Comparative assessment of natural radionuclides content of cement products from Assiut cement factories, Egypt

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Abstract

Cement industry is one of the basic industries that play an important role in the national economy of developing countries. In this study, a comparison between cement products from factories on Assiut, Egypt (Assiut Cement Company (ACC) & Building Materials Industry Company (BMIC)) was presented to evaluate their radiological impact on human health as building materials. Activity concentration of ^{226}Ra ^{232}Th, and ^{40}K in different types of cement products were collected from both factories has been measured using HPGe gamma spectrometry. The results indicated that a highest activity concentration from ACC was from the Portland cement where the lowest was SRC cement. In BMIC, the SRC cement activity concentration was almost similar with Portland cement activity concentration. The range of radionuclide concentrations in the all cement products for both factories were found to be lower than the world average limits (50, 50,500 Bq/Kg) for ^{226}Ra ^{232}Th and ^{40}K respectively in building materials. For estimating radiation hazard indices, the radium equivalent, external and internal hazard indexes, Representative level index ($I_{\gamma r}$), annual effective dose, the absorbed dose rate and excess lifetime cancer risk were considered. All of them were found below the acceptable limits. Therefore, this study confirmed that all cement samples from ACC & BMIC are radiologically safe to be used as building materials, with no significant impact of radiological hazards provided.

Keywords: Natural radioactivity, Cement, Radiation Hazards, Assiut Cement Company (ACC), Building Materials Industry Company (BMIC).

Introduction

Cement is considered as the important construction materials for houses and building in Egypt, it's used for plastering the buildings walls, which made of bricks, when mixed with other materials, such as fine sand, to make the concretes, sand blocks, floors, walls, bridges and even roof finishing [1] .There are many types of cement according to the chemical composition and hydraulic properties for each one. Portland cement is the most prevalent one, it results from the grinding of clinker. The clinker is produced by burning a mixture of limestone, clay, and gypsum at high temperatures (1450- 1600ºC) for the materials, and approximately 2000ºC for the combustion fumes [2].

Cement consists of natural occurring radioactive materials (NORM), such as uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K); depending on geological and geographical conditions as well as geochemical characteristics of these materials. Human exposure to radiation through cement industry as building materials can be divided into internal and external exposure, the internal exposure is caused by the inhalation of radioactive inert gas ^{222}Rn (a daughter product of ^{226}Ra) and its short-lived secondary decay products whereas the external exposure is caused by direct gamma radiation [2].

Workers who are exposed to cement for a long time in their manufactoring sites as well as people that spend about 80% of their time inside offices and homes, are exposure to radiation continuously [3,4]. Hence, it's great important to evaluate the radioactivity of cement to assess the radiological hazards to human health.

In the light of the various applications of cement industries, the knowledge of radiological hazard from cement is necessary. The aim of this study is to evaluate the natural radionuclide content of different types of cement product from Assiut factories and estimate the potential radiological hazards from using cement as building materials and comparing them with values obtained from other factories in Egypt and other countries . The data of this study may be used by the Egyptian Authority for the Development and Implementation of Radiation Protection guidelines for the use and management of cements in the country. The data obtained in this study will add to the world database of radioactivity content in cement as a building material.

Radioactivity is defined as the process of emitting of radiation in the form of particles because of nuclear reaction. There are different sources of radioactivity. The main sources of natural radiation are some radioactive materials in the earth's crust, emanation of radioactive gas from the earth, cosmic rays from outer space which bombard the earth, trace amounts of radioactivity in the body. Water, soil and food which are incorporated to the human body, to building materials, and to products that contain radioactive sources from nature are some examples of earth radioactivity sources. in the outer space. The radiation is produced by the atomic bombardment of the upper atmosphere by high-energy cosmic rays and sources in the atmosphere, such as the radon gas released from the Earth's crust, which then decays into radioactive atoms attach to airborne dust, and other particulate (granular, powder) materials.

Materials and method

1. The study area:

Assiut governorate has two large cement factories; Assiut Cement Company (ACC) & Building Materials Industry Company (BMIC). These two factories are far away from each other about 42 kilometers. They provide large cement products in the Assiut local market.

(1) Assiut Cement Company (ACC):

ACC has three cement production lines with production capacity of 3.8 million metric tons / year, CEMEX has invested to increase the capacity to 5.7 million metric tons / year, almost 50% more. It's located in the center of Egypt, 400 km south of Cairo, at (9°10'27" N 31°0'52"E), Al Wadi Al Gadid Road, and 3.5 km from Assiut city.

(2) Building Materials Industry Company (BMIC):

BMIC has one cement production line, with production capacity of 1.8 million metric tons/year. It's located at (27^{o} 02' 47'' N and 31^{o} 00' 43'' E) 22 Kilometers, Assiut Sohag desert Road, 53 km from Assiut city.

2. Chemical Analysis

Energy-dispersive X-ray fluorescence (EDXRF) is a device used in qualitative and quantitative elemental analysis. The X-ray fluorescence (XRF) technique is a nondestructive quick measurement, rapid sample preparation and the preparation can be automated. XRF analysis has unique advantages, allowing for non-destructive elemental analysis at ambient air pressure [5,6,7,8]. Multi-element concentrations were determined by using XRF technique (Model JSX-3222) in Central Laboratory, South Valley University, (Qena). Cement samples were crushed, then grind in Herzog mill to rich fine powder (it feels like flour when rubbed between the fingers). Two samples were prepared from each spacimen. One pressed powder sample was prepared in order to measure the trace elements, the other one (fused bead) was prepared in order to measure the major elements.

3. Sampling and Sample Preparation

A sample is a subset of a large group that is representative. This sample is used in research for economic reasons. Random sampling technique is used in this study in which twelve cement final product samples from ACC (Portland, El-Mohands, Sulphate resistant cement (S.R.C) and El

Saeed); for comparison with product from BMIC, twelve cement final products samples (Portland & S.R.C) were taken from Assiut local market to measure the specific radioactivity concentration of ^{226}Ra, ^{232}Th, and ^{40}K. The specifications of the different types of cement product from both factories are given in Table1. Each sample was packed in plastic container and sealed well, then weighed and stored for a minimum period of one month to reach secular equilibrium where the rate of decay of the radon daughters becomes equal to that of 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.

4. Radioactivity Measurement

All samples were measured in the Nuclear Physics Laboratory at the Physics Department, Faculty of Science, Assiut University, Egypt, using a gamma ray spectrometer with HPGe model GR4020 setup and multichannel analyzer of 16384 channels. The detector had closed-end coaxial Gamma-ray detectors (p-type) made of high purity germanium (HPGe) in a vertical configuration, cooled with liquid nitrogen with the following specifications: resolution (FWHM) ≤ 2.000 keV and ≤0.925 keV at 1.33 MeV and 122 keV, respectively, the relative efficiency is 40%. The germanium crystal is located inside a lead shield to reduce the environmental background. The detector is shielded in a chamber of 4 layers with the following specifications: Outer Jacket 9.5 mm (3/8 in.) thick low carbon steel, Bulk Shield 10 cm (4 in.), thick low background lead and Graded Lining 1 mm (0.040 in.) tin, and 1.6 mm (0.062 in.) Copper [9].

The system was calibrated for energy and efficiency. The energy calibration was carried out by acquiring a spectrum from radioactive standards of known energies such as ^{137}Cs (662 keV) and ^{60}Co (1332 and 1172 keV). For the efficiency calibration Canberra's Geometry Composer, instead of standard source, was used [9].

The spectra were either evaluated with the computer software program Genie2000, or manually with the use of a spread sheet (Microsoft Excel) to calculate the natural radioactivity. The radioactivity concentration of ^{226}Ra was determined from the photopeaks of ^{214}pb (295.22, 351.93 keV) and ^{214}Bi (609.31, 1120.29, 1764.49 keV). The concentration of ^{232}Th was determined from the photopeaks of ^{228}Ac (911.2, 968.97 Kev), ^{212}pb (238.63Kev) and ^{208}Ti (583.19, 2614 keV), while ^{40}K was determined from the 1460.8 keV photopeak.

Result and Discussion

1. Comparison between the Natural Radionuclides in Cement Product from ACC & BMIC

The measured activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K for ACC & BMIC cement final product are listed in tables (2&3) respectively. The tables show that a highest activity concentration from ACC cement type was the Portland cement whereas the lowest was SRC cement. In BMIC, the SRC cement activity concentration was almost similar with Portland cement activity concentration. The average activity concentrations of the radionuclides in Portland cement samples from ACC were found to be slightly high when compared with those of BMIC, while SRC cement samples from BMIC were somewhat higher than that in ACC. The range of radionuclide concentrations in the all cement products for both factories were found to be below world average of (50, 50, 500 Bq/kg) for ^{226}Ra, ^{232}Th, and ^{40}K respectively in building materials as shown in Fig.(3&4) [10]. Cement products from ACC & BMIC did not pose a significant radiological hazards when used for building construction.

The average activity concentration of ^{40}K in ACC & BMIC was the highest in all the samples when compared with the other two radionuclides (^{226}Ra &^{232}Th), as show in Fig.2. This is typical and expected from any geologically derived material due to the relative abundance of ^{40}K in the natural environment [11].

2. Comparison between the Natural Radionuclides in Portland Cement from (ACC & BMIC) With The Egyptian & World Cement Factories

Some experimental values were presented for reported data of other Egyptian & world cement factories are given for comparison in Fig. (5&6). In the Egyptian factories, the highest value of ^{226}Ra activity concentration in Portland cement was from the Qena Factory (48.4 Bq/Kg) and the lowest value was from the El-kawmya Factory (21.4 Bq/Kg), in ^{232}Th activity concentration the highest value was from in El-Kawmya factory (270.8 Bq/Kg) and the lowest value was from Helwan & Seuez Factories (16 Bq/Kg) and in ^{40}K activity concentration the highest value was from in ACC present study (277 Bq/Kg) and the lowest value was from Seuez Factory (88 Bq/Kg) as shown in Fig.5 [12]. There is a good agreement of our results for ^{226}Ra and ^{232}Th activity concentration with the results obtained by [13] in Portland cement from Assiut Cement Company (ACC), while a variation can be observed for ^{40}K activity concentration.

The average activity concentrations for the Portland cement in the current study was compared with other countries, the ^{226}Ra and ^{232}Th from ACC& BMIC were higher than the concentrations from Greece, Malaysia, Cuba and Qatar, factories , and lower than the concentrations from Jordan, China, Turkey and India, factories. For ^{40}K the activity concentrations from ACC & BMIC were higher than Malaysia, Qatar, Jordan, China, Turkey and India, factories, and lower than the activity concentrations from Greece and Cuba, factories as shown in fig.6 [12].

3. Comparison between the Radiation Hazard Indices in Cement Product from ACC & BMIC:

A common index termed radium equivalent activity is required to obtain the total activity concentration and is also used to assess the gamma radiation hazards. Since 98% of the radiological effects of the uranium series are produced by radium and its daughter products, the contribution from the ^{238}U and the other ^{226}Ra precursors is usually ignored, so that the Ra_{eq} of a sample can be expressed as [14].

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

Where A_{Ra}, A_{Th} and A_k is the specific activity in Bq/Kg. This equation is based on the assumption that 10 Bq/Kg of ^{226}Ra, 7 Bq/Kg of ^{232}Th and 130 Bq/Kg of ^{40}K produce the same γ-radiation dose rate. The radium equivalent of the average activity of the cement samples calculated from ACC is shown in Table 4. The highest value of Ra_{eq} was seen in Portland cement (90 Bq/kg) and the lowest in SRC cement (70Bq/kg). From Table 5, the highest value were from SRC cement (76 Bq/kg) whereas the lowest value was from Portland cement (72 Bq/kg) .However, all the values obtained from both factories for radium equivalent activity fall far below the criterion limit, as the use of materials whose radium equivalent activity concentration exceeds 370Bq/kg is discouraged.

Representative level index ($I_{\gamma r}$) is another radiation hazards index primarily used to estimate the level of γ radiation associated with different concentrations of some specified radionuclides and can be expressed as follows:

$$I\gamma r = \frac{1}{150} A_{Ra} + \frac{1}{100} A_{Th} + \frac{1}{1500} A_K \qquad (2)$$

Where A_{Ra}, A_{Th} and A_k is the specific activity in Bq/kg. The representative level index (Iγ) values obtained from ACC & BMIC are shown in Table 4 & 5. It should be noted that the average $I_{\gamma r}$ values for all kinds of cement samples from both factories observed fall within a very narrow range and are less than unity, the upper limit for the representative level. This would tend to confirm that the samples under investigation exhibit a very low gamma radiation level.

Beretka and Mathew [14] defined two other indices that represent the external and internal radiation hazards. The external hazard index is obtained from radium equivalent activity through the supposition that it allows a maximum value equal to unity. corresponding to the upper limit of Ra_{eq} (370Bq/kg). This index value must be less than unity in order to keep the radiation hazard insignificant. The radiation exposure, due to the radioactivity from construction materials, is limited to 1.0mSv/y. Then, the external hazard index can be defined as:

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

The highest values of H_{ex} from ACC were from Portland 0.24 and the lowest value from SRC 0.19, while in BMIC, the values of Portland and SRC were almost similar (0.19, 0.20).

The internal hazard index H_{in} was calculated and given by the equation:

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

The internal hazard index should also be less than unity. The highest values of H_{in} from ACC were from Portland (0.33) and the lowest from SRC (0.27). In BMIC the values of Portland and SRC were nearly the same (0.27, 0.28). The obtained results for cement products from both factories are lower than the acceptable level.

For evaluating the external exposure from naturally occurring radionuclides ,the absorbed dose rates outdoor (D) due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated by UNSCEAR (2000). The conversion factors used to compute the absorbed γ-dose rate (D) in air per unit activity concentration in Bq/kg (dry weight) corresponds to 0.462 nGy/h for ^{226}Ra (of U-series), 0.621 nGy/h for ^{232}Th and 0.0417 nGy/h for ^{40}K [15,16].

$$D\ (nGy/h) = 0.462A_{Ra} + 0.621\ A_{Th} + 0.042A_k \qquad (5)$$

Where A_{Ra}, A_{Th}, and A_k are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Bq/kg, respectively. Table 4 shows that the highest values of absorbed dose rate from ACC were from Portland (43 nGy/h) and the lowest from SRC (33nGy/h).while BMIC the values of Portland and SRC were very similar (32, 34), as shown in Table 5. The obtained data for the absorbed dose rate for both factories is still within the standard limit of 60 nGy/h.

To estimate the annual effective dose rates outdoor, one has to take into account the conversion coefficient from the absorbed dose in air to effective dose (0.7 Sv/Gy) and outdoor occupancy factor (0.2) proposed by UNSCEAR (2000) [16] are used. Therefore, the annual effective dose rate (mSv/y) was calculated by the formula [16].

$$AED\ (mSv/y) = D\ (nGy/h) \times 8760\ h \times 0.7 \times 10^{-6} (Sv/Gy) \times 0.2 \qquad (6)$$

The worldwide annual effective dose from the natural sources of radiation in areas of normal background is estimated to be 1 mSv/y by UNSCEAR (2000). Table 4&5 shows the estimated annual effective dose rate obtained in the general brands of cements analyzed, the values obtained from ACC & BMIC fall within a very narrow range (0.04 to 0.04) from0.03 mSv/y to 0.06 mSv/y with an average value of 0.05 mSv/y. The result is quite less than 1.0 mSv/y as prescribed by UNSCEAR (2000), the maximum tolerable dose from building materials. This indicates that the cements used in Assiut are radiologically safe going by the annual effective dose rate world standard.

Excess lifetime cancer risk (ELCR) can be defined as the excess probability of developing cancer at a lifetime due to exposure level of human to radiation. Excess lifetime cancer risk is calculated using the equation

$$ELCR = AEDE \times DL \times RF \qquad (7)$$

where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and risk factor (Sv^{-1}), fatal cancer risk per sievert. For stochastic effects, ICRP 60 uses values of 0.05 for the public [17.18,17]. Working in cement factory, staying in cement distribution (retail) store or living in a house built with cement as major building material may increase once chance of cancer risk. If the radioactivities in these environments are higher than the world average, it could be a source of radiation to the inhabitants whose ELCR would be greater than the world average of 0.29

mSv/y in such environment. From Table 4 & 5, the obtained ELCR levels in all the cement samples analyzed from ACC & BMIC were below the world standard limit.

4. The Comparison between Radiation Hazard Indices in Portland cement From (ACC & BMIC) With Egyptian Cement Factories

Figures (7&8) shows the comparison of the reported values of the radiation hazard indices in Portland cement obtained from the Egyptian cement factories with those determined in this study. It can be observed from these figures that the values of all radiation hazard indices in Portland cement from ACC & BMIC are within the range with all Egyptian cement factories except for El-Kawmya factory; this is due to the higher activity concentration value in ^{232}Th [16]. Elemental Analysis by Wavelength Dispersive X-Ray Fluorescence Spectrometry was used to determine the concentration of Si, Fe, Mg, Ca, Na, S, Ti and Al for different types of cement products from ACC & BMIC, as shown in table 6.

Conclusion

The natural radionuclide content and their consequent radiation hazard indices, due to different types of cement products from Assiut Cement Company (ACC) & Building Materials Industry Company (BMIC), were compared. The activity concentrations of ^{226}Ra ^{232}Th and ^{40}K for all measured samples of Portland cement in both factories are comparable with the corresponding values of other Egyptian factories. The obtained results showed that the average concentrations of the radionuclides in cement samples from ACC & BMIC factories were found to be lower than world values limits. The averages of radiation hazard parameters for both factories are lower than the acceptable level 370Bq/kg for radium equivalent Ra_{eq}, 1 for level index $I_{\gamma r}$, the external hazard index $H_{ex} \leq 1$ and 59 (nGy/h) for absorbed dose rate. In conclusion, the results of this study have clearly shown that cement used from ACC & BMIC for construction and building of houses is radiologically safe and may not cause any significant health hazard to human, and are well within values obtained in other countries of the world

Fig.1: location of ACC & BMIC.

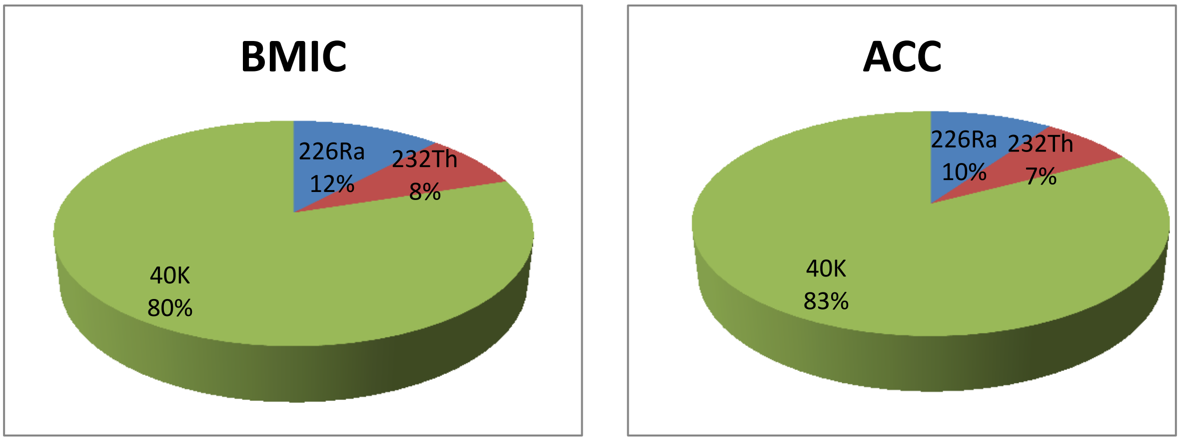

Fig.2: Percentage contribution of the three naturally occurring radionuclides in the cement product from ACC & BMIC.

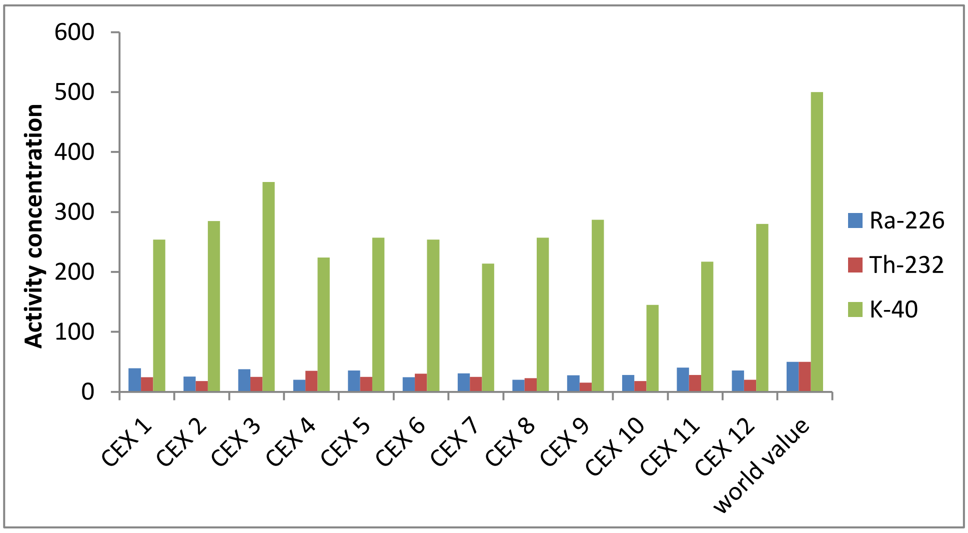

Fig.3: Comparison between activity concentration of ^{226}Ra, ^{232}Th and ^{40}K from ACC cement product with world value.

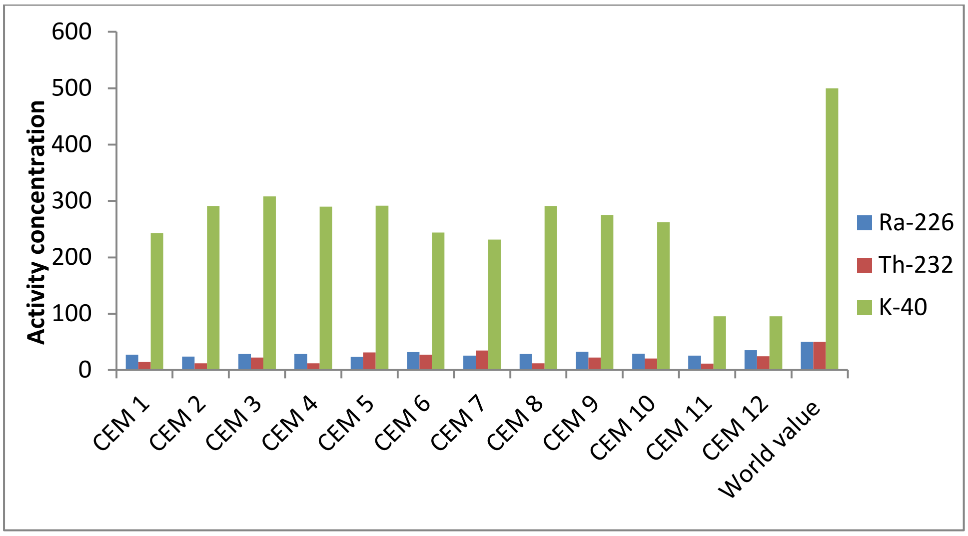

Fig.4: Comparison between activity concentration of ^{226}Ra ^{232}Th and ^{40}K from BMIC cement product with world value.

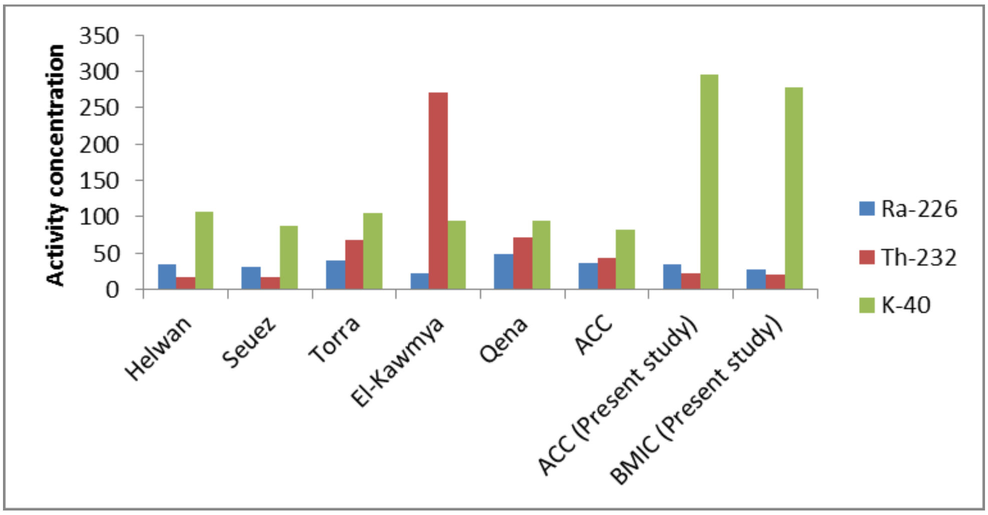

Fig. 5: Comparison of average activity concentration (Bq/Kg) of Portland cement samples from ACC & BMIC with Egyptian cement factories [16].

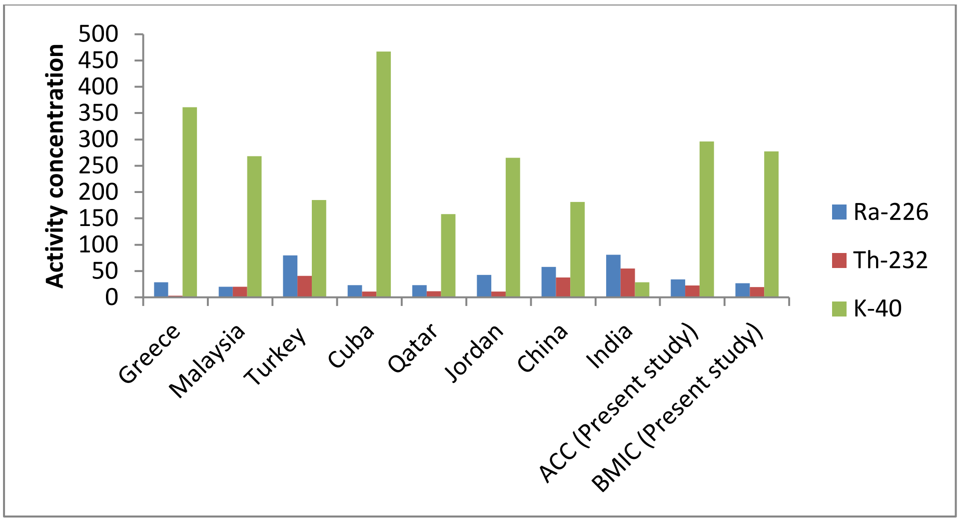

Fig. 6: Comparison of average activity concentration (Bq/Kg) of Portland cement samples from ACC & BMIC with world cement factories[16].

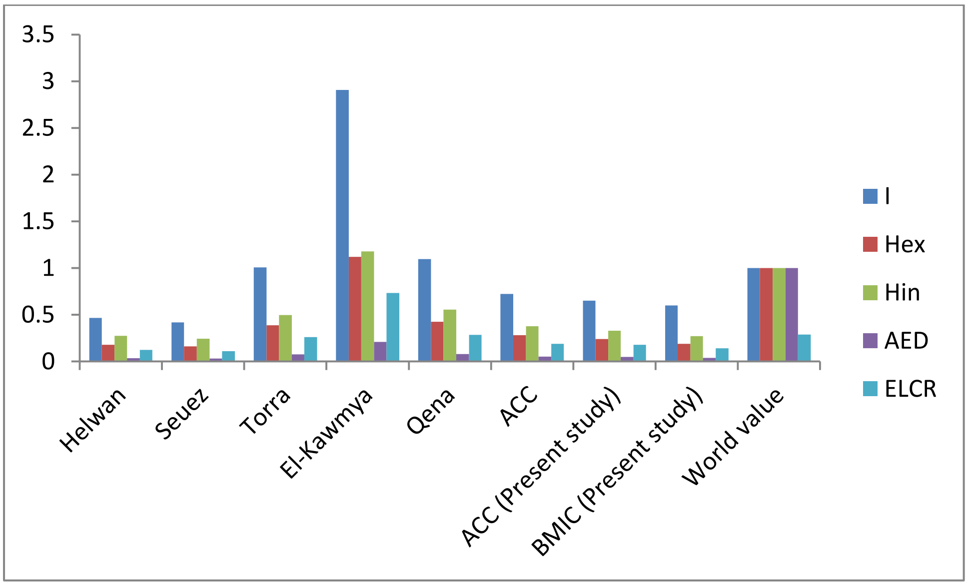

Fig.7: Comparison of some hazards indices for Portland cement samples from ACC & BMIC with those from Egyptian cement factories[16].

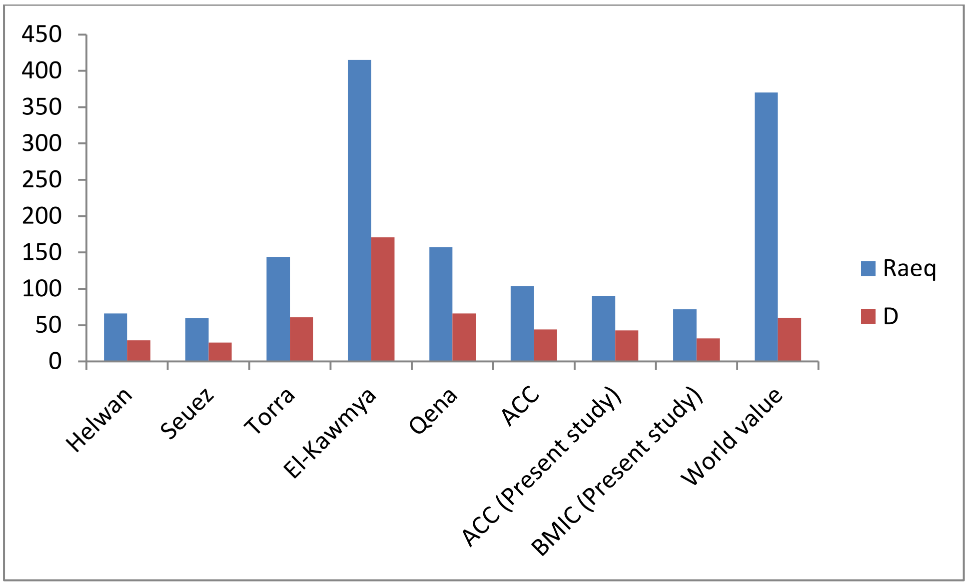

Fig.8: Comparison of Ra_{eq} and absorbed dose rate (D) for Portland cement samples from ACC & BMIC with those from Egyptian cement factories [16].

Table 1: Specifications of the different types of ACC & BMIC cement product.

Factory	Cement type	Raw materials
ACC	Portland SRC El- Mohandas	Clinker in range of 88-89%: natural gypsum 5%; limestone & slag 6%
	El Saeed	Clinker in range of 85%: natural gypsum 7%; limestone & slag 8%
BMIC	Portland SRC	Clinker in range of 90-95%: natural gypsum, limestone & slag 5%

Table 2: Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in different types from ACC cement product.

Cement type	Samples code	Activity concentration in (Bq/Kg) ^{226}Ra	^{232}Th	^{40}K
Portland	CEX 1	41.9±7.6	24.46±7.82	254±12
	CEX 2	24.9±5.2	18±7.52	285.±15
	CEX 3	38.8±4.1	25±5.6	350±21
	Average	35.2±4.7	22.4±5.52	296±18
SRC	CEX 4	21.3±5.6	20.1±7.3	221±12
	CEX 5	32.5±5.3	22±4.2	259±15
	CEX 6	21.3±7.4	13±4.5	255±17
	Average	25±6.4	18.3±6.5	245±14
El-Mohandas	CEX 7	30.6±4.7	24±4.6	212±12
	CEX 8	19± 7.3	23± 4.9	259±13
	CEX 9	26.7±6.2	16.3± 2.7	287±14
	Average	25.4±6.9	21.1± 4.5	252.6±20
El Saeed	CEX 10	28.2±6.2	18±2.7	245±11
	CEX 11	41.3±5.5	27±4.4	217± 8
	CEX 12	34.8±8.2	21±4.4	280±9
	Average	34.7±6.2	22±5.2	247±22

.

Table 3: Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in different types from BMIC cement product.

Cement type	Samples code	Activity concentration in (Bq/Kg) ^{226}Ra	^{232}Th	^{40}K
Portland	Cem 1	27.4±6.6	14.46±1.82	242.82±10.8
	Cem 2	23.63±6.21	11.8±1.52	240.8.±12.76
	Cem 3	28.5±6.3	22±2.9	220±12.1
	Cem 4	28.5±0.72	12±1.52	210±13.7
	Cem 5	23.3±5.6	31.1±3.3	212.7±12.7
	Cem 6	31.5±7	27±3.28	220±11
	Average	27±5.6	19.7±2.56	224±12.5
SRC	Cem 7	25.3±6.6	34.4±4.5	231.4±10.1
	Cem 8	28.5±6.4	11.8±1.51	290.5±12.71
	Cem 9	32.6±7.7	22±2.61	275±12.1
	Cem 10	29± 8.1	20.6± 1.9	262±13
	Cem 11	25.7±7.2	11.2± 0.75	95.3±3.7
	Cem 12	35.3±5.9	24.2± 1.5	200.8±7.8
	Average	29.4±5.6	20.7±1.6	225.5±10.4

Table 4: Average radiation hazards indices in different types from ACC cement product.

Cement type	Ra_{eq}	$I_{\gamma r}$	H_{ex}	H_{in}	D	AED	ELCR
Portland	90	0.65	0.24	0.33	43	0.05	0.18
SRC	70	0.5	0.19	0.25	33	0.04	0.14
El- Mohandas	76	0.55	0.20	0.27	36	0.04	0.15
El Saeed	85	0.6	0.23	0.32	40	0.05	0.16

Table 5: Average radiation hazards indices in different types from BMIC cement product.

Cement type	Ra_{eq}	$I_{\gamma r}$	H_{ex}	H_{in}	D	AED	ELCR
Portland	72	0.52	0.19	0.27	32	0.04	0.14
SRC	76	0.55	0.20	0.28	34	0.04	0.15

Table 6: Chemical analysis of different types of cement samples from ACC & BMIC.

Factory	Cement type	Si%	Fe%	Mg%	Ca%	Na%	S%	Ti%	Al%
ACC	Portland	27.9	7.44	2.32	45.43	1.33	4.26	0.91	6.59
	SRC	20.27	5.27	1.47	57.88	0.69	3.95	0.54	4.55
	El-Mohandas	27.29	7.37	2.2	47.21	1.30	4.23	0.90	6.40
	El Saeed	28.90	6.13	1.31	51.90	0.66	1.53	0.56	4.41
BMIC	Portland	19.99	5.38	1.47	57.33	0.34	5.64	0.44	4.95
	SRC	21.94	5.75	1.62	57.97	0.40	4.22	0.41	4.72

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تقييم لمحتوى منتجات الاسمنت للنويدات المشعة الطبيعية: دراسة خاصة بمصانع الاسمنت في أسيوط-جمهورية مصر العربية

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الملخص

هدفت هذه الدراسة إلى تقييم محتوى منتجات الاسمنت للنويدات المشعة الطبيعية ومدى تأثيرها على صحة الانسان: دراسة خاصة بمصانع الاسمنت في أسيوط-جمهورية مصر العربية. تمت المقارنة بين مصنعي شركة اسمنت أسيوط وشركة صناعات مواد البناء.
استخدمت تقنية مطيافية جاما لتحليل العينات باستخدام كاشف الجرمانيوم عالي النقاوة وتم حساب تركيز النظائر المشعة بوحدات بيكريل/كغم لكل من للنويدات المشعة والراديوم-226 والثوريوم-232 والبوتاسيوم-40 على التوالي في الاسمنت البورتلاني والاسمنت المقاوم للكبريتات.
لقد أظهرت نتائج التحليل بأن أكثر تركيز النشاط الإشعاعي في مصنع شركة اسمنت أسيوط كان عاليا في الاسمنت البورتلاندي بينما كان منخفضًا في الاسمنت المقاوم للكبريتات. بالنسبة لشركة صناعات مواد البناء فقد كان التركيز متشابهًا أو متساويًا. لقد أظهرت الدراسة أيضًا بأن معدل النويدات المشعة في كلا المصنعين لكلا النوعين من الاسمنت كانت منخفضة عن المعدل العالمي. وبالتالي فإن هذه الدراسة تؤكد بان كلا النوعين من الاسمنت في كلا المصنعين آمنة ويمكن استخدامها في مواد البناء من بدون أي اضرار أو مخاطر إشعاعية للإنسان.

الكلمات المفتاحية: النشاط الإشعاعي، الاسمنت، مخاطر إشعاعية، مصنع اسمنت أسيوط، شركة صناعات مواد البناء.