S61	2.08	0.02	0.15	0.12	0.17	0.06	0.55	0.62	0.85	4.62	0.24	0.26
	S62	2.75	0.23	0.15	0.1	0.19	0.07	1.14	1.57	0.88	7.08	0.39	
	S63	0.25	0.18	0.08	0.09	0.11	0.07	0.49	0.68	0.83	2.79	0.21	
	S67	1.08	0.19	0.07	0.12	0.16	0.05	0.54	0.67	1.25	4.15	0.27	
	Average	1.5	0.16	0.11	0.11	0.16	0.06	0.68	0.88	0.95	4.6	0.27	

Soil at the third company was classified as very high contamination with Cd, Cu, Pb and Zn (average $C_{Fi}^i=107, 6.0, 34.8$ and 18.6 respectively), considerable contamination with Cr (average $C_{Fi}^i=3.0$), moderate contamination with Mn and As (average $C_{Fi}^i=2.4$ and 2.6 respectively) and low contamination with Fe and Ni (average $C_{Fi}^i=0.5$ and 0.7 respectively). Soil at the fourth company was classified as very high contamination with Cd, Pb and Zn (average $C_{Fi}^i=15.4, 7.9$ and 9.6 respectively), moderate contamination with Cr, Mn and As (average $C_{Fi}^i=1.7, 1.5$ and 1.0 respectively) and low contamination with Cu, Fe and Ni (average $C_{Fi}^i=0.9, 0.2$ and 0.17 respectively). Soil at the fifth company was classified as moderate contamination with Cd (average $C_{Fi}^i=1.5$) and low contamination with other metals.

The first company, the second company, the third company, the fourth company, and the fifth company have C_{deg} values ranged from (5.62 to 95.4), (7.51 to 36.4), (27.3 to 559), (19.4 to 78.0) and (2.79 to 7.08), with an average values of 40.1, 18.5, 176.1, 38.7 and 4.6 respectively.

The first company, the second company, the third company, the fourth company, and the fifth company, have PLI values ranged from (0.5 to 3.4), (0.65 to 1.1), (1.29 to 12.0), (0.86 to 3.4) and (0.21 to 0.39), with an average values of 1.5, 0.85, 4.7, 1.5 and 0.27 respectively. The studied areas are divided into five zones, first zone contains the first company sites, second zone contains the second company sites, third zone contains the third company sites, fourth zone contains the fourth company sites and fifth zone contains the fifth company sites. The PLI for the first, second, third, fourth and fifth zones were calculated according to Eq. 11 and were estimated to be 1.26, 0.83, 3.3, 1.3 and 0.26 respectively.

DISCUSSION

Activity Concentrations

The radionuclide contents in all soil samples are lower than worldwide average values (33, 45

and 412) $Bqkg^{-1}$ for ^{226}Ra , ^{232}Th and ^{40}K respectively (UNSCEAR, 2008). Except some soil samples around the first company have higher concentrations for ^{226}Ra and ^{40}K than worldwide average values, this may be attributed to that the contamination of the area during transportation of waste to the storage area, where waste (blast furnace slag) of this company has elevated activity concentration of ^{226}Ra ($551.7 Bqkg^{-1}$) as reported by Bakr (2004).

The activity concentrations of ^{137}Cs in all soil samples are under the detection limits except soil sample S50 was collected near to EAF of the third company also soil samples S47 and S48 lies beside company wall have ^{137}Cs , that may be related to contamination of soil by EAFD which transported by air and deposited into the soil. The presence of ^{137}Cs in EAFD may be related to the residues of material that were used in technological processes and nuclear tests in the past and were recycled as scrap in EAF. Also, radiological accidents must be taken in the consideration for example, in May 1998; ^{137}Cs source was accidentally melted in a steel factory in Spain (Bakr, 2004).

The average activity concentrations for ^{226}Ra , ^{232}Th and ^{40}K of soil samples of the first company has the highest activity concentration of ^{226}Ra while the third company has the lowest average activity concentrations as indicated in Figure 2. Average specific activity of ^{226}Ra , ^{232}Th and ^{40}K of soil samples under investigation are relatively higher than the reported values of ^{226}Ra and ^{232}Th in some countries such as Denmark, Poland and Greece as reported by UNSCEAR (2000).

Table 4 shows results of the activity concentrations for ^{226}Ra , ^{232}Th , ^{40}K and ^{137}Cs in waste. The values of slag are below worldwide concentrations in blast furnace slag ($150 Bq/kg$ for ^{226}Ra and ^{232}Th) (UNSCEAR, 2000). The brick sample produced from EAF of the third company has activity concentrations 85.9, 85.1, 129.5 and $4.1 Bqkg^{-1}$ for ^{226}Ra , ^{232}Th , ^{40}K and ^{137}Cs respectively and the presence of ^{137}Cs may be attributed to brick sample

contaminated with EAFD. The EAFD of the fourth-company has activity concentrations of ^{226}Ra , ^{232}Th , ^{40}K and ^{137}Cs are 13.5, 7.02, 656.7 and 1.5 Bqkg⁻¹ respectively. Presence of ^{137}Cs in EAFD indicates that it might originate from scrap contaminated by ^{137}Cs . This agrees with previous work (**Tahir et al., 2010**) who report edactivity of ^{226}Ra (5.9-13.3 Bqkg⁻¹), ^{232}Th (3.9-8.3 Bqkg⁻¹), ^{40}K (320-582 Bqkg⁻¹) and ^{137}Cs (6.8-20.9 Bqkg⁻¹) in the EAFD. The values of Scale are lower than values given by **Bakr (2004)** 9.5 Bqkg⁻¹ for ^{226}Ra and 4.9 Bqkg⁻¹ for ^{232}Th in scale of the fourth company.

The radiological hazard indices

All R_{eq} values in present work are lower than the maximum permissible limit (370 Bqkg⁻¹) (**UNSCEAR, 2000**), which are acceptable for safe use except Bauxite from the fifth company (1009.3 Bqkg⁻¹).

The average values of gamma radiation representative level index I_{γ} in soil samples are below the international maximum permissible value (1.0) (**UNSCEAR, 2000**), therefore the samples aren't radiologically hazardous except soil samples around the first company which have values(1.18 and 1.77) and fluorspar from the third company (1.07) and Bauxite from the fifth company (6.94).

Both soil samples and raw materials have absorbed dose rate lower than world widean average value (60 nGyh⁻¹) reported by **UNSCEAR (2000)** except soil samples which have absorbed dose rates (74.2, and 120.2 nGyh⁻¹) around the first company and fluorspar from the third company and bauxite from the fifth company (69.37, and 442.7 nGyh⁻¹ respectively).

The annual effective dose in both soil samples and raw materials is lower than the maximum permissible value for public (1000 μSvy^{-1}) according to **ICRP (1990)** except bauxite from the fifth company (1009.3 μSvy^{-1}).

The average values of AGED in both soil samples and raw materials are lower than the world av-

erage (0.3 mSvy⁻¹) reported by **UNSCEAR (2000)** except the soil samples around the first company which have values (0.553, and 0.812 mSvy⁻¹) and fluorspar from the third company (0.49 mSvy⁻¹) and bauxite from the fifth company which have values (3.02 mSvy⁻¹).

The average values of ELCR in soil samples and raw materials are lower than the world average of 0.29×10^{-3} (**UNSCEAR, 2000; ICRP, 2007; Taskin et al., 2009**) except soil samples around the first company which have values (0.319×10^{-3} and 0.517×10^{-3}) and bauxite from the fifth company (1.9×10^{-3}).

Assessment of heavy metal pollution

All heavy metals are within the worldwide natural range in all soil samples, except the concentrations of Cd, and Pb in soil sample S50 (the third company), Cu in soil samples S50 (the third company) and S52 (the fourth company), Mn in soil samples S5, S13, S14, and S16 (the first company), and Zn in 45% of soil samples are higher than worldwide natural range. This may a result from contamination with electric arc furnace dust (EAFD) (**Cappelletti et al., 2016**).

The first company (sample S5) has the maximum concentration value for Mn, the second company has the maximum concentration value for As, and Fe (samples S25, and S36 respectively, and the third company (sample S50) has the maximum concentration value for Cd, Cr, Cu, Ni, Pb, and Zn.

The abundance order of heavy metal in soil samples contents according to average concentration was: Fe > Mn > Zn > Cr > Pb > Cu > Ni > As > Cd.

Sample S50 (the third company) has the highest contamination factor for Cd, Cr, Cu, Ni, Pb, and Zn, sample S36 (the second company) has the highest contamination factor for Fe, sample S5 (the first company) has the highest contamination factor for Mn and sample S25 (the second company) has the highest contamination factor for As.

The third company has the highest average contamination factor for Cd, Cr, Cu, Ni, Pb, and Zn and the second company has the highest average contamination factor for Fe, Mn and As.

The C_{deg} average values classified the states of the soil as very high degree of contamination, considerable degree of contamination, very high degree of contamination, very high degree of contamination and low degree of contamination for the first company, the second company, the third company, the fourth company, and the fifth company, respectively. The third company has the highest average C_{deg} (176) and the fifth company has the lowest average C_{deg} (4.6).

The PLI values classified the states of the soil as deterioration of site quality, perfection of pollution, deterioration of site quality, deterioration of site quality and perfection of pollution for soils of the first company, the second company, the third company, the fourth company, and the fifth company, respectively. Sample S50 (the third company) has the highest pollution load index value and sample S63 (the fifth company) has the lowest pollution load index.

The most pollution zone is the third company (third zone) showing $PLI = 3.3$ and the most contributed site is S50 (beside EAF) as a result of its elevated concentrations of Cd, Zn, and Pb.

The first company has elevated pollution load index zone (1.26) because its samples S13, S14, and S16 have elevated concentrations of Mn, As, Cd, and Zn. The third company has elevated pollution load index zone (3.34) because its samples S44, S45, S49 and S50 have elevated concentrations of Cd, Zn, Pb, and As. The fourth company has elevated pollution load index zone (1.33) because its sites S52, and S56, have elevated concentrations of Cd, Zn, and Pb.

CONCLUSION

The average activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in soil samples is lower than worldwide

average values 33, 45 and 412 Bqkg^{-1} respectively (UNSCEAR, 2008). except ^{226}Ra and ^{40}K in some soil samples around the first company may be attributed to contamination of soil during transportation of the waste to the storage area, where waste (blast furnace slag) of this company has elevated activity concentration of ^{226}Ra (551.7 Bq/kg) as reported by previous studies. The clear variation and elevation in ratios of $^{226}\text{Ra} / ^{232}\text{Th}$ indicates that normal pattern of the soils may be affected by contamination of industry and human activities. The activity concentrations of ^{137}Cs for all soil samples are under the detection limit except S50, S47 and S48 in the third company have ^{137}Cs that may be related to contamination of soil by EAFD which transported by air and deposited into the soil. The presence of ^{137}Cs in EAFD may be as a result of using contaminated scrap in EAF. So, monitoring of artificial isotope ^{137}Cs in the scrap and EAFD is needed.

The activity concentrations of coke and slag in the present study are lower than the world average range and previous studies. Thermal brick sample from EAF of the third company, and EAFD from the fourth company have ^{137}Cs as a result of using contaminated scrap with ^{137}Cs . So, monitoring of artificial isotope ^{137}Cs in the scrap and EAFD is necessary.

From the results of hazard indices, it has found that the soil samples and raw materials in study area are considered to be safe and can be used as a construction material without posing any significant health risk to the population except two soil samples S3, S19 (the first company), fluorspar from the third company and bauxite from the fifth company.

According to PLI of zones there are three polluted zones from the five studied zones. The most pollution zone is the third company showing $PLI = 3.3$ and the most contributed site is sample S50 (beside EAF) as a result of its elevated concentrations of Cd, Zn, and Pb.

RECOMMENDATIONS

To reduce and eliminate contamination and exposure due to iron & steel industry in the future we recommended that:

1. The concentration of radioactive and heavy metals in the raw materials mustn't exceed the permissible limit.
2. Radiation monitoring of the used scrap to prevent producing radioactive iron and radioactive waste.
3. Monitoring for ^{137}Cs in the dust of the EAFD before leaving the production cycle to protect the environment from pollution through the use of dust in other industries or during its disposal.
4. Factory workers must know how to handle the resulting waste materials and wearing protective cloths during the process are necessary.
5. The resulting waste from the iron and steel industry should be collected and transported in sealed vehicles to storage area to prevent exposure of workers and the environment to the radiation dose and contamination with radioactive and heavy metals.
6. The governmental and organizational bodies must periodically monitor environmental samples around iron and steel factories to detect any increase in the radioactive and heavy metals concentration and the polluted soil should be remediated.
7. It is recommended that effective remediation strategy and environmental management plan is required to control and reduce the input of toxic metals (Cd and Pb), which would significantly minimize the potential of further pollution of the environment.

This study can be used as a database for future investigations and the data obtained in this study may be useful for natural radioactivity mapping. The

results may also be used as a reference data for monitoring possible radioactivity pollutions in future.

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