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Natural radioactivity levels and radiological hazards indices of chemical fertilizers commonly used in Upper Egypt

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ABSTRACT

In order to determine the radiological hazards indices of chemical fertilizers commonly used in Upper Egypt, The concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in seven types of chemical fertilizers used in Upper Egypt have been measured by gamma spectrometry using NaI (Tl) 3″ × 3″ detector. The ranges of concentration levels of ^{226}Ra, ^{232}Th and ^{40}K were 12 ± 0.6–244 ± 12.6, 3 ± 0.2–99 ± 4.9, and 109 ± 5.5–670 ± 34 Bq kg^{-1}, respectively. In the other side, the range values obtained from fertilizer samples under investigation were (33.1–392.3 Bq kg^{-1}), (0.6–2.7), (15.6–177.8 nGy h^{-1}) and (20.1–229.1 μSv y^{-1}) for radium equivalent activity, γ-radiation hazard index $I_{\gamma r}$, Dose rate (nGy h^{-1}) and annual effective dose equivalent (AED) in the air to the occupational workers, respectively. The obtained values were compared with available reported data from other countries in literature.

1. Introduction

During the last decades agricultural activities have expanded widely, resulting in an increase in the applications of the different chemical fertilizers. Chemical fertilizers are chemical compounds that provide necessary chemical elements and nutrients to the plants. Fertilizers have become essential to the agricultural field all over the world (Chauhan, Chauhan, & Gupta, 2013). Phosphate rocks together with potassium ores and nitrogenous compounds are the main raw materials used for fertilizers in industrial production. As a matter of fact phosphorus, potassium and nitrogen are essential elements for plants growth.

More than 30 million tons of phosphate fertilizers are annually consumed worldwide, which increase crop production and land reclamation (El-Taher and Althoyaib, 2012). However, a possible negative effect of fertilizers is the contamination of cultivated lands by t some naturally occurring radioactive materials (NORM) (Lambert, Grant, & Sauve, 2007). The natural radionuclide of fertilizers consists mainly of uranium and thorium series radioisotopes and natural ^{40}K. Phosphate rocks are the starting material for the production of all phosphate products and main source of phosphorus for fertilizers. Phosphate rock can be of sedimentary, which represent about 85% of the phosphate rocks, were formed mainly from organic residues, the remaining parts of the phosphate rock, are of volcanic origin (Roselli, Desideri, Meli, & Feduzi, 2010).

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The concentration of ^{238}U and its decay products tends to be elevated in phosphate deposits of sedimentary origin, where typical ^{238}U series concentration is about 1500 Bq kg^{-1} (UNSCEAR, 1993). Therefore, when this rock is processed into phosphates' fertilizers, most radionuclides come into the fertilizers. Thus, fertilizers redistribute naturally occurring radionuclides at trace levels throughout the environment and become a source of radioactivity. This phenomenon may result in potential radiological risks due to possible migration of elements from the agricultural fertilizers to soil and plants, and via the food chain, to human begins where this may lead to internal exposure through ingestion of food grown on fertilizer soils, (Rehman, Imtiaz, Faheem, & Matiullah, 2006). In addition, during handling, packing and transporting fertilizers, some workers can receive additional external exposure. Therefore, it is important to measure natural radioactivity in fertilizers, because the high radioactive content may lead to significant exposure of miners, manufacturers and end users. Furthermore, such measurements provide basic data for the estimation of the amount of radioactivity spread on agricultural land along with fertilizers.

The present study has been carried out to establish a consistent radiological database for the concentration of the natural radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in some local fertilizer types, that used in agricultural soil of EL- Mynia governorate, Upper Egypt, to estimate their radiological impacts as a part of NRUE (Natural Radioactivity in Upper Egypt) project in physics department (faculty of science, Al-Azher University, Assuit branch, Egypt). The common fertilizers generally used in Upper Egypt are commercially named: Ammonium nitrate, Single super phosphate, Urea improved, Proprioceptive urea, Golden fertilizers and Mixed fertilizers (Nitrogen phosphorus, nitrogen potassium fertilizers and nitrogen phosphorus potassium).

2. Experimental technique

2.1. *Sample description and preparation*

Seven chemical fertilizers types were collected from the farmers and the markets. The investigated samples types are Urea improved (UI), Proprioceptive urea (PU), Ammonium Nitrate (AN), Single super phosphate (SSP), Nitrogen Potassium Fertilizers (NK), Nitrogen phosphorus (NP), and Golden Fertilizers (GF). The elemental analysis of one sample from each type of fertilizer was performed using X-ray fluorescence technique (XRF) the obtained results are listed in Table 1.

As shown in Table 1 the major range values of elemental concentrations in fertilizer samples using XRF were: Ca (0.0830–80.8%), Fe (1.95–31.19%), S (5.90–25.34%), Si (2.59–18.65%), P (2.76–10.1%), K (2.02–80.45%) and Mg (1.34–15.29%). The highest concentration of P was found in SSP (10.1%) and NP (8.45%) fertilizers. As expected the highest concentration of K was observed in NK (80.8%) fertilizer. Whereas GF fertilizer contain the highest concentration of Fe (31.19%) and Si (18.65%).

Forty-three samples of seven chemical fertilizers types were collected from the farmers and the markets. The collected samples, each are about 500 gm in weight, were dried in an oven at about 110 °C for 24 h to ensure that

Table 1 – Chemical composition (ms%) for different fertilizer samples using XRF spectrometry.

Element concentration %							
Elements	UI	PU	AN	SSP	NK	NP	GF
Mg	–	–	15.29	–	–	1.86	1.34
Ca	51.26	45.51	75.08	56.34	–	60.41	27.81
V	–	–	0.72	–	–	–	–
Mn	–	–	3.68	–	–	0.69	1.02
Fe	–	–	5.23	4.16	1.95	6.76	31.19
Al	–	–	–	–	–	–	5.59
Si	–	–	–	3.56	–	2.59	18.65
P	–	–	–	10.10	–	8.45	2.76
S	–	–	–	25.34	17.60	18.52	5.90
K	–	–	–	–	80.45	–	2.02
Ti	–	–	–	–	–	–	3.04
Zn	–	4.37	–	–	–	–	0.69
Sr	–	–	–	0.51	–	0.72	–
Cu	7.86	12.60	–	–	–	–	–
As	3.78	0.54	–	–	–	–	–
Rb	–	4.24	–	–	–	–	–
Nb	–	8.14	–	–	–	–	–
Hf	–	21.66	–	–	–	–	–
Ir	–	2.93	–	–	–	–	–
Co	9.96	–	–	–	–	–	–
Ni	6.20	–	–	–	–	–	–
As	–	0.54	–	–	–	–	–
Zr	3.30	–	–	–	–	–	–
Mo	7.29	–	–	–	–	–	–
Pb	10.34	–	–	–	–	–	–

moisture is completely removed; the samples were crushed, homogenized, and sieved through a 200 μm, which is the optimum size enriched in heavy minerals. Samples were placed in polyethylene beaker, of 350 cm^3 volume each and weighted. The beakers were completely sealed for 4 weeks to reach secular equilibrium when the rate of decay of the daughters becomes equal to that the parent this step is necessary to ensure that radon gas is confined within the volume and the daughters will also remain in the sample (Abbady, Uosif, & El-Taher, 2005).

2.2. *Instrumentation and calibration*

Radioactivity measurements were performed by gamma ray spectrometer, employing a scintillation detector 3 × 3 inch. Its hermetically sealed assembly which includes a high-resolution NaI (Tl) crystal, photomultiplier tube, an internal magnetic/light shield, aluminum housing and a 14 pin connector coupled to PC-MCA Canberra Accuspes. It has the following specifications: resolution 7.5% specified at the 662 keV peak of ^{137}Cs, window aluminum 0.5 mm thick, density147 mg/cm^2, reflector oxide; 1.6 mm thick; density 88 mg/cm^2, magnetic/light shield-conetic lined steel and operating voltage positive 902 V (dc). To reduce gamma ray background, a cylindrical lead shield with a fixed bottom and movable cover shielded the detector. The lead shield contained an inner concentric cylinder of copper (0.3 mm thick). The soft component of cosmic rays, consisting of photons and electrons is reduced to a very low level by 100 mm of lead shielding. The X-ray (73.9 keV) emitted from lead by its interaction with external radiation is suppressed by the copper layer (Abbady et al., 2005). The detection array was energy calibrated using ^{60}Co (1173.2 and 1332.5 keV), ^{133}Ba (356.1 keV) and ^{137}Cs (661.9 keV). The efficiency calibration curve was made using different energy peaks covering the range up to ~2000 keV. Efficiency and energy calibrations for each sample measurement were carried out to maintain the quality of the measurements. All procedures are described in previous publications (Uosif, 2007).

In order to determine the background distribution in the environment around the detector, an empty sealed beaker was counted in the same manner and in the same geometry as the samples. The measurement time of activity or background was 43,200 s. The background spectra were used to correct the net peak area of gamma rays of measured isotopes. The offline analysis of each measured γ-ray spectrum has been carried out by a dedicated software program genie 2000 (GENIE-2000, 1997). The ^{226}Ra radionuclide was estimated from the 351.9 keV γ -peak of ^{214}Pb, and 609.3 keV, 1120.3 keV, 1728.6 keV and 1764 keV γ -peak of ^{214}Bi. The 186 keV photon peak of ^{226}Ra was not used because of the interfering peak of ^{235}U, with energy of 185.7 keV. The ^{232}Th radionuclide was estimated from the 911.2 keV γ -peak of ^{228}Ac and the 238.6 keV γ -peak of ^{212}Pb. The ^{40}K radionuclide was estimated using the 1461 keV γ -peak from ^{40}K itself (Shams, Mohamed, and Reda, 2013). Fig. 1 represents an example of the energy spectra, indicating the gamma-ray lines of different origin compared with the background.

3. Results and discussion

3.1. *Activity concentrations*

Measured activity concentrations, as well as the uncertainty of ^{226}Ra, ^{232}Th and ^{40}K of different fertilizers types were listed

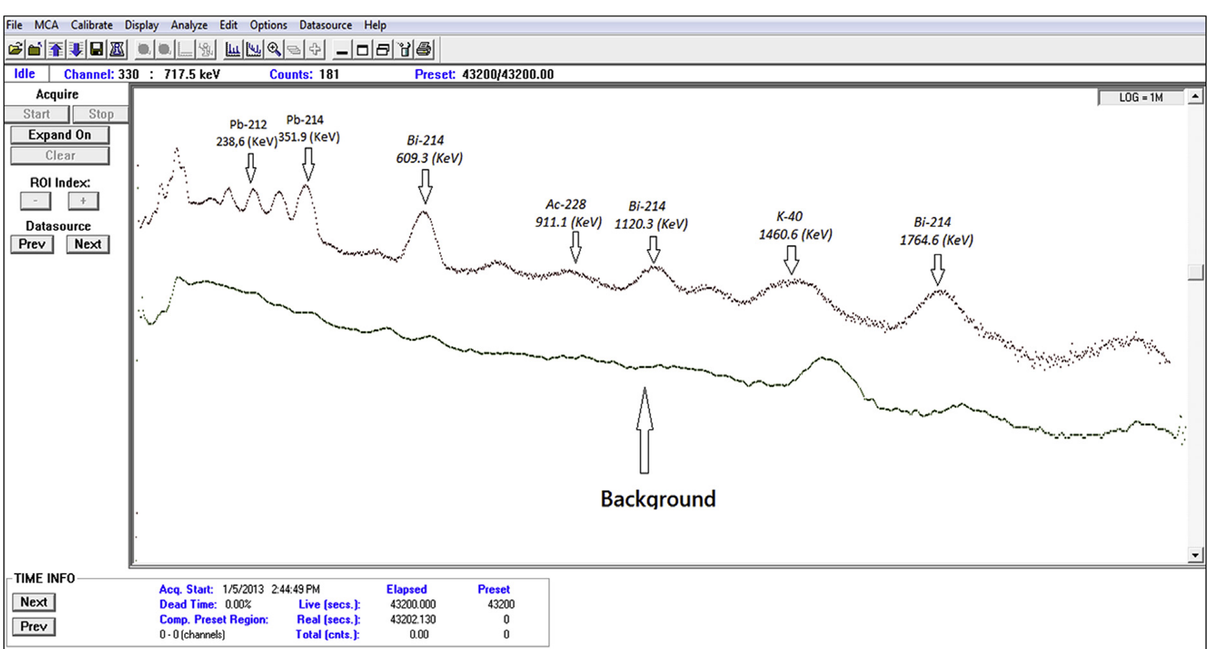

Fig. 1 – Typical spectrum after calibration indicating the gamma-ray lines of different origin compared with the background.

in Table 2. While Fig. 2, shows a comparison between the activity concentrations in Bq kg^{-1} for the all fertilizers samples under investigation. From the shown results can be seen that, the values of activity concentrations in the studied fertilizers varied from 12 ± 0.6 to 244 ± 12.6, 3 ± 0.2 to 99 ± 4.9 and from 109 ± 5.5 to 670 ± 34 Bq $kg^{-1}$for ^{226}Ra, ^{232}Th and ^{40}K respectively. The variation of radionuclides concentration in studied chemical fertilizers may be due to the different origins of raw material and chemical processing of the raw during fertilizer manufacture. The ^{226}Ra average concentrations in all studied chemical fertilizers except for NK and GF are higher than ^{232}Th concentrations. The highest mean value of ^{226}Ra activity concentrations are found in SSP fertilizer, while the corresponding values of ^{232}Th and ^{40}K are found in NK fertilizers. AN fertilizer presented the lowest mean values for ^{226}Ra and ^{40}K activity concentrations, while PU fertilizer presented the corresponding value for ^{232}Th.

Table 2 – Activity concentrations of 226Ra , 232Th and 40K in fertilizers samples.

Fertilizer code	Sample no.	Activity (Bq kg^{-1})		
		^{226}Ra	^{232}Th	^{40}K
UI	1	44 ± 2.2	10 ± 1.4	162 ± 8.1
	2	40 ± 2	11 ± 0.5	184 ± 9.2
	3	48 ± 3.2	8 ± 0.2	177 ± 8.6
	4	42 ± 2	12 ± 1.8	170 ± 8.2
	5	48 ± 2.4	10 ± 0.5	215 ± 10.8
	6	49 ± 2.5	12 ± 0.6	233 ± 11.6
	7	33 ± 1.6	3 ± 0.2	136 ± 6.8
	8	25 ± 1.2	8 ± 0.4	182 ± 9.1
	9	44 ± 2.1	8 ± 0.3	203 ± 10
Mean		41.4 ± 2.1	9.1 ± 0.7	184.7 ± 9.2
PU	10	15 ± 0.8	7 ± 1	209 ± 10.4
	11	17 ± 0.9	4 ± 0.2	203 ± 10.1
	12	18 ± 0.9	4 ± 0.7	200 ± 10
	13	12 ± 0.6	8 ± 0.4	213 ± 10.6
	14	21 ± 1	9 ± 1	160 ± 8
	15	17 ± 0.8	8 ± 1.19	164 ± 8.2
Mean		16.7 ± 0.8	6.7 ± 0.7	191.5 ± 9.6
AN	16	14 ± 0.7	6 ± 0.3	164 ± 8.2
	17	15 ± 0.8	7 ± 0.3	151 ± 7.6
	18	23 ± 1.2	11 ± 1.4	176 ± 8.8
	19	12 ± 0.8	7 ± 0.4	177 ± 8.8
	20	12 ± 0.7	8 ± 1.1	126 ± 6.3
	21	17 ± 1.1	5 ± 0.5	129 ± 7
Mean		15.5 ± 0.9	7.3 ± 0.7	153.8 ± 7.8
SSP	22	162 ± 8.1	36 ± 1.8	417 ± 20.9
	23	170 ± 8.4	40 ± 2.1	430 ± 21.1
	24	242 ± 12.4	90 ± 4.5	280 ± 14
	25	244 ± 12.6	88 ± 4.2	284 ± 14.3
	26	160 ± 8	98 ± 4.9	109 ± 5.5
	27	166 ± 8.3	58 ± 2.9	159 ± 11.3
Mean		190.7 ± 9.6	68.3 ± 3.4	279.8 ± 14.5
NK	28	43 ± 2.2	88 ± 4.4	639 ± 32
	29	59 ± 3	80 ± 4	591 ± 29.6
	30	41 ± 2	93 ± 5.3	670 ± 34
	31	57 ± 4.7	99 ± 4.9	364 ± 18.2
	32	44 ± 2.2	92 ± 4.6	346 ± 17.3
	33	66 ± 7.3	95 ± 4.7	435 ± 21.8
Mean		51.7 ± 3.6	91.2 ± 4.7	507.5 ± 25.5
NP	34	98 ± 4.9	31 ± 1.6	193 ± 9.7
	35	103 ± 5.2	43 ± 6.5	213 ± 10.8
	36	53 ± 2.7	15 ± 0.8	137 ± 6.9
	37	77 ± 4.3	55 ± 2.8	180 ± 9
	38	61 ± 3.4	40 ± 2	188 ± 9.4
	39	58 ± 3	29 ± 1.4	153 ± 7.7
Mean		75.0 ± 3.9	35.5 ± 2.5	177.3 ± 8.9
GF	40	52 ± 2.6	81 ± 4.1	206 ± 10.3
	41	48 ± 1.8	84 ± 3.3	199 ± 9.1
	42	42 ± 2.1	70 ± 3.5	186 ± 9.3
	43	46 ± 2.3	87 ± 4.4	177 ± 8.9
Mean		47.0 ± 2.2	80.5 ± 3.8	192.0 ± 9.4

Except for PU and AN fertilizers, all fertilizer samples showed that the mean concentrations of ^{226}Ra were higher than the permissible activity levels which are 35, 35 and 400 Bq kg^{-1} respectively for ^{226}Ra, ^{232}Th, and ^{40}K (UNSCEAR, 2000), while the mean concentrations of ^{232}Th were lower than the permissible activity levels except for SSP, NK and GF fertilizers. The mean concentrations of ^{40}K were lower than the permissible activity levels in all fertilizer samples except for NK fertilizer.

According to the average application rate of phosphate fertilizers is about 80 kg of P/ha/yr (Modaihsh, Al-Swailem, & Mahjoub, 2004). Therefore, the average annual rates of phosphate fertilizers are in the range of about 700–2000 kg/ha/yr that depend on the phosphate percentages (17–52%).Generally, the phosphate fertilizers are applied at rates of 600 kg/ha/yr (1 ha = 10, 000 m^2) (Da Conceicao & Bonotto, 2006). Based on this average application rate (600 kg/ha/yr). Thus, the range of the annual addition of natural radionuclides specific activities distributed per unit of arable land corresponds to 2.2–27.2, 0.95–13 and 9.7–72.3 Bq/m^2 for ^{226}Ra, ^{232}Th and ^{40}K, respectively. The results for the activity of ^{226}Ra, ^{232}Th and ^{40}K (Bq kg^{-1}), of the present work compared with other studies are presented in (Table 3).

4. The radiation hazard indices

4.1. *Radium equivalent (Ra_{eq})*

In order to compare the activity concentration of fertilizers samples, which contain ^{226}Ra, ^{232}Th and ^{40}K, the radium

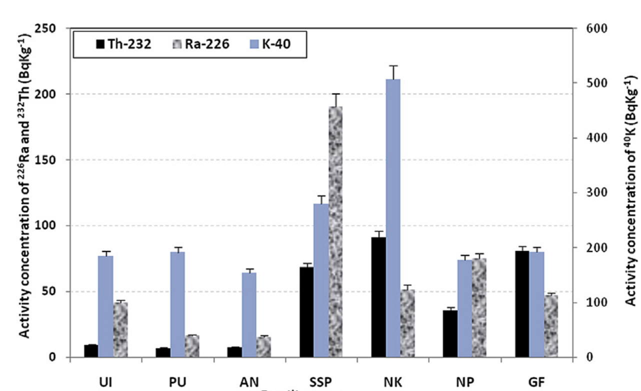

Fig. 2 – Comparison between Average values 0f ^{226}Ra, ^{232}Th and ^{40}K activity concentration in Bq kg^{-1} for Fertilizers samples.

Table 3 – Comparison of Mean of radioactivity concentration in fertilizers samples under investigation with those in other countries.

Country	Fertilizer type	Activity (Bq kg^{-1})			Ref.
		^{226}Ra	^{232}Th	^{40}K	
Egypt (EL-Mynia)	UI	41.4	9.1	184.7	Present work
	PU	16.7	6.7	191.5	Present work
	AN	15.5	7.3	153.8	Present work
	SSP	190.7	68.3	279.8	Present work
	NK	51.7	91.2	507.5	Present work
	NP	75.0	35.5	177.3	Present work
	GF	47.0	80.5	192.0	Present work
Egypt (Qena)	SSP	366	66.7	4	Ahmed and El-Arabi. (2005)
Egypt	SSP	8.2	61	627	Mourad, Sharshar, Elnimr, and Mousa (2009)
Pakistan	SSP	556	49.7	221	Khater and Al-Sewaidan (2008)
	NPK	386	38	885	Tahir, Alaamer, and Omer (2009)
India	SSP	527	7	87	Chauhan et al. (2013)
	NPK	79	28	1024	Chauhan et al. (2013)
	Urea	73	202	3	Chauhan et al. (2013)
Saudi Arabia	SSP	55.2	8.86	553	El-Taher and Mohamed (2013)
	NPK	70	25	2700	El-Taher and Mohamed (2013)
Bangladesh	SSP	292	15.6	143	Alam et al. (1997)
	Urea	5.4	3.4	7.9	Alam et al. (1997)
Algeria	NPK	162.5	124.5	8478	Wassila and Boucenna (2011)
USA	NPK	780	49	200	Guimond and Windham. (1975)
Germany	NPK	520	15	720	Khan, Khan, Tufail, Khatibeh, and Ahmad (1998)
Finland	NPK	54	11	3200	Mustonen (1985)
Nigeria	NPK	143	9	4729	Jibiri and Fasae (2012)
Brazil (Panama)	NPK	302	382	562.5	Becegato, Ferreira, and Machado (2008)
Brazil	SSP	871	100	375	Saueia, Mazzilli and Favaro (2005)

equivalent activity as a common index was used to obtain the sum of activities. The radium equivalent activities (Ra_{eq}) have been calculated on the estimation that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K produce the same gamma ray dose rate (Mohanty, Sengupta, Das, Saha, & Van, 2004). Therefore, the Ra_{eq} is given by (Camacho et al., 2010):

$$Ra_{eq} = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_{k} \quad (1)$$

where A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K (Bq kg^{-1}) respectively.

4.2. *Absorbed gamma dose rate (D)*

The absorbed dose rates due to gamma radiations in air 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 based on guidelines provided by UNSCEAR (Palomo, Peñalver, Aguilar, & Borrull, 2010). The conversion factors used to compute absorbed gamma dose rate (*D*) in air per unit activity concentration in Bq kg^{-1} (dry weight) corresponds to 0.462 nGy h^{-1} for ^{226}Ra, 0.604 nGy h^{-1} for ^{232}Th and 0.042 nGy h^{-1} for ^{40}K. Therefore *D* can calculate as follows (Ross and Riaz, 2008):

$$D = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.0417\ A_K \quad (2)$$

where A_{Ra}, A_{Th} and A_K having the same meaning as in Eq. (1).

4.3. *Gamma radiation hazard index $I_{\gamma r}$*

Another radiation hazard index called the representative level index, $I_{\gamma r}$, is defined from the following formula (Alam, Chowdhury, Kamal, Ghose, & Ismal, 1999; NEA-OECD, 1979), Where A_{Ra}, A_{Th} and A_K having the same meaning as in Eq. (1).

$$I_{\gamma r} = 0.0067\ A_{Ra} + 0.01\ A_{Th} + 0.00067\ A_K \quad (3)$$

4.4. *Annual effective dose (AED)*

Annual estimated average effective dose equivalent (AED) received by an individual was calculated using a conversion factor of 0.7 Sv Gy^{-1}, which was used to convert the absorbed rate to the human effective dose equivalent. The annual effective dose is determined using the following equations:

$$AED = DTF \quad (4)$$

where *D* is the calculated dose rate (in nGy h^{-1}), *T* is the occupancy time and *F* is the conversion factor (0.7 Sv Gy^{-1}).

Table 4 shown the obtained results for the radium equivalent (Ra_{eq}), Dose rate, γ radiation hazard index ($I_{\gamma r}$) and annual effective dose equivalent (AED) of the studied samples. From Table 4 it is observed that the values of radium equivalent in fertilizers samples are lower than the allowed maximum value of 370 Bq kg^{-1} (Beretka & Mathew, 1985) and fluctuate from 33.1 to 392.3 Bq kg^{-1}. ^{232}Th is the main contributor to Ra_{eq} in NK and GF fertilizers, while ^{226}Ra is main contributor to Ra_{eq} in other fertilizers. The sum of the relative contribution of ^{226}Ra and ^{232}Th to Ra_{eq} is 64–93% in all analyzed fertilizers as shown in Fig. 3.

The calculated $I_{\gamma r}$ values for the samples under investigation are given in Table 3. It is clear that the fertilizers samples lower than unity (Palomo et al., 2010), except in **SSP** (2.1) **and NK** (1.6) fertilizers. As shown in Fig. 4, ^{40}k is the lowest contributor to $I_{\gamma r}$ in all fertilizers except for PU fertilizer. The sum of the relative contribution of ^{226}Ra and ^{232}Th to $I_{\gamma r}$ is 58–91% in all analyzed fertilizers as we can see in (Fig. 5).

As listed in Table 3 the mean value of dose rates in UI, PU and AN fertilizers are lower than the international limit 59 nGy h^{-1} (Palomo et al., 2010), and it is higher than the international limit in SSP, NK, NP and GF fertilizers with mean values of 141, 100.1, 63.5 and 78.3 nGy h^{-1} respectively. Taking the occupancy time (that is, for a working period of 1820 h in a year) and a conversion factor of 0.7 Sv Gy^{-1} (UNSCEAR, 1988) to convert the γ-ray absorbed dose to effective equivalent for workers. The calculated of annual effective dose rate values in all samples received by the workers of the fertilizer plants are lower than the world allowed dose of 20 mSv/y (ICRP-60, 1990) and ranged from 20.1 to 229.1 μSv/y which do not cause any harm to the workers. As can be seen from Fig. 6, the sum of the

Table 4 – The equivalent radium (Ra_{eq}), dose rate and γ radiation hazard index ($I_{\gamma r}$) and annual effective dose (AED) of the studied samples.

Fertilizertype	Sample no.	Ra_{eq} (Bq kg^{-1})	Dose rate (nGy/h)	$I_{\gamma r}$	AED (μSv/y)
UI	1	70.8	33.1	0.5	42.7
	2	69.9	32.8	0.5	42.2
	3	73.1	34.4	0.5	44.3
	4	72.3	33.7	0.5	43.5
	5	78.9	37.2	0.6	47.9
	6	84.1	39.6	0.6	51
	7	47.8	22.7	0.3	29.3
	8	50.5	24	0.4	30.9
	9	71.1	33.6	0.5	43.3
Mean		68.7	32.4	0.5	41.7
PU	10	41.1	19.9	0.3	25.6
	11	38.4	18.7	0.3	24.1
	12	39.1	19.1	0.3	24.6
	13	39.8	19.3	0.3	24.8
	14	46.2	21.8	0.3	28.1
	15	41.1	19.5	0.3	25.1
Mean		40.9	19.7	0.3	25.4
AN	16	35.2	16.9	0.3	21.8
	17	36.6	17.5	0.3	22.5
	18	52.3	24.6	0.4	31.7
	19	35.6	17.2	0.3	22.1
	20	33.1	15.6	0.2	20.1
	21	34.1	16.3	0.3	20.9
Mean		37.8	18	0.3	23.2
SSP	22	245.6	114.0	1.7	146.8
	23	260.3	120.6	1.8	155.4
	24	392.3	177.8	2.7	229.1
	25	391.7	177.7	2.7	228.9
	26	308.5	137.7	2.1	177.3
	27	261.2	118.4	1.8	152.4
Mean		309.9	141	2.1	181.6
NK	28	218.0	99.7	1.6	128.4
	29	218.9	100.2	1.6	129.1
	30	225.6	103.1	1.7	132.7
	31	226.6	101.3	1.6	130.5
	32	202.2	90.3	1.4	116.3
	33	235.3	106.0	1.7	136.5
Mean		221.1	100.1	1.6	128.9
NP	34	157.2	72.0	1.1	92.8
	35	180.9	82.4	1.3	106.2
	36	85.0	39.3	0.6	50.6
	37	169.5	76.3	1.2	98.3
	38	132.7	60.2	0.9	77.5
	39	111.3	50.7	0.8	65.3
Mean		139.4	63.5	1.0	81.8
GF	40	183.7	81.5	1.3	105.0
	41	183.4	81.2	1.3	104.6
	42	156.4	69.4	1.1	89.4
	43	184.0	81.2	1.3	104.6
Mean		176.9	78.3	1.2	100.9

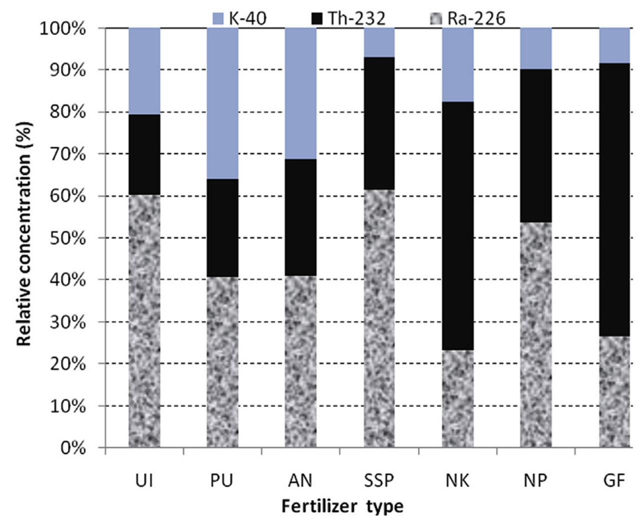

Fig. 3 – The relative concentration of ^{226}Ra, ^{232}Th and ^{40}K to Ra_{eq} in chemical fertilizers.

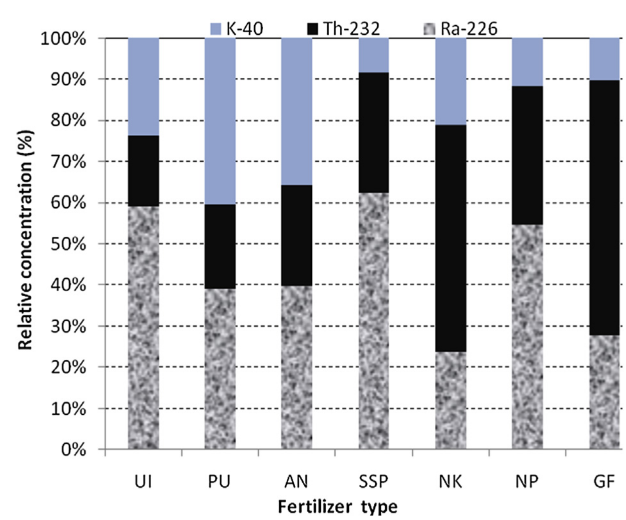

Fig. 4 – The relative concentration of ^{226}Ra, ^{232}Th and ^{40}K to dose rate and AED in chemical fertilizers.

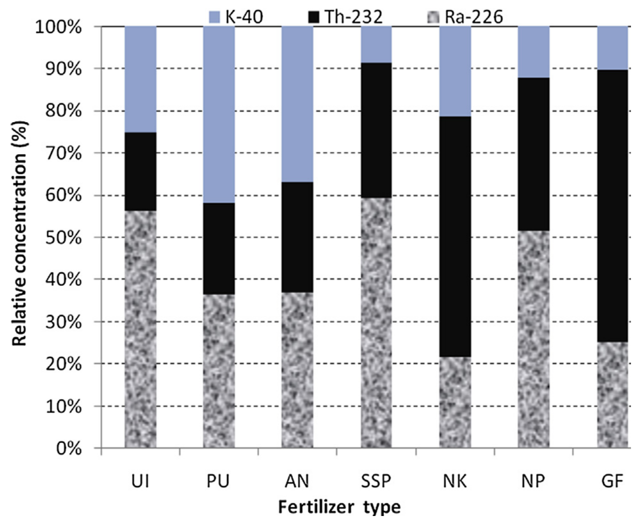

Fig. 5 – The relative concentration of ^{226}Ra, ^{232}Th and ^{40}K to $I_{\gamma r}$ in chemical fertilizers.

relative contribution of ^{226}Ra and ^{232}Th to doses is 60–92% in all analyzed fertilizers. ^{226}Ra is the main contributor to doses in most fertilizers. ^{40}k is the lowest contributor to doses in all fertilizers except for PU fertilizer.

5. Conclusion

The levels of natural radioactivity and related radiation hazards in various chemical fertilizers used in Upper Egypt were assessed by γ-ray spectrometry. The following conclusions can be obtained:

1. The activities in **SSP** > **NK** > **GF** > **NP** > **UI** > **PU** > **AN**.
2. The more save chemical fertilizers for agriculture soil are proprioceptive urea (PU) fertilizer and Ammonium nitrate (AN) fertilizers.

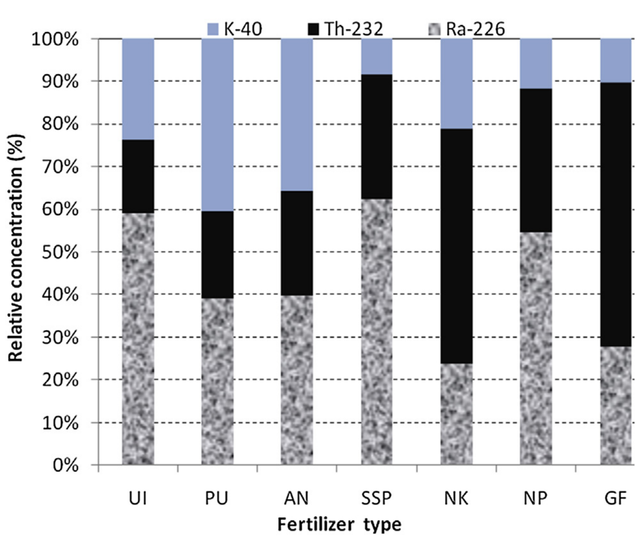

Fig. 6 – The relative concentration of ^{226}Ra, ^{232}Th and ^{40}K to dose rate and AED in chemical fertilizers.

3. In all investigated samples, the values of annual effective dose rate AED received by the workers of the fertilizer plants are lower than the world allowed dose of 20 mSv/y (ICRP-60, 1990) and ranged from 20.1 to 229.1 μSv/y.
4. The use of fertilizers in large extent have affected radionuclides concentration, especially phosphorus and potassium containing fertilizers are the one of the cause of presence of high activity of ^{226}Ra and ^{40}K in soil. The application of these fertilizers has the effect of an accumulation of radioactivity in soils that can be harmful for the health of farmers, workers and consumers of the products.

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