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Radiometric Assay of Hazard Indices in Egyptian Phosphate Profile and Phosphoric Acid Due to Natural Radioactivity

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Abstract:-Radionuclide concentrations in phosphate sediments have always been higher than normal. Using a gamma ray spectrometer's Multi-Channel Analyzer (MCA), radionuclides from phosphate ore are redistributed throughout the environment through the production and enrichment of phosphogypsum and phosphatic acid. Dose evaluation and radiological effects were measured in each of the Nile Valley's sedimentary phosphate ores, domestic phosphoric acid, and insoluble calcium sulfate wastes precipitated during the primary raw materials for the production of phosphatic fertilizers have always been phosphate sediments and phosphatic acid. For Nile Valley low grade phosphate sediment, phosphoric acid, and insoluble calcium, natural radionuclides from the thorium and uranium series, radium equivalent activity (Raeq), external and internal hazards index (Hex&Hin), radioactivity level index (Gamma index) (I), alpha index (I), gamma-absorbed dose rate (DEx), exposure rate (ER), and annual effective dose equivalent (AEDE) were all calculated. East Sebaiya phosphate sediments are suitable for agricultural phosphatic fertilizers due to their high hazards indices. The total annual effective dose equivalent (AEDE) was the only exception, registering 2.96 mSvy^{-1} indoors and 0.74 mSvy^{-1} outdoors. The exposure rate (ER) was found to be higher than the world's permissible standard because of the waste's extremely high specific activity for the naturally occurring ^{226}Ra radionuclide. This necessitated specific radiological risk management measures.

Keywords:-Phosphate sediment; phosphoric acid; Radionuclides; Radiological effects; Thorium; Uranium; gamma ray spectroscopy; radiation hazard indices; Radioactivity; agriculture fertilizer.

I. INTRODUCTION

Numerous studies have demonstrated that phosphate deposits contain a variety of natural radioactive substances (NORM); particularly potassium, thorium, and uranium radionuclides [(1)].consequently, the mining and treatment of phosphate sediments redistributes these radionuclides among the various products, byproducts, phosphate dust, and wastes produced by the phosphate industry. Radiation exposure to the general public can be attributed to a number of factors, including excessive use of inorganic phosphate fertilizers and environmental pollution. The most significant external and internal exposure sources are the gamma radiation and alpha particles released by radionuclides of the uranium ^{238}U, thorium ^{232}Th, and ^{40}K series found in phosphate sediments [(2,3)]. Inhaling radon and its offspring results in internal exposure to particles, whereas gamma rays result in external exposure. Because of this, the dose of the particles directly reaches the tissue in the bronchi, which may raise the risk of radiogenic lung cancer [(4-6)]. Radiation safety necessitates constant monitoring of natural radioactivity in individuals because the radiation released by NORMs (phosphate ores and fertilizers) has the potential to cause cancer in individuals who are exposed to dangerous amounts of radiation[(7)]. According to [(8)], sedimentary phosphate deposits have a higher concentration of 238U and its decay products than volcanic or biogenic phosphate deposits. While^{232}Th series radionuclide concentrations in sedimentary phosphate ores are not significantly elevated above values found in normal sediments and soils, individual ^{238}U series radionuclide concentrations in sedimentary phosphate ores range from approximately 0.5 to 3 Bq/g. However, the concentrations of the ^{238}U and ^{232}Th series radionuclides in igneous phosphate ores rise to approximately 0.1–0.2 Bq/g and 0.1–0.4 Bq/g, respectively. The concentrations of radionuclides in the ^{238}U series are lower than in sedimentary phosphate sediments, but the concentrations of radionuclides in the ^{232}Th series are higher [(9)]. When phosphate material is digested with sulfuric acid to form phosphoric acid, which is the fundamental starting point for the synthesis of numerous major phosphate products, some radionuclides, particularly radium isotopes, become concentrated in phosphogypsum[(9)]. The evaluation of radiation hazard indices (RHI) of sedimentary phosphate deposits in Egypt's Nile Valley, in addition to locally generated H_3PO_4 and insoluble calcium sulfate. For the purpose of determining the radiological impact in a work environment where employees are continuously exposed to

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radiation doses, such as the fertilizer industry and miners, this assessment is essential.

II. LOCATION OF THE PHOSPHATE STUDIED AREA

On both sides of the Nile Valley, the Sebaiya plateau can be found between 320 30' and 330 30' longitudes. There are numerous areas in this region that contain phosphatase-Mahamid and Sebaiya (East and West) stand out most in this region [(10)]. The investigation utilized a sedimentary phosphate sample from the East Sebaiya belt. Figure 1 depicts a map of the research area [(11, 12)].

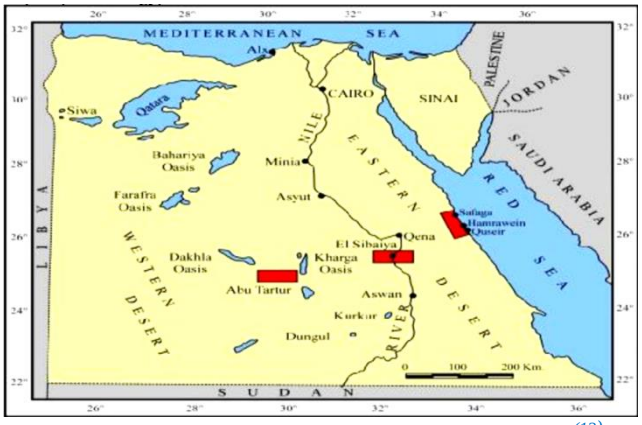

Fig. 1: Locations of phosphate sediments in Egypt [(12).]

- **Experimental:** Phosphate sediment samples were provided by the study area, while samples of phosphoric acid and insoluble calcium sulfate were provided by the Abu-Zaabal fertilizer and chemical company (AZFCO). The gamma ray spectrometer's Multi-Channel Analyzer (MCA) was used to measure the activity concentrations of ^{238}U, ^{226}Ra, ^{232}Th, and ^{40}K. The gamma ray spectrometer has a 76 x 76 mm^{2}NaI (TL) Bicron scintillation detector that is connected to an amplifier model NE-4658, a high voltage power supply model Tc 952, and A label has been applied to each plastic container to indicate its location. To measure background, a sealed, empty canister with the same geometry was left for 30 days. The contributions of the ^{238}U and ^{226}Ra predecessors are generally ignored because radium ^{226}Ra and its offspring account for approximately 98.5 percent of the radiological effects of the uranium series. As a result, when discussing radionuclides in the ^{238}U series, ^{226}Ra is frequently used in place of ^{238}U [(13)]. The 351.9 keV peaks of 214Pb, 609.31 keV peaks of 214Bi, and 1120.3 keV peaks of 214Bi were utilized to measure the concentration of ^{226}Ra.The concentration of ^{232}Th was estimated using the 228Ac peak at 911.1 keV and the 208Tl peak at 583.19 and 2614.53 keV, respectively. The concentration of ^{40}K was estimated using the 1460 keV peak from ^{40}K. The following equation was used to calculate the specific activity concentration (Bq kg^{-1}) of these radionuclides [(14)]:

$$A = \frac{C}{pwt\varepsilon} (1)$$

where, C is the net count above the background, p is the absolute emission probability of the gamma ray decay, w is the net dry sample weight (kg), t is the measurement time, and ε is the absolute efficiency of the detector. All samples were analyzed at Nuclear Materials Authority (NMA), Cairo, Egypt.

- **Determination of Radiation Hazard Indices:**Standard parameters known as radiation hazards are utilized to estimate the effects of radiation exposure on human and environmental health. The radiological effects of samples containing the radionuclides 40K, 232Th, and 238U can be estimated using these indices by a single parameter, taking into account the radiation risk they pose. The equations that go along with the indices are shown below [(15)]. The naturally occurring radionuclides 238U, 232Th, and 40K, as well as their decay products, are typically found in phosphate sediments. Some radionuclides, particularly radium isotopes, become concentrated in residues when phosphate sediment is digested with acid to produce phosphoric acid.
- **RadiumEquivalentActivity (Raeq):**Is a common index to compare specific activities in materials represents a weighted sum of activitiesof^{226}Ra, ^{232}Th and ^{40} K, this index is mathematically defined as[(16)]

$$\mathbf{R_{aeq} = A_{Ra} + 1.43A_{Th} + 0.077A_k} (2)$$

A_{Ra}, A_{Th}, and A_K are ^{226}Ra, ^{232}Th, and ^{40}K-specific activities, respectively.This equation is based on estimation that 10 Bqkg^{-1} of ^{226}Ra, 7 Bqkg^{-1} of ^{232}Th and 130 Bqkg^{-1} of ^{40}K will generate the same gamma-ray dose rate. The maximum value of **Raeq** in soil must be less than 370 Bqkg^{-1}.

- **External hazard index (Hex):**The external hazard index (Hex) was determined from the criterion formula as follow [(16)].

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

A_{Ra}, A_{Th}, and A_K are ^{226}Ra, ^{232}Th, and ^{40}K-specific activities, respectively,inBqkg^{-1}. To limit the external gamma radiation doseto 1.5mSvy^{-1}, external hazardindex must be less than unity inordertomaintaintheradiationhazardnegligible[(17)].

- **Internal Hazard Index (Hin):**Apart from the external Hazardindex, radon and its short-lived compounds are also harmful to the lungs.The internal exposure to radon and its progenies is qualified by the internal hazard index (Hin), which is given by the equation [(18)].

$$\mathbf{H_{in} = (A_{Ra}/ 185) + (A_{Th}/259) + (A_K/4810)} (4)$$

A_{Ra}, A_{Th}, and A_K are ^{226}Ra, ^{232}Th, and ^{40}K-specific activities, respectively.For a safe limit and coexistence with and inhaled radon gas, especially in closed workplaces, its value must be less than unity [(17)].

- **Representative Gamma Index (Iγ):**The representative gamma index (Iγ) is used to calculate gamma radiation related to the natural radionuclide in specific investigated samples. It is defined accordingto[(19,20).]

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

The world safety limit for this index is ≤ 1Bqkg^{-1}. The increment in the indicative gamma index more than the universal standard of unity may outcome in radiation risk leading to the deformation of human cells thereby causing cancer [15].

- **Alpha index (Iα):**Is an index to detect the indoor excess alpha radiation from inhalation of radon originating in the work environment of the *building materials is assessed by the alpha index (Iα) which is defined according to the following equation*[21].

$$I\alpha = \frac{ARa}{200} \quad (6)$$

The world safety limit for this index up tothe unity, this index is directly proportional with the value of ^{226}Ra accumulated in the chemical building materials. The optimum levels of ^{226}Ra in between 100 to 200 Bqkg^{-1} to obtain a range of index ≤ 1

- **External Absorbed dose rate (DEx):**The absorbed dose rates due to gamma radiations in air **(D_{Ex})** at 1 m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra,^{232}Th and^{40}K) were calculated using equation7[22-24]

$$D_{Ex}\ (nGyh^{-1}) = (0.462A_{Ra}) + (0.604A_{Th}) + (0.041\ A_K) \quad (7)$$

A_{Ra}, A_{Th}, and A_K are ^{226}Ra, ^{232}Th, and ^{40}K-specific activities, respectively. The conversion factors used to compute absorbed gamma dose rate (D_{Ex}) in air per unit activity concentration in Bq kg^{-1} (dry weigh corresponds to 0.462 nGy h^{-1} for ^{226}Ra, 0.604 nGy h^{-1} for ^{232}Th and 0.041 nGy h^{-1} for ^{40}K.The standard safe limit for the external absorbed dose rate is 57 nGy h^{-1}[25,26].

- **Annual effective dose equivalent, (AEDE):**The conversion factor (0.7SvGy^{-1}) from absorbed dose rate in air in nGyh^{-1} to effective dose rate in mSv y^{-1} is used with outdoor occupancy factor of 0.2 and indoor occupancy factor of 0.8 to estimate the (AEDE) to γ-ray emitted from radionuclides of ^{226}Ra, ^{232}Th, and ^{40}K in East Sebaiya low grade phosphate sediment sample, H_3PO_4 and insoluble calcium sulfate.

The following formulae (15) were used to calculate (AEDE):

- **AEDE (Indoor)(mSvyr^{-1}) = D_{air} (nGyh^{-1}) x 8766h x 0.8 x 0. 7Sv.Gy^{-1}x 10^{-6}**(8)
- **AEDE (Outdoor)(mSvyr^{-1}) = D_{air} (nGyh^{-1}) x 8766h x 0.2 x 0. 7Sv.Gy^{-1}x 10^{-6}**(9)

The (AEDE) (indoor) occurs within a house whereby the radiation risks due to building materials only are taken intoconsideration while (AEDE) (outdoor) involves a considerationof the absorbed dose emitted from radionuclides in theenvironment such as ^{226}Ra,^{238}U, ^{232}Th and ^{40}K[15].The (AEDE) (Outdoor) standard value is 70 Svyr^{-1}, while the (AEDE) (Indoor) standard value is 450 Svyr^{-1}. These indices assess irradiated individuals' proclivity to random, predetermined outcomes [27].

- **Exposure rate (ER):**According to the United States Environmental Agency, the amount of ionizing radiation per hour in a person's vicinity is measured in milliRoentgen per hour, mR/h (EPA). The following relationship was used to calculate the exposure rate: [28,29].

$$ER(mRh^{-1}) = 1.90A_{Ra} + 2.82A_{Th} + 0.179A_k \quad (8)$$

A_{Ra}, A_{Th}, and A_K are ^{226}Ra, ^{232}Th, and ^{40}K-specific activities, respectively.

III. RESULTS AND DISCUSSION

The specific activities of ^{226}Ra,^{238}U, ^{232}Thand ^{40}K: Tables1 and 2 show the measured radioelement concentrations (^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K) and specific activities in East Sebaiya low grade phosphate sediments, phosphoric acid, and insoluble calcium sulfate samples. The radionuclide concentrations in the phosphate sediments sample were ^{226}Ra=1.0 ppm, ^{238}U=47 ppm, ^{232}Th=1.0 ppm, and ^{40}K=0.1 percent. For ^{226}Ra, ^{238}U, ^{232}Th, and ^{40}k, the radionuclide concentrations in the phosphoric acid sample were 0.8 ppm, 6.0 ppm, 0.4 ppm, and N.D, respectively. The radionuclide concentrations in the insoluble calcium sulfate sample were 93ppm, 58ppm, 2.0ppm, and 0.2 percent for ^{226}Ra,^{238}U,^{232}Th, and ^{40}k, respectively.

Sample	^{226}Ra, ppm	^{238}U, ppm	^{232}Th, ppm	^{40}k, %
East Sebaiya Phosphate ore	1.0	47	1.0	0.1
H_3PO_4	0.8	6.0	0.4	N.D
Insoluble calcium sulfate	93	58	2.0	0.2

Table 1: Radionuclide concentration238U,232Th, 226Ra and 40K

**N. D: Not detected*

For East Sebaiya low grade phosphate sediments samples, the specific activities of radionuclides ^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K are 16.4, 291, 2.5, and 11 Bqkg^{-1}, respectively. Radionuclide specific activities for phosphoric acid were 5, N.D., 3, and 29 Bqkg^{-1}, respectively. For insoluble calcium sulfate samples, the specific activities of ^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K are 1300, 102, 2.67, and 45 Bqkg^{-1}, respectively.

Sample	*^{226}Ra, $Bqkg^{-1}$*	*^{238}U, $Bqkg^{-1}$*	*^{232}Th, $Bqkg^{-1}$*	*^{40}k, $Bqkg^{-1}$*
East Sebaiya Phosphate ore	*16.4*	*291*	*2.5*	*11*
H_3PO_4	*5*	*N.D*	*3*	*29*
Insoluble calcium sulfate	*1300*	*102*	*2.67*	*45*
Safety boundaries [29,30]	*1550*	*1500*	*7-50*	*100-700*

Table 2 : Specific activities of radionuclides ^{238}U,^{232}Th,^{226}Ra and ^{40}K

In comparison to the Committee on the Effects of Atomic Radiation [29,30], the samples of both East Sebaiya (Nile Valley) low grade phosphate sediments, phosphoric acid, and insoluble calcium sulfate of H_3PO_4 are limited around the detection system for ^{226}Ra, ^{238}U, ^{232}Th, and ^{40}K. However, ^{226}Ra has a high normal range of detection in the case of insoluble calcium sulfate.

IV. DOSE ASSESSMENT AND RADIOLOGICAL EFFECTS

- **Radium equivalent concentration:** To keep the γ-ray dosage below 1.5 $mSvy^{-1}$, the value of Raeq in East Sebaiya low grade phosphate sediments, H_3PO_4, and insoluble calcium sulfate samples must be less than 370 Bq kg^{-1}. In East Sebaiya low grade phosphate sediments, H_3PO_4, and insoluble calcium sulfate samples, the measured activity concentrations of radium radionuclide equivalent concentration are shown in Table3.

Sample	Ra_{eq}, $Bqkg^{-1}$
East Sebaiya Phosphate	28.44
H_3PO_4	31.62
Insoluble calcium sulfate	1338.46
Safety boundaries [29,30]	370

Table 3: Assessed activity concentrations of radium radionuclide Ra_{eq}

Raeq values for East Sebaiya low grade phosphate sediment and H_3PO_4 were 28.44 and 31.62 Bq kg^{-1}, respectively, with the highest value found in insoluble calcium sulfate samples at 1338.46 Bq kg^{-1}. This means that the East Sebaiya low grade phosphate sediment sample and the locally manufactured H_3PO_4 are less than the global limit, whereas the insoluble calcium sulfate sample exceeded the recommended global mean value of 370 Bq kg^{-1}[29,30].

V. EXTERNAL HAZARD INDEX (HEX)

Table 4 shows the calculated external hazard indexes for East Sebaiya low grade phosphate sediments, H_3PO_4, and insoluble calcium sulfate samples.

In this study, phosphoric acid and East Sebaiya low grade phosphate sediment samples have an external hazard index that is significantly lower than the international reference standards of 0.056 and 0.031 Bq.kg-1, respectively. On the other hand, the (Hex) of insoluble calcium sulfate was evaluated at 3.53 Bq, exceeding the recommended values for the sample.kg-1. In addition to the external threat, radium and its short-lived compounds pose a threat to the respiratory system. Radon is a naturally occurring radioactive gas that is produced when uranium undergoes radioactive decay. It can be found in water as well as a wide variety of soils and sediments. From the earth, radon enters the air and decays into new, more radioactive [31].

The internal exposure to radon and its progeny produced is quantified by an internal hazardindex (Hin) according to aforementioned equation4.

Table 4 displays the calculated external and internal hazards indices for East Sebaiya low grade phosphate sediment, H_3PO_4, and insoluble calcium sulfate samples.

Sample	Hex, Bq .kg^{-1}	Hin, Bq .kg^{-1}
East Sebaiya Phosphate sediments	0.056	0.1
H_3PO_4	0.031	0.044
Insoluble calcium sulfate	3.53	7.0
Safety boundaries[29]	1	1

Table4: The External and internal hazard index factors:(H_{ex}), (H_{in})

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East Sebaiya's low-grade phosphate sediments have an internal hazard index of 0.1 Bq kg-1, H3PO4 has an internal hazard index of 0.044 Bq kg-1, and insoluble calcium sulfate samples have an internal hazard index of 7.0 Bq kg-1. This indicates that the East Sebaiya phosphate sample and H3PO4 are both within the safe limit for the world, whereas the insoluble calcium sulfate

- **Gammalevel index***was recorded in Table 5 according to equation 5.*

Sample	Bq .kg^{-1}
East Sebaiya Phosphate sediments	0.14
H_3PO_4	0.08
insoluble calcium sulfate	8.72
Safety boundaries [15]	≤ 1

Table 5: Gamma index, I_γ

According to Table 5, the radioactivity level index (I_γ) of both East Sebaiya Phosphate sediments and H_3PO_4 is less than 1 Bq.kg-1. As a result, it is possible to draw the conclusion that East Sebaiya Phosphate sediments is more useful in the phosphatic fertilizer industries and does not pose any health risks. However, the insoluble calcium sulfate waste from the production of phosphoric acid has an alarmingly high gamma index, which poses significant health risks and dangers.

- **Alpha index (Iα):**The alpha index for East Sebaiya phosphate sediments, H_3PO_4, and insoluble calcium sulfate has been calculated using equation 6. The values of (Iα) were 0.082, 0.025, and 6.5, respectively. The observed alpha index values for both phosphate sediments and H_3PO_4 are less than one, indicating that construction materials are safe from environmental radiation hazards. However, the calculated (Iα) insoluble calcium sulfate origin is six times higher than the safety limit. As a result of radon exhalation from insoluble calcium sulfate building materials, indoor radon concentrations may exceed 200 Bq.kg^{-1}.
- **External Absorbed dose rate (D_{Ex}):**Table6presentsthe evaluated result of gamma-absorbed dose rate. The lowest values noted for the phosphate sediments and phosphoric acid, the values of estimated results are 9.53 and 5.31 respectively. On the other side, the highest value reported for insoluble calcium sulfate. According to [25], this means that $D_{EX}$of insoluble calcium sulfateis higher than the normal rate by about ten times than the dose limit for members of the public in planned exposure situations. This inferred that the laborers of the phosphoric acid plant will be more exposed to gamma radiation escaped from the insoluble calcium sulfate.

Sample	*Dose rate (nGy h^{-1})*
East SebaiyaPhosphatesediments	*9.53*
H_3PO_4	*5.31*
Insoluble calcium sulfate	*604.05*
Safetyboundaries[25]	*57*

Table 6: External absorbed dose rate, D_{Ex}

- **Annual effective dose equivalent, (AEDE):** Table7 shows the calculated total annual effective dose equivalent (AEDE), indoor (AEDE), and outdoor (AEDE) values.

Sample	Indoor AEDE, mSv y^{-1}	Outdoor AEDE, mSv y^{-1}
East Sebaiya Phosphate	0.047	0.011
H_3PO_4	0.02	0.0
Insoluble calcium sulfate	2.96	0.74
Safety boundaries [27]	450.0	70.0

Table 7: Total annual effective dose equivalent, (AEDE)

The outdoor and indoor effective dose results for all samples show that all values were within the corresponding worldwide values.

- **Exposure rate (ER):**Table 8 displays the calculated exposure rate for both East Sebaiya phosphate low grade sediments, H3PO4, and insoluble calcium sulfate samples.

Sample	Exposure rate (mRh^{-1})
East Sebaiya Phosphate	40.17
H_3PO_4	23.15
Insoluble calcium sulfate	2485.5
Safety boundaries [29]	50

Table8: Exposure rate (mRh^{-1}) estimation of the studied samples

Table 8 shows that the exposure rate values for East Sebaiya low grade phosphate sediments and H_3PO_4 are 40.17 and 23.15 (Rh^{-1}) below the UNSCEAR threshold, respectively. In contrast, an insoluble calcium sulfate sample was found to be 50 times higher than the global limit. In the long run, this high exposure rate for insoluble calcium sulfate location increases the chances of developing gonads, bone marrow problems, sterility, or even leukemia.[12].

VI. CONCLUSIONS

Using a Multi-Channel Analyzer (MCA) of Gamma Ray Spectrometer, the activity concentrations of ^{238}U, ^{226}Ra, ^{232}Th, and ^{40}K were measured in samples of East Sebaiya low grade phosphate sediments, phosphoric acid, and insoluble calcium sulfate collected from (AZFCO). The obtained activity concentrations were used to calculate radiometric parameters and radiation hazards indices. The results showed that all radiation hazard indices (Raeq, Hex, Hin, I_α, I_γ, DEx), (AEDE) indoor and outdoor, and (ER) calculated for phosphate sediments and phosphoric acid had generally low trends, with values falling below the allowable threshold for the two samples. The total annual effective dose equivalent (AEDE) (Indoor) is less than the permissible limit of 450 $mSvy^{-1}$, while the AEDE(Outdoor) is less than the permissible limit of 70 $mSvy^{-1}$.Most hazard indices calculated for insoluble calcium sulfate waste samples, on the other hand, reveal extremely high levels, with the exception of the total annual effective dose equivalent (AEDE), which is 2.96 Indoor (AEDE), $mSvy^{-1}$ and 0.74 Outdoor (AEDE), $mSvy^{-1}$. Due to the extremely high specific activity of the naturally occurring ^{226}Ra radionuclide in the insoluble calcium sulfate waste, the calculated exposure rate (ER) for insoluble calcium sulfate was found to be higher than the world permissible standard. The calculated hazard indices revealed that East Sebaiya low grade sedimentary phosphate sediments are suitable for use as material fertilizers in agriculture.

VII. THE ENVIRONMENTAL IMPLICATIONSOF THE RESULTS

Phosphates' Environmental Hazards: Inhaling dust and phosphate dust loaded with radioactive elements during operations (extraction, crushing, grinding, and manufacturing) at work sites and surrounding areas may infect the public with cancerous diseases and kidney diseases because this environment is dusty (Figure 2 and 3).Pollution of groundwater with radioactive elements in phosphate mines or ore washing water poses environmental risks when used in agriculture, drinking, or even bathing, (Figures 4 and5).

Contamination of phosphate fertilizers with toxic radioactive elements causes these elements to accumulate in the soil and thus be absorbed by plants, where they are then transmitted to humans when they eat vegetables and fruits, causing cancerous diseases, because phosphate rock contains high levels of uranium. According to an International Atomic Energy Agency(IAEA) [31] report from 1988, the permissible percentages of uranium in agricultural soils should not exceed 6 ppm. It should not exceed 0.1 ppm in plants, and there have been numerous Egyptian studies in areas where uranium levels have reached many times that percentage.

Because it is used in the fertilizer, pharmaceutical, food, pesticide, industrial detergents, animal feed, leather tanning, and chemical industries, phosphoric acid contaminated with radioactive elements poses a serious risk to human health if it is not purified of radioactive and toxic elements. See Figure (6).

Fig. 2: Dust saturation in the workplace during phosphate ore mining.

Fig. 3: Dust in the workplace during phosphate ore grinding.

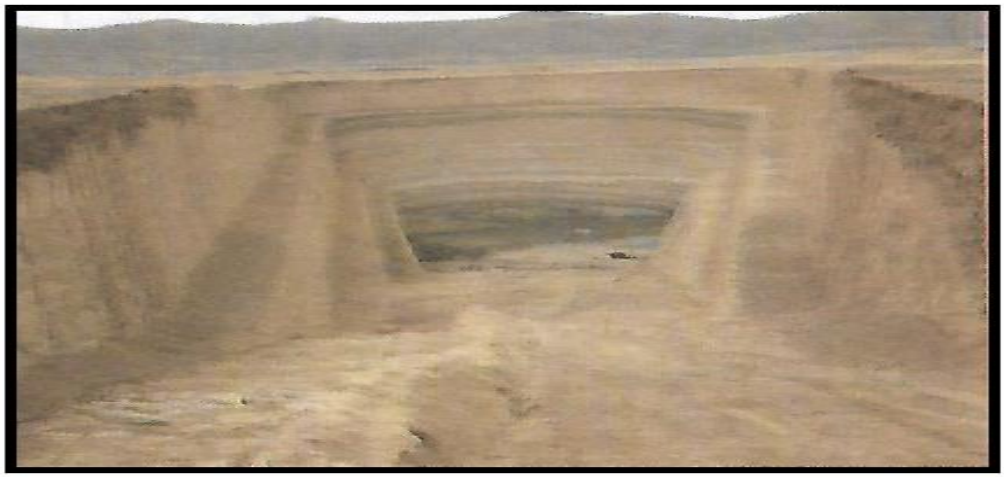

Fig. 4: Depicts groundwater presence in phosphate mines.

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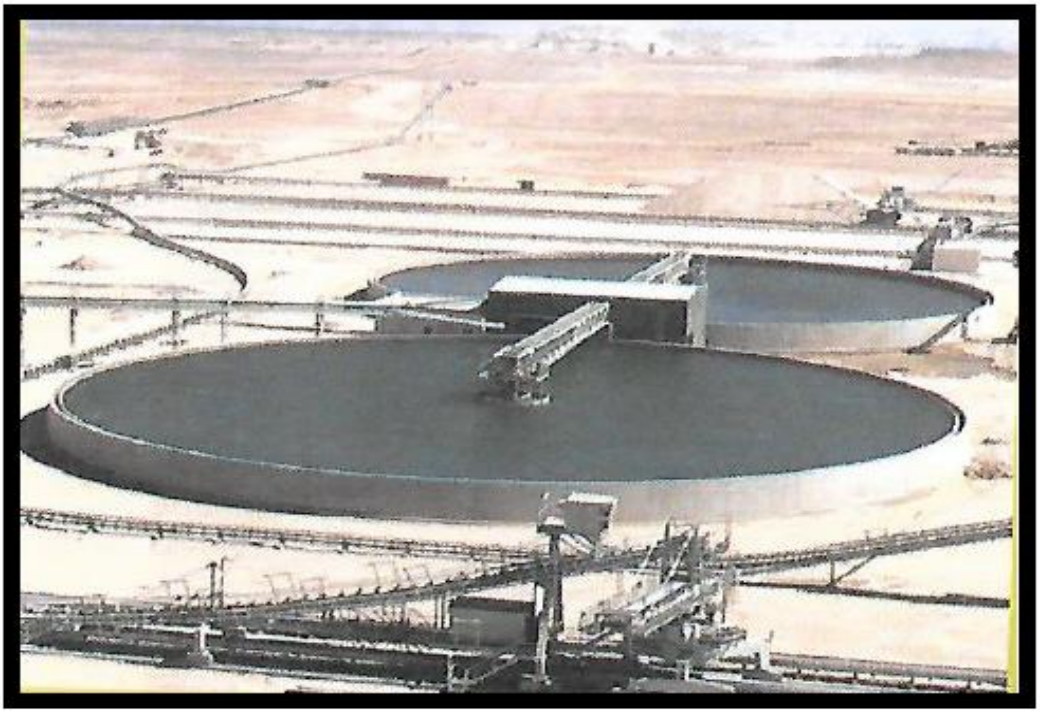

Fig. 5 depicts the phosphate ore washing water.

Fig. 6: Local phosphoric acid before and after treatment

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VIII. RECOMMENDATION

Insoluble calcium sulfate samples with a higher value of radium equivalent activity, external-internal hazard index, alpha and gamma absorbed dose rate, and exposure rate necessitate a specific measurement to control radiological hazards, along with periodic examination of laborers because they are more exposed to radiation hazards.

IX. WAYS TO SAFEGUARD WORKERS FROM PHOSPHATE-RELATED ENVIRONMENTAL DANGERS INCLUDE

Housing for phosphate mining and extraction employees should be placed away from work sites in the mines, taking into consideration that those buildings face the opposite direction of the wind, and phosphate fertilizer facilities should be built away from areas of population increase. Wearing work clothing on production sites (helmet, muzzle, glasses, shoes, gloves, and overalls), but not in sleeping quarters.Food should not be consumed in the workplace, whether in mines, factories, or chemical analysis laboratories.It is forbidden to use groundwater associated with phosphate layers or phosphate ore washing water in agriculture, drinking, or bathing because it contains radioactive elements that are harmful to both individual and societal health.Considering the proportions of radioactive and toxic elements in the phosphate fertilizer and phosphoric acid industries.Examining mine and phosphate fertilizer factory laborers on a regular basis and keeping medical records.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES

[1.] Olszewska-Wasiolek M., “Estimates of the occupational radiological hazards in phosphatefertilizers industry in Poland”,Radiat. Protect. Dosim. 58 p. 269-276 (1995).
[2.] Saueia C.H.R., Mazzilli B.P., “Distribution of natural radionuclides in the production and use ofphosphate fertilizers in Brazil” J. Environ. Radioact. 89 p. 229-239 (2006).
[3.] Sabiha-Javied M., Tufall M., Asghar M. “Hazard of NORM from phosphorite of Pakistan.” J. Hazard. Mater, 176 (1/3) p. 426-433 (2010).
[4.] Kovler K, Perevalov A, Levit A, Steiner V, Metzger L. “Radon exhalation of cementations materials made with coal fly ash: Part 2 testing hardened cement fly ash pastes” J Environ Radioactive 82(3):335-50; (2005).
[5.] Hassan S. F., Mira H. I. (internal report, Nuclear Materials Authority)"The Radiological and Environmental Survey of Black Sand Assessment Project",p16-17 (2014).
[6.] Iwaoka K., TabeH. and Yonehara H., "Natural radioactivity of bedsediment bath instruments and hot spring instruments in Japan”. J. Radioanal. Nucl. Chem. 295 p. 817-821(2013).
[7.] Nazaroff W.W., “Radon transport from soil to air” Rev. Geophys. 30 p. 137-160 (1992).
[8.] Korkmaz, B., & Turgut, S. A. “Research on the urea hydrolysis rate in the soil of Thrace region” Journal of Central European Agriculture, 6(2), 107e114 (2005).
[9.] International Atomic Energy Agency (IAEA), “Radiation Protection and Management of Norm Residues in the Phosphate Industry”. Safety Series No. 78 (2013).
[10.] ElmaadawyKh. G., Ezz El Din M, Khalid A. M., Abouzeid A.Z. “Mineral Industry in Egypt”– Part II Non Metallic Commodities –Phosphate Rocks, Journal of Mining World Express (MWE) 4, (2015).
[11.] Shehata, A. M., "Studies on the preparation of high purity phosphoric acid from some Egyptian phosphate ores". M. Sc. Thesis, Fac. of Sci., Zagazig Univ, (1993).
[12.] UNSCEAR, " Source, Effects and Risks of Ionizing Radiation. Report to the General Assembly", United Nations, New York (1998).
[13.] C. H. R. SAUEIA. “Radiochemical characterization of phosphorus andradiological implications of its use as a material forconstruction “, Dissertation, IPEN/CNEN, São Paulo University, 72p (1998).
[14.] Farai I.P. and Ademola J.A. “Radium equivalent activity concentrations in concrete building blocks in eight cities in Southwestern Nigeria“ J. Environ. Radioact., 79 p. 119–125 (2005).
[15.] Avwiri, G. O., Olatubosun, S. A., Ononugbu, C. P.“Evaluation of Radiation Hazard Indices for Selected Dumpsites in Port Harcourt, Rivers State, Nigeria “IJST., V3. P.663-673 (2014).
[16.] UNSCEAR, “Sources and Effects of Ionizing RadiationReport to the General Assembly “, New York: UnitedNation (2000).
[17.] K.A. Zarie, K.S. Al Mugren, “Measurement of naturalradioactivity and assessment of radiation hazard in soilsamples from Tyma area (KSA) “, Isotope Rad. Res. 42: 1-9.2 (2010).
[18.] Hassan N.M., Mansour N.A., Fayez-Hassan M. and Sedqy E." Elemental Analysis of Egyptian Phosphate Fertilizer Components Samples by TGA, DTA and IR Methods”, IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT), 7, p. 98–107(2013).
[19.] M.N. Alam, M.I. Chowdhury, M. Kamal, S. Ghose, M.N. Ismal,"The R, Th and K activities in beach sand minerals and beach soil of Cox’s Bazer, Bangladesh". J. Envron. Rad. 82: 1-6 (1999).
[20.] E.M.K Ashraf, H.A. Layi, A.A., Amany, A.M. Al-Omran, "NORM in clay deposits. Proceeding of third European IRPA Congress 2010" June 14-18, Helsinki, Finland. 1-9 (2010).

[21.] Righi S and BruzziL."Natural radioactivity andradon exhalation in building materials used in Italiandwellings". J Environ Radioact, 88: 158-170(2006).
[22.] Xinwei, L. &Xiaolon, Z. "Natural radioactivity measurements in Rock samples of Chihua Mountain National Geological Park", China.Radiat. Prot. Dosi. 128, 77–82 (2008).
[23.] Omeje, M. et al. "Natural radioactivity concentrations of 226-Ra, 232-Th, and 40-K in commercial building materials and their lifetime cancer risk assessment in dwellers", H. & Ecol. Risk Assess. An Inter. J. 24(8), 1–15 (2018).
[24.] Ravisankar, R. et al. "Spatial distribution of gamma radioactivity levels and radiological hazard indices in the East Coastal sedimentsofTamilnadu, India with statistical approach".Radiat. Phys. Chem. 103, 89–98. j. radphyschem. 2014. 05. 037(2014).
[25.] UNSCEAR, "Sources, effects and risk of ionizing radiation. Report to the general assembly, with scientific annexes (A and B) ", UnitedNations, New York (2012).
[26.] Shehzad, W. et al. "Estimation of background radiation levels and associated health risks in mineral rich district Chiniot, Pakistan". J. Radioanal. Nucl. Chem. 319(3), 1051–1058. (2019).
[27.] Alias, M., Hamzah, Z., Saat, A., Omar, M., Wood, A.“Assessment of Absorbed Dose and Radiation Hazard Index from Natural Radioactivity.”The Malaysian. J of Analytical Sciences. Vol 12 No. 1 pp 195-204 (2008).
[28.] Akhtar, N., Tufail, M., Ashraf, M. and Mohsin Iqbal, M. “Measurement of Environmental Radioactivity for Estimation of Radiation Exposure from Saline Soil of Lahore” Pakistan. Radiation Measurements, 39 p. 11-14 (2005).
[29.] UNSCEAR, "United Nations Scientific Committee on the Effects of Atomic RadiationSources and effects of ionizing radiation". Report to the General Assembly, with Scientific Annexes, (2008).
[30.] UNSCEAR, "United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and Effects of Ionizing Radiation", Report to the General Assembly. New York, NY, USA (2016).
[31.] IAEA, "Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards", Vienna, (2014).