THE RADIOLOGICAL IMPACTS OF TE-NORM ACTIVITY IN UPPER EGYPT

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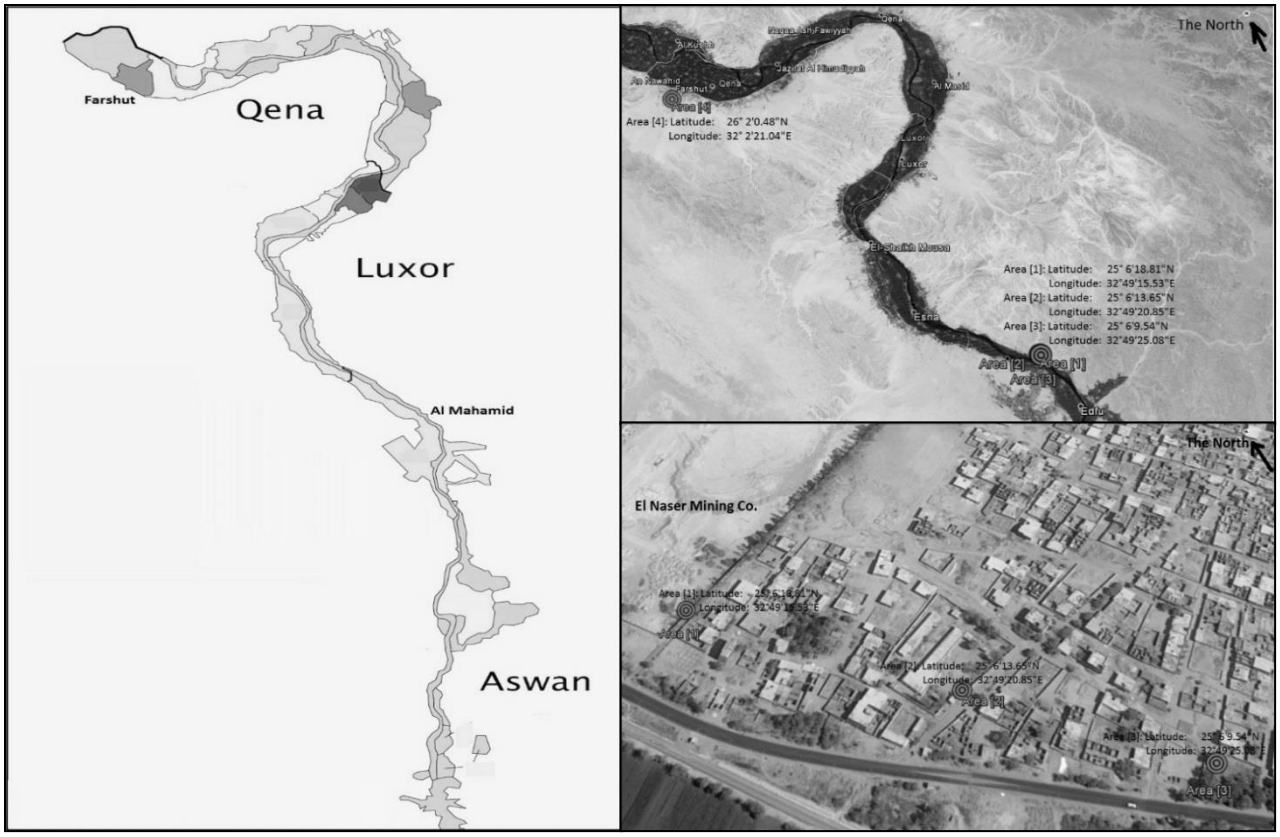
ABSTRACT

A survey was carried out to determine activity concentration levels and associated hazard indices from the naturally occurring radionuclides Ra-226, Th-232, and K-40 in four different areas affected to varying degrees by **TE-NORM** activity by using of The High Purity Germanium Detector (**HPGD**). The average activity concentration levels due to radionuclides were measured for soil and fine dust samples collected from these areas. From the accumulated spectra, the average activity concentration were varied from 76.03 to 36.63, 43.79 and 10.63 **Bq/Kg** for Ra-226, 12.92 to 15.67, 15.77 and 12.94 **Bq/Kg** for Th-232, and 219.99 to 235.01, 205.03, and 204.06 **Bq/Kg** for K-40 for soil, and for fine dust were varied from 446.18 to 199.74, 45.84, and 6.8 **Bq/Kg** for Ra-226, 11.09 to 8.82, 10.58, and 12.94 **Bq/Kg** for Th-232, and 108.66 to 153.52, 169.39, and 204.06 **Bq/Kg** for K-40, of area (1), area (2), area (3), and area (4) respectively. The mean values of radium equivalent, absorbed dose rate **(D_{out}),** and Effective dose rate **(D_{eff})** were 111.29, 77.14, 82.14, and 44.85 **Bq/Kg**, 52.24, 36.46, 38.58, and 21.46 **(nGy/h),** 0.06, 0.04, 0.05 and 0.03 **($mSvyr^{-1}$)** for soil, and were 470.40, 224.18, 74.02, and 44.85 **Bq/Kg**, 217.55, 104.16, 34.81, and 21.46 **(nGy/h)**, 0.26, 0.13, 0.04, and 0.03 **($mSvy^{-1}$)** for fine dust of area (1), area (2), area (3), and area (4) respectively. Internal **(H_{in})** and external **(H_{ex})** hazard indices were calculated. In addition, the total effective dose from external, internal exposure and ingestion from uranium series (Ra-226) and thorium series (Ra-228) of different areas received by characteristic individuals were estimated.

1. Introduction

Gamma radiations emitted from naturally occurring radionuclides, represent the main external source of irradiation of the human body [1, 2, 3, 4]. A number of human activities contribute to our natural radiation environment and a number of non-nuclear industries are sources of technologically enhanced natural radiation (**TE-NORM**) as they contribute to the re-distribution of radioactive nuclei in the environment [5, 6]. Phosphate ores are typically enriched in uranium and they are one of technologically enhanced natural radiation (**TE-NORM**). The discovery of phosphate rocks in Egypt dates back to the end of the last century in regions along the Nile valley, the Red Sea coast and in the Western Desert [7]. In the Nile valley, 13 phosphate-bearing areas have been identified, the most important economically being the El-Mahamid deposits [8]. The objective of the following study is to assess the radiological impact of phosphate industry (non-nuclear industry) at El-Mahamid in Upper Egypt on the environment and population. This study is conducted on four areas, three areas locate on the south-west of the factory at equal distances from each other, and the fourth area locates on north-east at sufficient distance away from the effects of the factory.



Map 1 the areas under investigation

2. SAMPLING AND MEASUREMENT

Samples of soil and fine dust were collected from 4 areas at different distances from the El-Naser mining for phosphate. At each area soil samples were collected twice a year to a depth of 25 cm from 3 circles with a diameter of 1 m. All the samples from the circles were mixed thoroughly to get homogenous sample that is representative for the area. Fine dust samples were collected twice a year from the fine dust deposited on plants, the upper surfaces of the ground, and buildings of each area. The samples were properly marked, catalogued and brought to the radiation Physics Laboratory at, Qena faculty of science south valley university, Egypt for processing before measuring. Samples were dried at about 100 ^{o}C to remove moisture. The dried soil samples were crushed, and pulverized to powder. Each sample was passed through a 2-mm mesh sieve, then the homogenized samples were packed in 7.5 × 8 cm bottle. The measurements were made 1 month later to assure secular equilibrium between the uranium and thorium decay series [9]. The natural radioactivity concentration of Ra-226, Th-232 and K-40 in the collected samples were measured by using The High Purity Germanium Detector **(HPGD)** system consists of an **N-type HPGD (CANBERRA)** coupled to a computer based multi-channel analyzer **(MCA)** mounted in a cylindrical lead shield High Purity Germanium Detector **(HPGD) (100 mm thick)** and cooled in liquid nitrogen. For the efficiency calibration a multi-element standard of known activities was used. Assuming secular equilibrium in the uranium and thorium decay series, the U-238 and the Th-232 activities were determined indirectly via activities of their daughter. The nuclides chosen were Bi-214 (609.3, 1120.3 and 1764 keV) and Pb-214 (351 keV) for U-238, Tl-208 (2614 keV), Pb-212 (238 keV) and Ac-228 (911 Kev) for Th-232 [10, 11]. The specific activity of K-40 was determined directly by 1461 keV photo peak. The counting time for each sample was 24 hour to achieve statistically smaller error levels. The background was measured frequently and subtracted from the net count for all measured samples. The activity concentrations of the natural radionuclides in the measured samples were computed using the following relation [12]:

$$A_S = N / \varepsilon P_r M \quad \text{(Bq/kg)} \quad (1)$$

Where N is the net counting rate of γ-ray (counts per second) corrected for background, ε the detector efficiency of the specific γ-ray, P_r the absolute transition probability of γ-decay and M the mass of the sample (kg).

3. RESULTS AND DISCUSSION

Activity Concentration.

From the obtained results, the average activity concentrations of Ra-226 were 446.18, 199.74, 45.84, and 10.63 **Bq/kg** for fine dust, and 76.03, 36.63, 43.79, and 10.63 **Bq/kg** for soil of area (1), area (2), area (3), and area (4) respectively. While the activity concentrations of Th-232 were 11.09, 8.82, 10.58, and 12.94 **Bq/kg** for fine dust, and 12.92, 15.67, 15.77, and 12.94 **Bq/kg** for soil of area (1), area (2), area (3), and area (4) respectively, and the average activity concentrations of K-40 were 108.66, 153.52, 169.39, and 204.06 **Bq/kg** for fine dust, and 217.99, 235.01, 205.03, and 204.06 **Bq/kg** for soil of area (1), area (2), area (3), and area (4) respectively.

Area NO.	Fine dust			Soil		
	Ra-226	**Th-232**	**K-40**	**Ra-226**	**Th-232**	**K-40**
Area [1]	446.18	11.09	108.66	76.03	12.92	217.99
Area [2]	199.74	8.82	153.52	36.63	15.67	235.01
Area [3]	45.84	10.58	169.39	43.79	15.77	205.03
Area [4]	10.63	12.94	204.06	10.63	12.94	204.06

Table 1 The average activity concentration of Ra-226, Th-232, and K-40 **Bq/Kg** for fine dust and soil samples of different areas.

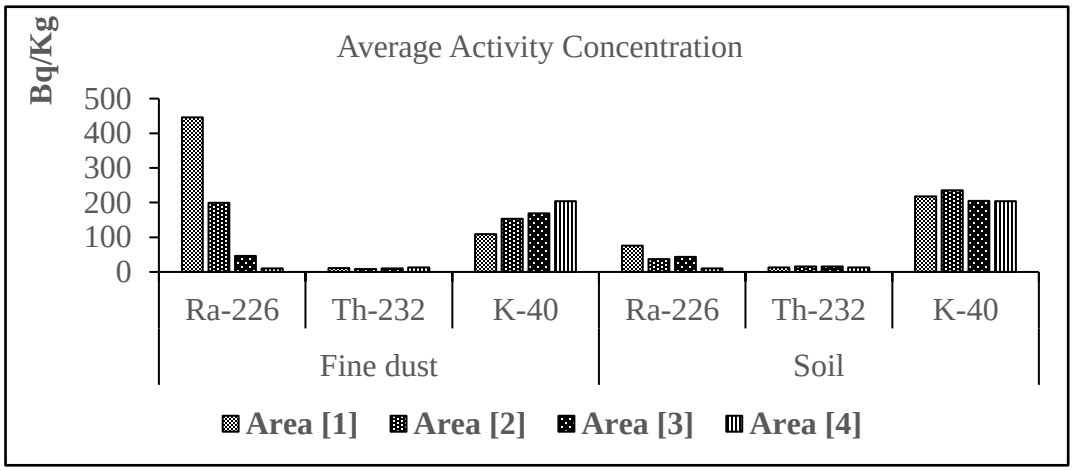


Fig. 1 The variation of average activity concentration **Bq/Kg** with area number.

Activity concentration of K-40 for soil samples is much higher than that of Ra-226 and Th-232 where the soil samples are muddy sand and contain a high percentage of calcium carbonate and a high potassium level. The high concentrations of Ra-226 in fine dust of the two first areas near the factory are due to the particles produced from Phosphate rocks milling process inside the factory do not move large distances away from the factory as they are solid heavy particles can't carried by wind over large distances and Deposited on the areas near the factory. Potassium and thorium activity concentrations in fine dust samples are similar to that in soil samples. Radium activity concentrations in fine dust samples of area (1) and area (2) are much higher than that found in soil samples of the same areas because phosphate ore contain relatively high concentration of U-238 and its decay products, whereas concentrations of Th-232 series and K-40 in phosphate rocks are similar to those observed normally in soil.

Radiation Hazard Indices

Radiological indices such as radium equivalent activity, absorbed dose rate, annual effective dose rate, and external and internal hazard indices depend on the activity concentrations of Ra-226, Th-232 and K-40. These values of radiological indices for different materials contribute significantly to health risk if they were greater than the world average values. In this study, the radiological parameters such as indices of radium equivalent activity Ra_e, external

hazard index $\mathbf{H_{ex}}$, internal hazard index $\mathbf{H_{in}}$, the absorbed dose rate $\mathbf{D_{out}}$, and the annual effective dose $\mathbf{D_{eff}}$, have been estimated for soil and fine dust samples of all different areas under investigation.

Radium Equivalent

Distribution of Ra-226, Th-232 and K-40 in environment is not uniform, so that with respect to exposure to radiation, the radioactivity has been defined in terms of radium equivalent activity **(Ra_{eq})** in Bq/kg to compare the specific activity of materials containing different amounts of Ra-226, Th-232 and K-40. The maximum value of $\mathbf{Ra_{eq}}$ must be less than 370 Bq/kg [13]. Radium equivalent defined as an estimation of radiation 370 Bq/kg of Ra-226, 259 Bq/kg of Th-232 and 4810 **Bq/kg** of K-40 that produces the same gamma ray dose rate. Radium equivalent **(Ra_{eq})** is calculated using the following equation [14]:

$$\mathbf{Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K} \quad \mathbf{(2)}$$

Where A_{Ra}, A_{Th} and A_K in **Bq/kg** are the activity concentration of Ra-226, Th-232, and K-40, respectively.

Area NO.	Soil	Fine dust
Area [1]	111.29	470.40
Area [2]	77.14	224.18
Area [3]	82.14	74.02
Area [4]	44.85	44.85

Table 2 Radium equivalent for soil and fine dust of areas under investigation

From **table 2**, radium equivalent value for fine dust in area (1) is greater than the safe value which reported in the preceding paragraph. The values of radium equivalent for fine dust samples in area (1) and (2) are much higher than the values of radium equivalent for soil samples from the same areas. The values of radium equivalent for fine dust samples of different areas is gradually decrease by increasing the distance from the factory which indicates the effect of the deposition of fine dust produced from the factory which disappear in the area (4) as the value of radium in soil sample is identical to the value of radium equivalent in fine dust sample of the same area.

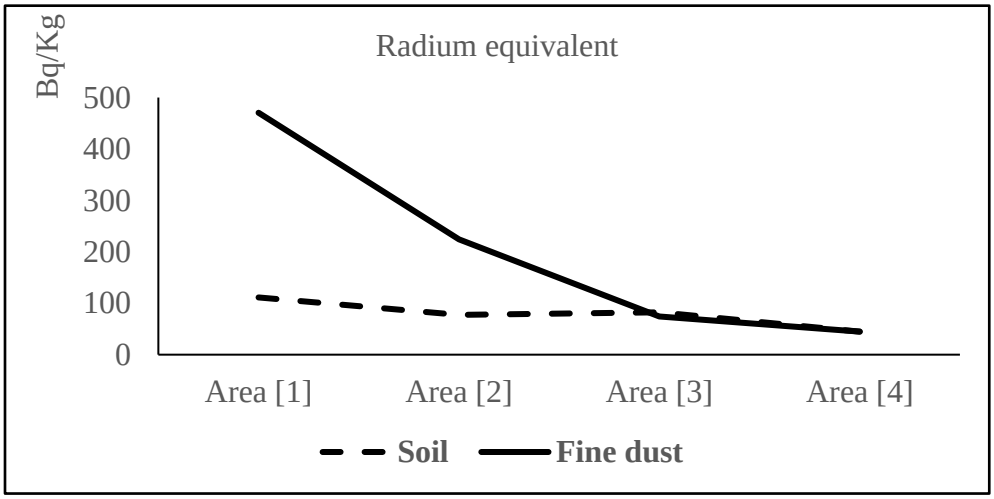


Fig. 2 The variation of radium equivalent for soil and fine dust with areas number.

External [H_{ex}], and internal [H_{in}] indices.

The external hazard index **(H_{ex})** was used to measure the external hazard due to the emitted gamma radiation. It was calculated by the equation from [15]

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \leq 1 \quad (3)$$

In addition to external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. So, the internal radon and its daughter products are quantified by the internal hazard index H_{in} which is given by:

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \leq 1. \quad (4)$$

The value of these two indices must be less than unity for the radiation hazard to be negligible.

Area NO.	Soil		Fine dust	
	Hex	Hin	Hex	Hin
Area [1]	0.30	0.51	1.27	2.44
Area [2]	0.21	0.31	0.61	0.98
Area [3]	0.22	0.34	0.20	0.39
Area [4]	0.12	0.15	0.12	0.18

Table 3 H_{ex}, H_{in} hazard indices for Soil and fine dust samples of different areas.

From **table 3**, the values of H_{ex}, and H_{in} for fine dust of area (1) are greater than the values recommended by UNSCEAR (2000) where it is the area next the factory and affected much by deposition process from milling and loading and different processes that tack place inside the factory. The values of **H_{ex}**, and **H_{in}**, for soil samples of different investigated areas are within the safety limits recommended by UNSCEAR (2000) [16].

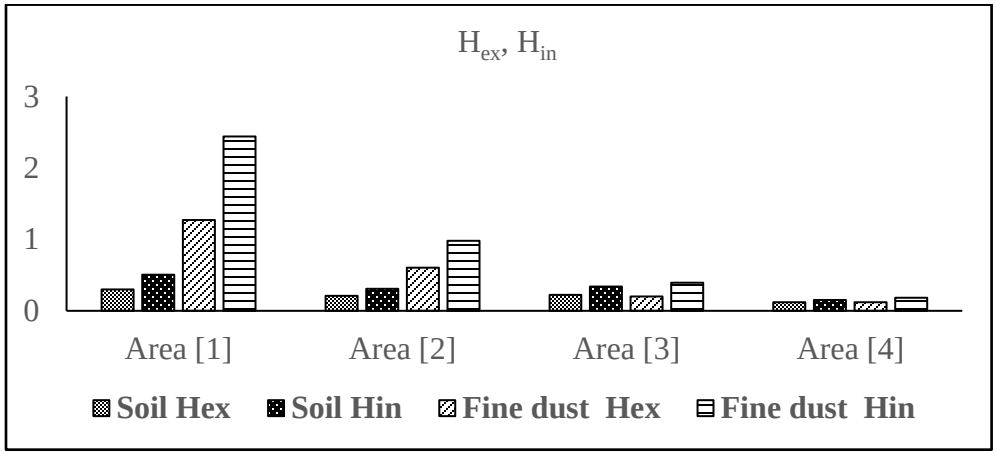


Fig. 3 The variation of **H_{ex},** and **H_{in},** hazard indices for Soil and fine dust samples with areas number.

Absorbed dose rates [D_{out}].

The absorbed dose rate, **D_{out} (nGyh^{-1})** in air at 1 m above the ground level for soil and fine dust samples is calculated using the equation [16, 17, and 18]:

$$D\ (nGyh^{-1}) = 0.462\ A_{Ra} + 0.621\ A_{Th} + 0.0417\ A_K \quad (5)$$

The mean values of external absorbed dose rates obtained for soil and fine dust of different areas under investigation decreases as we move away from the factory, as it has highest values 217.55, and 52.24 **nGyh^{-1}** for fine dust and soil respectively of area (1), and lower values for both soil and fine dust 21.46 **nGyh^{-1}** of area (4).

Area NO.	Soil	Fine Dust
Area [1]	52.24	217.55
Area [2]	36.46	104.16
Area [3]	38.58	34.81
Area [4]	21.46	21.46

Table 4 The absorbed dose rates **[D_{out}] (nGyh^{-1})** for soil and fine dust samples of different areas.

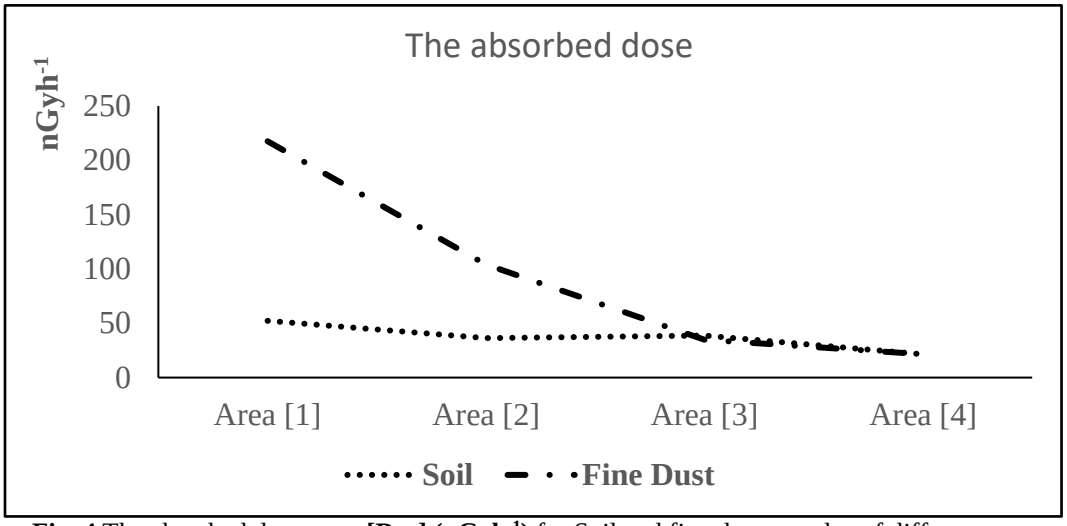


Fig. 4 The absorbed dose rates **[D_{out}] (nGyh^{-1})** for Soil and fine dust samples of different areas.

Annual effective dose rate [D_{eff}].

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose **(0.7SvGy^{-1})** and outdoor occupancy factor (0.2) proposed by UNSCEAR (2000) [16] are used. Therefore, the annual effective dose rate **(mSvy^{-1})** was calculated by the following formula.

[D_{eff}] (mSvy^{-1}) = D (nGyh^{-1}) × 8760 hy^{-1}×0.7 × (103 mSv/109) nGy × 0.2 =D×1.21×10^{-3} (mSvy^{-1}) **(6)**

From **table 5** The annual effective dose decrease from 0.06 **mSvy^{-1}** for soil of area (1) to be 0.03 **mSvy^{-1}** for soil of area (4), and decrease from 0.26 **mSvy^{-1}** for fine dust of area (1) to be 0.03 **mSvy^{-1}** for fine dust of area (4). The average values for fine dust of area (1), and area (2) were greater than annual value of 0.07 **mSvy^{-1}** for outdoor exposures [16].

Area NO.	Soil	Fine Dust
Area [1]	0.06	0.26
Area [2]	0.04	0.13
Area [3]	0.05	0.04
Area [4]	0.03	0.03

Table 5 Annual effective dose rate **[D_{eff}] (mSvy^{-1})** for Soil and fine dust samples of different areas

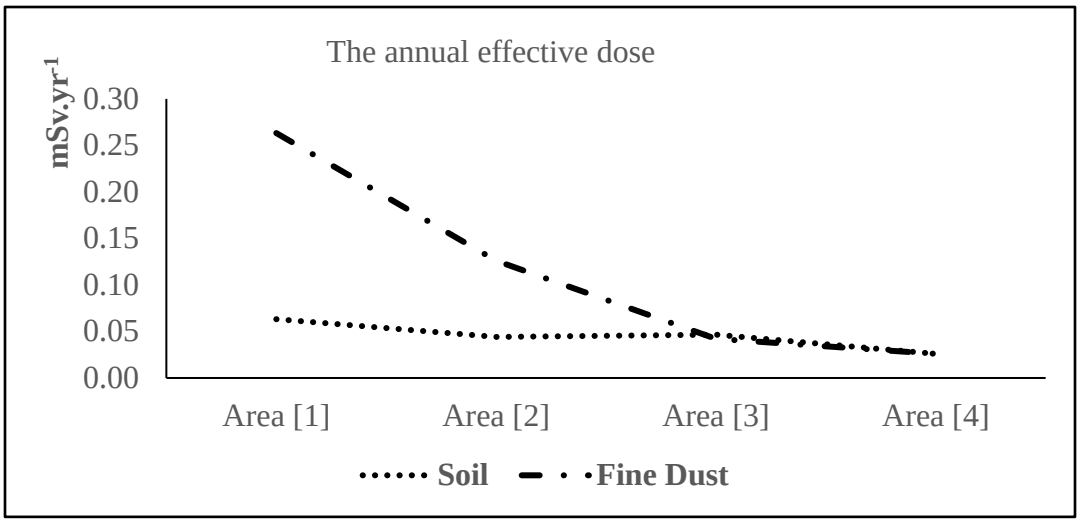


Fig. 5 The variation of Annual effective dose rate **[D_{eff}] ($mSvy^{-1}$)** for soil and fine dust with areas number

External and Internal Gamma Radiation Exposure

In the flowing study; the methodology used to calculate the doses for different population subgroups (i.e. infants, children and adults). It considers all major routes of exposure i.e. external exposure and internal exposure (ingestion and inhalation). The estimated doses are presented in order-of-magnitude dose bands of "characteristic" individual doses for four areas considered.

External Gamma Radiation Exposure.

The amount of radiation an individual accumulates from external exposure will depend on how long the individual stays outdoors versus indoors, shielding, type of radiation and its energy. Dose coefficients for external irradiation are expressed in dose rate **($mSvh^{-1}$)** per activity content of the source **(Bq/kg).** The annual effective dose from external gamma radiation are calculated for each nuclide and age group from the following equation [19].

$$D_{ext,\,a} = f_{con,\,a} \sum \left(D_{x,s} - D_X^U \right) . t_{exp,\,a,\,s} . a_{x,\,s} \qquad (7)$$

Where $D_{ext,\,a}$ annual effective dose from external gamma radiation in **Sv,** $D_{X,\,s}$ Photon - equivalent dose in air at 1 m above ground in **Sv**, D_X^U Photon - equivalent dose for natural gamma radiation in air at a height of 1 m above ground in **Sv,** $f_{con,\,a}$ Conversion factor from photon-equivalent dose to effective dose, $t_{exp,\,a,\,s}$ the annual spent time in **h**, $a_{x,\,s}$ factor for consideration of the shield (protection) on the exposure site s for gamma radiation in air non-dimensional**.** $D_{X,\,s} = A_{soil,\,s} \cdot g_{ext}$, $D_X^U = A_{soil}^U \cdot g_{ext}$ where $A_{soil,\,s}$ specific activity for radionuclide where the Uranium-Radium series in radioactive equilibrium for surface soil layers (0-30 cm) for the exposure site $_s$ in Bq/kg for dry soil, A_{soil}^U Specific natural subsurface activity for radionuclide where the Uranium-Radium series in radioactive equilibrium for surface soil layers (0-30 cm) for the exposure site $_s$ in Bq/kg for dry soil, g_{ext} conversion factor for the conversion the Specific activity of soil Uranium-Radium series in radioactive equilibrium to the photon-equivalent dose in air at a height of 1 m above ground in **Sv kg/Bq h** , $g_{ext} = 5.3\ 10^{-10}$ **Sv kg/Bq h**

Group age	Fine dust				Soil			
	Area [1]	**Area [2]**	**Area [3]**	**Area [4]**	**Area [1]**	**Area [2]**	**Area [3]**	**Area [4]**
<1 y	0.39	0.18	0.05	0.03	0.08	0.06	0.06	0.03
1-2 y	0.35	0.16	0.05	0.02	0.08	0.05	0.05	0.02
2-7 y	0.35	0.16	0.05	0.02	0.08	0.05	0.05	0.02
7-12 y	0.35	0.16	0.05	0.02	0.08	0.05	0.05	0.02
12-17 y	0.30	0.14	0.04	0.02	0.06	0.04	0.05	0.02
>17 y	0.30	0.14	0.04	0.02	0.06	0.04	0.05	0.02

Table 6 External gamma radiation exposure **(mSv)** from soil and fine dust.

The total effective dose from external exposure from uranium series (Ra-226) and thorium series (Ra-228) were 0.39, 0.18, 0.05, and 0.03 **mSv** for infants (<1 year), 0.35, 0.16, 0.05, and 0.02 **mSv** for children (2-7 years) and, 0.30, 0.14, 0.04, and 0.02 **mSv** for adults (>17 years) for area (1), area (2), area (3), and area (4) respectively for fine dust, and the values for soil were 0.08, 0.06, 0.06, And 0.03 **mSv** for infants (<1 year), 0.08, 0.05, 0.05 and 0.02 **mSv** for children (2-7 years), and 0.06, 0.04, 0.05, and 0.02 **mSv** for adults (>17 years) for area (1), area (2), area (3), and area (4) respectively. From previous data the first area recorded the highest values for infants, children and adults, as it is nearest area to the factory, and the values decrease gradually as we move away from the factory. External exposure values resulting from fine dust and soil of the two third and fourth area have nearly the same values, as they are far from the impact of the factory.

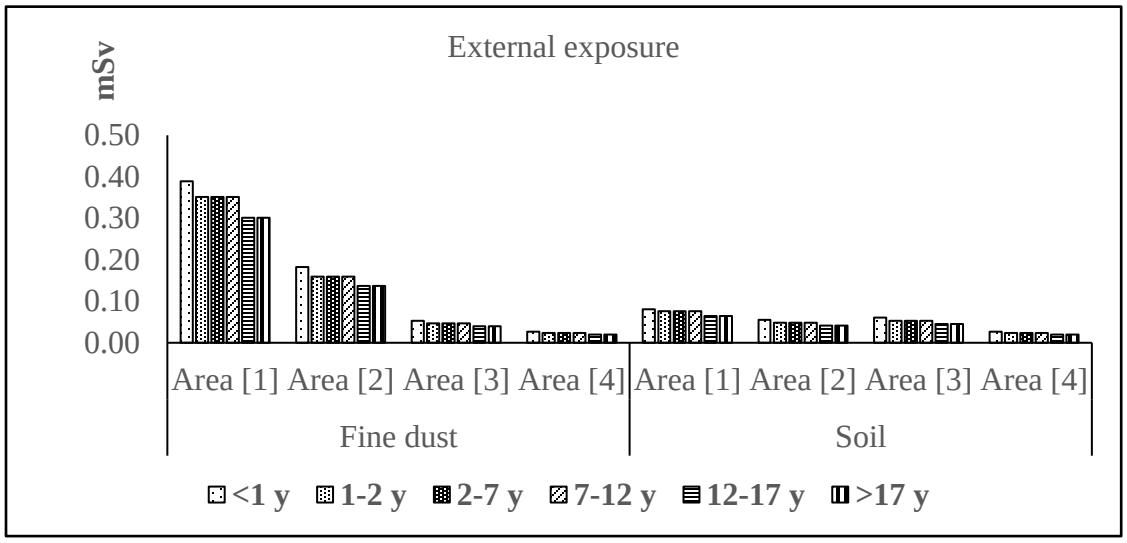


Fig. 6 The variation of External gamma radiation exposure (mSv) for soil and fine dust Samples with area number.

Internal gamma radiation exposure from inhalation.

In the following the annual effective dose from inhalation dust from soil and fine dust **(D_{inh}, a)** will be estimated applied to six different age groups by using equation (8).

$$D_{inh,\,a} = V_a \sum_s \sum_r \left(A_{air,r,s} - A^U_{air,r}\right) g_{inh,\,r,\,a} \cdot t_{exp,\,a,\,s} \cdot a_{air,\,s} \qquad (8)$$

Where; D_{inh} annual effective dose from inhalation of dust in **Sv,** $A_{air,\,r,\,s}$ activity concentration of Dust for radionuclide r in Bq/m^3, $A^U_{air,r}$ natural subsoil-activity concentration of the dust for radionuclide r in external air for the exposure site s in Bq/m, $A^U_{air,\,r} = 0$, V_a breathe rate in **m^3/h**, $g_{inh,\,r,\,a}$ coefficient of inhalation dose for radionuclide

r and reference man a in Sv/Bq, $t_{exp, a, s}$ the annual time spent on the exposure site s in **h,** $a_{air, s}$ factor to determine the concentration of dust on exposure site s from concentration of dust in air,

$$A_{air, r, s} = (A_{soil\ (0.02), r, s} - A^{U}_{soil(0.02), r}) S_{dust}$$

$A_{soil\ (0.02), r, s}$ specific activity of radionuclides r in the fraction of dust (<0.02 mm) in **Bq/kg** for dry soil, $A^{U}_{soil(0,02), r}$ specific natural subsoil - activity for radionuclides r in the fraction of dust (<0.02 mm) in **Bq/kg** for dry soil, S_{dust} reference value of the concentration of dust = $\mathbf{5x10^{-8}\ kg/m^3}$,

$$A_{soil\ (0.02), r, s} = (A_{soil, r, s} - A^{U}_{soil, r}) AF_{0.02, r}$$

$A_{soil, r, s}$ specific activity of radionuclides r in all samples in Bq/kg for dry soil, $A^{U}_{soil, r}$ specific natural subsoil-activity for radionuclides in all samples which the surface soil layers in Bq/kg for dry soil, $AF_{0.02, r} \approx 4$ for all radionuclides r.

The total inhalation exposure were 0.33, 0.15, 0.04, and 0.02 **μSv** for infants (<1year), 0.46, 0.21, 0.06, and 0.03 **μSv** for children (2-7 years), and 0.59, 0.27, 0.07 and 0.03 **μSv** for adults (>17 years) for fine dust of area (1), area (2), area (3), and area (4) respectively, and the values were 0.07, 0.04, 0.05, and 0.02 **μSv** for infants (<1year), 0.09, 0.06, 0.06, and 0.03 μSv for children (2-7 years), and 0.11, 0.07, 0.08, and 0.03 **μSv** for adults (>17 years) for soil of area (1), area (2), area (3), and area (4) respectively.

From previous data the values of annual external gamma radiation exposure **(μSv)** for group age decrease by increasing the distance from the factory. The annual external dose rate for fine dust and soil of area (3) and area (4) are nearly the same values for group age. The values of annual external gamma radiation exposure for fine dust are more than values of annual external gamma radiation exposure (μSv) for soil of area (1) and area (2).

	Fine dust				**Soil**			
Group age	**Area [1]**	**Area [2]**	**Area [3]**	**Area [4]**	**Area [1]**	**Area [2]**	**Area [3]**	**Area [4]**
<1 y	0.33	0.15	0.04	0.02	0.07	0.04	0.05	0.02
1-2 y	0.44	0.20	0.06	0.02	0.09	0.05	0.06	0.02
2-7 y	0.46	0.21	0.06	0.03	0.09	0.06	0.06	0.03
7-12 y	0.57	0.26	0.07	0.03	0.11	0.07	0.08	0.03
12-17 y	0.69	0.32	0.09	0.04	0.14	0.09	0.10	0.04
>17 y	0.59	0.27	0.07	0.03	0.11	0.07	0.08	0.03

Table 7 Internal gamma radiation exposure **(μSv)** from inhalation dust from soil and fine dust**.**

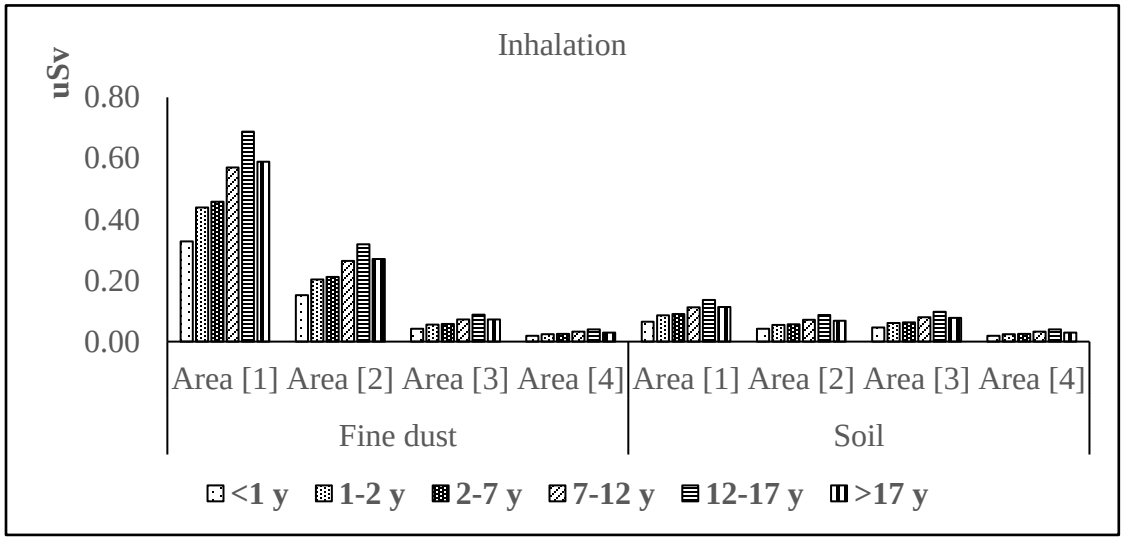


Fig. 7 The variation of internal gamma radiation exposure **(μSv)** from inhalation dust from soil and fine dust samples with area number.

Internal dose due to inadvertent ingestion of radionuclides.

Estimates of risk attributable to soil contamination are often dependent upon assumed soil ingestion rates [21]. The individual effective dose $D_{ing,\ soil,\ a}$ in **(Sv)** to the ingested quantity of radioactivity in **(Bq/kg)** apply for 6 ages groups of the general population estimated from the following [18, 19, 20, and 21].

$$D_{ing,\ soil,\ a} = U_{soil,\ a} \sum_{s} t_{exp,\ a,\ s} \sum_{r} \left(A_{soil\,(0.5),\ r,\ s} - A^{U}_{soil\ (0.5),\ r} \right) g_{ing,\ r,\ a} \qquad (9)$$

Where $D_{ing,\ soil,\ a}$ annual effective dose from direct ingestion of soil per year in **Sv,** $A_{soil\ (0.5),\ r,\ s}$ Specific activity of radionuclides r in **Bq/kg** for dry soil, $A^{U}_{soil\ (0.5),\ r}$ Specific natural subsoil-activity for radionuclides r **Bq/kg** for dry soil, $U_{soil,\ a}$ taking rate of soil **kg/h,** $t_{exp,\ a,\ s}$ annual spent time in **h,** $g_{ing,\ r,\ a}$ Coefficient of ingestion dose for the radionuclide r and reference man a in **Sv/Bq** in the investigation,

$$A_{soil\ (0.05),\ r,\ s} = (A_{soil,\ r,\ s} - A^{U}_{soil,\ r})\ AF_{0.02,\ r}$$

$A_{soil,\ r,\ s}$ specific activity of radionuclides r in all samples in Bq/kg for dry soil, $A^{U}_{soil,r}$ specific Natural subsoil activity for radionuclides in **Bq/kg** for dry soil, $AF_{0.05,\ r} \approx 2$ for all radionuclide

Group age	Fine dust				Soil			
	Area [1]	Area [2]	Area [3]	Area [4]	Area [1]	Area [2]	Area [3]	Area [4]
<1 y	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1-2 y	95.76	51.13	23.44	20.30	31.25	31.88	32.45	20.30
2-7 y	36.81	19.43	8.65	7.32	11.62	11.62	11.86	7.32
7-12 y	9.40	4.88	2.08	1.70	2.83	2.74	2.82	1.70
12-17 y	17.19	8.62	3.28	2.42	4.59	4.09	4.26	2.42
>17 y	3.14	1.53	0.52	0.34	0.75	0.61	0.64	0.34

Table 8 Internal gamma radiation exposure **(μSv)** from direct ingestion of soil and fine dust.

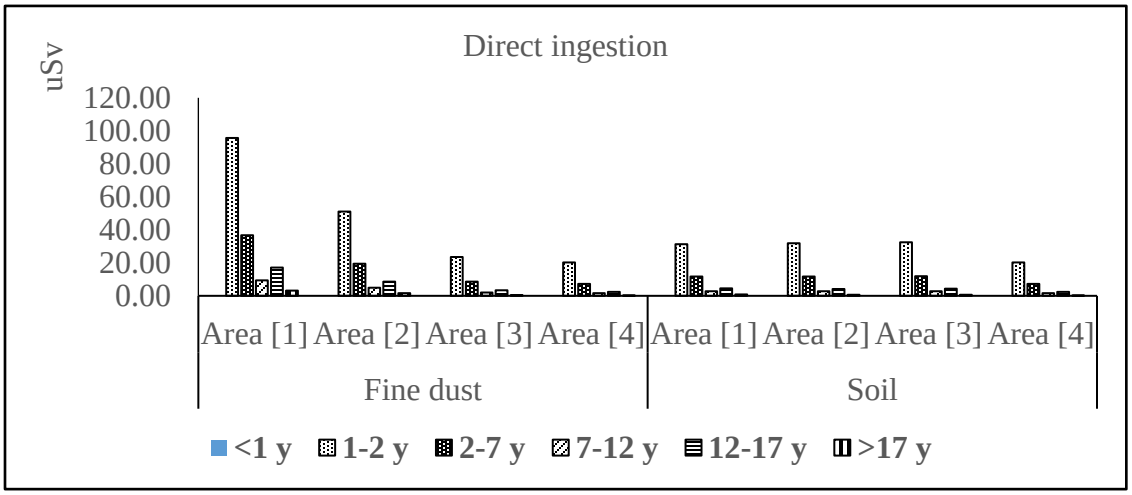


Fig. 8 The variation of internal gamma radiation exposure from direct ingestion of soil and fine dust with area number.

From **table 8** and **fig.8** the annual effective dose rates were, 36.81, 19.43, 8.65, and 7.32 **μSv** for children(2-7 years), 3.14, 1.53, 0.52, and 0.34 **μSv** for adults(>17 years) for fine dust of area (1), area (2), area (3), and area (4) respectively, and the values for soil were, 11.62, 11.62, 11.86, and 7.32 **μSv** for children(2-7 years), and 0.75, 0.61, 0.64, and 0.34 for adults of area (1), area (2), area (3), and area (4) respectively.

From the results listed in table.8, that annual exposure ingestion of fine dust for all group age of all areas decrease by increasing the distance from the factory, the internal annual exposure ingestion for baby less than 1 year is zero, and the maximum annual exposure ingestion for age 1-2 years for all radionuclides and all areas.

4. CONCLUSION

The results of this study obtained by the gamma-ray spectroscopic analysis, have indicated that the activity concentration of Ra-226 in fine dust is much higher than that in soil samples and the radium content is always higher than that of Th-232 and K-40 in fine dust samples of areas near the factory. The values of radium equivalent, absorbed dose rates **(D_{out})**, Effective dose rate, external hazard index **H_{ex}** and internal hazard index **H_{in}** for soil of the study areas are less than the recommended safe levels. The levels of natural radioactivity were higher than the international recommended limits for fine dust samples of the area near the factory, where the external hazard index **H_{ex}** was 1.27 ,the internal hazard index **H_{in}** was 2.44, the average absorbed gamma dose was 217.55 **$nGyh^{-1}$**, and the average effective dose rate was 0.26 **$mSvy^{-1}$**. The total average annual internal effective dose rates estimated that could result from inhalation of fine dust particles during daily practices in area near the factory was 0.46 **µSv** for children, and 0.59 **µSv** for adults, and from ingestion was 36.81 **µSv** for children, and 3.14 **µSv** for adults. These exposure pathways are seem to be hazardous in the area near the factory. The study indicates that there will be an increase of the radiation rate in the area near the activity of concern could pose serious health hazards and Safety rules, precautions and appropriate procedures must be taken to reduce exposure to fine dust produced from milling processes. The results can be considered as a base for the **TE-NORM** effects of phosphate industry.

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