

SHORT REPORT

Measurement of radioactivity and hazard index of Gonadal dose in selected Cement samples in Iraq

Abdulhussein Abdalmear Alkufi, Shatha Farhan Alhous, Shaymaa Awad Kadhim

Abstract

Given the importance of cement as a basic material in construction, this study was undertaken to evaluate the level of radioactivity in a selected group of cement samples most used in construction to determine whether they are safe for human health. In this investigative study, nine samples of cement, both domestic and imported, that are often used in construction projects in Iraq were gathered. A NaI (TI) gamma-ray spectrometer (3"x3") was used to measure the radioactivity in the samples. The average specific activity levels in the tested cement samples were 11.373 ± 0.522 , 5.795 ± 0.230 , and 179.123 ± 2.207 Bq/Kg, respectively. Also calculated was the average of the radium, which was equivalent to 33.449 ± 1.022 Bq/kg. As for the risk indicators, the internal risk coefficient was 0.121 ± 0.004 and external risk coefficient was 0.090 ± 0.002 . While studying the radiation doses, the values of effective annual internal dose was 0.080 mSv/y, external dose rates were 0.020 mSv/y, absorbed dose ratio was 16.321 ± 0.476 nGy/h, and gamma index was 0.253 ± 0.007 . In the end, and depending on what was studied from various variables, with an average of 115.59 Sv/y, the annual gonadal equivalent dose risk (AGED) was calculated. The world average values were used to compare all the results. Finally, it was discovered that the radiation parameter levels of none of the samples had a detrimental effect on human health.

Keywords: Radium, Radioactivity, Thallium, Potassium, Uranium, Gamma Rays, Cement.

DOI: <https://doi.org/10.47391/JPMA-BAGH-16-87>

Introduction

Globally, there has been an increase in the need for cement manufacturing, and there has been increased riding¹. Several studies have been conducted to look into the radionuclides, for example uranium (^{238}U), thorium (^{232}Th), and radioactive potassium isotope (^{40}K) series,

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Department of Medical Physics, University of Babylon, Babel, Iraq.

Correspondence: Shaymaa Awad Kadhim

Email: Shaymaa.alshebly@uokufa.edu.iq

etc., present in cement since it has been used as a building material². Furthermore, thorough knowledge of the radiological properties of cement enables a more accurate estimation of radiation exposure. When used as raw materials in the production of cement, slag, fly ash, silica fume, kiln, and automobile and truck tires generate both occupational and environmental health issues³. Even low-level natural radioactivity in building materials can result in exposure to it, both internally and externally⁴. The main source of internal radiation exposure the short lived radon daughter products that are released into the room air from construction materials primarily harm the respiratory system⁵. Gamma radiation from uranium and thorium decay chains as well as potassium in soil samples gathered from various places in Najaf can produce external radiation exposure⁶. In order to evaluate the radioactive dangers to human health, it is essential to be aware of the radioactivity in building materials⁷. A study observed that all raw material samples had radioactive levels that were below the normal levels for building materials around the world⁸. The objective of the current study is to quantify the ^{238}U , ^{232}Th , and ^{40}K of nine cement samples procured from markets in Najaf province. After that, the radiological parameters of natural radionuclides such as the equivalent activity of radium, annual effective internal and external dose rates, internal and external danger indices, as well as the rate of indoor absorbed dose, and annual gonadal equivalent dose risk have been measured in cement samples as it is more sensitive to radiation.

Methods

Sampling and sample preparation: Most of the cement used in Iraq's construction and housing comes from local markets and manufacturers. Of the nine samples analysed, four were local and five imported. Samples were gathered in Iraq from the study area, Najaf and Kufa, near the cement factory, in March 2020, to study the extent to which samples are free from high radiation levels. Samples were divided into two categories, as indicated in Table 1, based on colour. The sample code, colour, name, and nation of origin are shown in front of each sample in Table-1.. To prevent radon loss and give radon daughters enough time to reach equilibrium before gamma

measurement spectrometry, samples were prepared in containers that were closed, fixed, and stored for more than 30 days. Since the samples were already in powdered form with a mass of one kilogram, they were measured without any processing. The spectra were first measured with empty containers (empty samples), and then the measurement was performed immediately, without any chemical processing, with the containers loaded with weighed amounts of materials⁹. The background and sample counting were done for a period of five hours. Gamma-ray detector measurements were carried out in the physics department of University of Kufa's school for girls.

Gamma ray spectrometric analysis: High penetrating strength of gamma rays was analysed in the materials and identification of radioisotopes present in cement as ²³⁸U, ²³²Th, and ⁴⁰K by using gamma-ray spectroscopy technology. A scintillation detector NaI (TI) with a 3" x 3" crystal dimension and a multi-channel analyser (MCA) (ORTEC-Digi Base) with 4096 channels are connected via an interface to an analogue-to-digital convertor (ADC) device¹⁰. The spectroscopic measurements and analysis were performed using the MAESTRO-32 programme on the lab PC¹¹.

Calculation of Specific Activity and Radiation Hazard Indices: The gamma line, that showed up in each sample's spectrum five hours after it was placed in the detector system, was used to determine the precise activity for each sample, based on the equilibrium weighted mean value of their individual decay products. The specific activity of ²³⁸U was calculated using the gamma-ray lines 1765 keV (214Bi) and flow halt, and the similar results of ²³²Th were calculated using the gamma-ray lines 2614 keV (208Tl), as the specific activity of ⁴⁰K was measured by its own gamma ray at 1460.8 keV. The

$$A \frac{\text{Bq}}{\text{kg}} = \frac{N}{\epsilon \cdot I_\gamma \cdot m \cdot t} \quad (1)$$

relative technique was used to calculate the estimated activity quantities, as shown in the following equation¹².

Where I_γ gamma is the intensity, N net area of the peak (counts per second), detector efficiency at particular energy, m sample weight (kg), and t counting time (sec).

Calculating the radium equivalent activity (R_{eq}), which is a weighted sum of the activities of ²³⁸U, ²³²Th, and ⁴⁰K and is based on the premise that 370 (Bq/kg) R_{eq} is

$$R_{\text{eq}} \frac{\text{Bq}}{\text{kg}} = A_U + 1.43 A_{\text{Th}} + 0.077 A_K \quad (2)$$

defined by the formula given below, allows to evaluate e

the radiation dangers associated with the radionuclides¹³.

Where: A_U , A_{Th} , and A_K are, respectively, the activity concentrations of ²³⁸U, ²³²Th, and ⁴⁰K in Bq/kg.

For radiation hazard to be deemed insignificant, the

$$H_{\text{in}} = \frac{A_U}{370} + \frac{A_{\text{Th}}}{259} + \frac{A_K}{4810} < 1 \quad (3)$$

internal hazard index (H_{in}) and the external hazard index

$$H_{\text{ex}} = \frac{A_U}{185} + \frac{A_{\text{Th}}}{259} + \frac{A_K}{4810} < 1 \quad (4)$$

(H_{ex}) from the formulae below should both be less than unity¹⁴:

In order to determine the yearly effective dose (AD), one

$$\text{Indoor } \frac{\text{mSv}}{y} = AD(\text{nGy h}) \times 10^{-6} \times \frac{8760\text{h}}{y} \times 0.8 \times 0.7 \frac{\text{Sv}}{\text{Gy}} \quad (5)$$

must consider the conversion factor (0.7 SvG/y). The

$$\text{Outdoor } \frac{\text{mSv}}{y} = AD(\text{nGy h}) \times 10^{-6} \times 8760\text{h}/y \times 0.2 \times \frac{0.7\text{Sv}}{\text{G}} \quad (6)$$

occupancy factors of 0.2 and 0.8, respectively, were used to calculate the yearly effective dose rates in units of mSv/y, which are common for indoor and outdoor environments globally¹⁵.

Any material that a radioactive substance interacts with absorbs the radiation it emits. The United Nations

$$AD \frac{\text{nGy}}{\text{h}} = 0.462 A_U + 0.604 A_{\text{Th}} + 0.042 A_K \quad (7)$$

Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2000)¹⁶, gave the following dosage conversion factors: 0.462, 0.604, and 0.042, respectively. For converting the activity concentrations of ²³⁸U, ²³²Th, and

$$I_\gamma = \frac{A_U}{150} + \frac{A_{\text{Th}}}{100} + \frac{A_K}{1500} < 1 \quad 8$$

⁴⁰K into dose rates, these variables are used to compute the total absorbed dose rate in air as follows:

Finally, using the following equation, gamma index I_γ was used to determine the danger from gamma radiation associated with radioactive natural nuclei studied in the

$$\text{AGED } (\mu\text{Sv}/y) = 3.09 A_U + 4.18 A_{\text{Th}} + 0.314 A_K \quad (9)$$

sample under study ¹⁷.

For UNSCEAR (2008)¹⁸, the reproductive organ is crucial. Due to the particular activity of ²³⁸U, ²³²Th, and ⁴⁰K, this dose is, therefore, equivalent to yearly effective dose rates. To determine the annual gonadal equivalent dose (AGED), the following formula was used¹⁹.

The average annual gonadal equivalent dose (AGED) for the samples under examination was 7.751×10^{-3} mSv/y, which was below the global permitted value and does not endanger human health.

Due to their high radiation sensitivity, the reproductive glands are vital to UNSCEAR, since it is well known that an increase in AGED has an impact on the bone marrow, and red blood cells are destroyed and replaced by white blood cells. Therefore, the equal annual reproductive dose from cement samples must be determined²⁰.

Results and Discussion

Table 1 lists the radionuclide's particular activity that was examined in the samples, along with the related statistical error, where the values of ²³⁸U, ²³²Th, and ⁴⁰K ranged from 4.220 ± 0.327 to 20.187 ± 0.716 Bq/kg, 3.616 ± 0.184 to 8.002 ± 0.274 Bq/kg, and 85.917 ± 1.542 to 266.747 ± 2.717

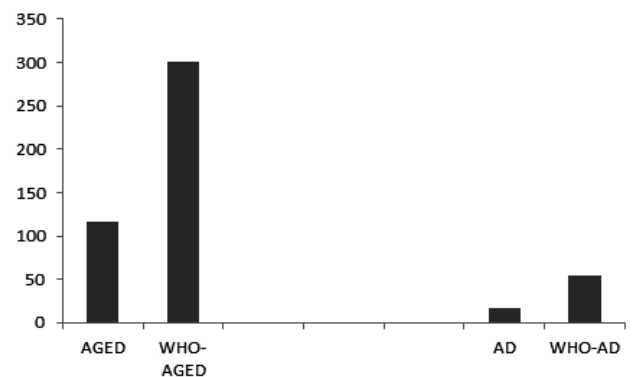


Figure: Comparison between the total absorbed annual dose and annual gonadal equivalent dose risk.

Bq/kg, respectively.

The results in Table 1 indicate that sample C9 had the highest concentration of uranium and sample C1 had the lowest concentration, while sample C8 had the highest concentration of thorium and sample C6 had the lowest. However, sample C9 had the highest concentration of potassium and sample C7 had the lowest concentration. All the results for ²³⁸U, ²³²Th, and ⁴⁰K were below the permissible limit, as published by UNSCEAR (2000)¹⁶.

The values shown in Table 1 for cements from different nations have also been compared to the specific activity of the nuclides studied in the current study. In the samples computed using equation 2, from lowest to greatest, the radium equivalent ranged between 20.359 ± 0.788 to 51.632 ± 1.308 Bq/kg, according to Table 2. In the current study (Raeq), the values were lower than the maximum advised limit of 370 Bq/kg²¹. Samples' internal and external hazard indices (Hin and Hex, respectively) were determined, which ranged from 0.077 ± 0.003 to 0.194 ± 0.005 and 0.054 ± 0.002 to 0.139 ± 0.003 , respectively. The results indicate that Hin and Hex are less than unity in samples investigated. Gamma metric ly: in order to determine whether the safety criteria for building materials are being met, samples were analysed and 'I' was used to evaluate the risk from gamma radiation linked with radioactive natural nuclei, where it ranged from 0.150 ± 0.005 to 0.388 ± 0.009 ²¹.

The lowest and maximum values of the indoor annual effective dose, as well as the yearly effective dose rates and absorbed dose, were determined as given in Table 2. Outdoor annual effective dose, and absorbed dose varied from 0.047 ± 0.001 to 0.123 ± 0.002 mSv/y, 0.011 ± 0.004 to 0.030 ± 0.007 mSv/y, and 9.779 ± 0.370 to 25.185 ± 0.610 nGy/h, during the current study. The annual effective

Table-1: Specific activity in some types of cement and comparison with other countries of the world.

Sample code	Name of sample	Origin (nation)	Specific Activity (Bq/kg)		
			²³⁸ U	²³² Th	⁴⁰ K
C1	Algesr	Iraq (Karbala)	4.311 ± 0.201	4.220 ± 0.327	183.404 ± 2.253
C2	Saveh	Iran (Arak)	8.491 ± 0.464	4.555 ± 0.206	155.669 ± 2.075
C3	Saman	Iran (Kermanshah)	18.051 ± 0.677	6.161 ± 0.240	171.391 ± 2.178
C4	Portland	Turkey (Merin)	14.187 ± 0.600	6.508 ± 0.247	178.532 ± 2.222
C5	Saman	Iran (Kermanshah)	9.432 ± 0.489	7.523 ± 0.265	178.615 ± 2.223
C6	Carr	Iraq (Najaf)	5.161 ± 0.362	3.616 ± 0.184	179.003 ± 2.225
C7	Benvid	Iran (Isfahan)	8.237 ± 0.600	3.850 ± 0.190	85.917 ± 1.542
C8	Larestan	Iran (Fars)	14.365 ± 0.604	8.002 ± 0.274	212.799 ± 2.426
C9	Alasad	Iraq (Najaf)	20.187 ± 0.716	7.626 ± 0.267	266.747 ± 2.717
Min	-	-	4.220 ± 0.327	3.616 ± 0.184	85.917 ± 1.542
Max	-	-	20.187 ± 0.716	8.002 ± 0.274	266.747 ± 2.717
Ave	-	-	11.37 ± 0.5222	5.795 ± 0.230	179.12 ± 2.207
Worldwide	-	-	35	30	400
Slovakia	-	-	156.5	18.4	-
Pakistan	-	-	272.9	28.7	-
Cameroon	-	-	184.8	24.6	-
Turkey	-	-	55.0	5.0	-
Japan	-	-	505.2	25.6	32.3
Nigeria	-	-	140.5	62.7	30.1
Finland	-	-	251.0	19.9	-
Saudi Arabia	-	-	86.0	45.3	-
Sudan	-	-	77.6	8.9	25.1
Egypt	-	-	93.0	19.0	35.0

Table-2: Radiological hazard indexes, effective dose rate and radiation doses .

ID	Raeq (Bq/kg)	Hazard Index		I _y	Effective dose rate(mSv/y)		AD(nGy/h)	AGED(μSv.y ⁻¹)
		Hin	Hex		Indoor	Outdoor		
C1	24.507±0.788	0.077±0.003	0.066±0.002	0.193	0.060	0.015	12.274	88.649
C2	26.992±0.920	0.095±0.003	0.072±0.002	0.205	0.064	0.016	13.243	94.157
C3	40.059±1.189	0.156±0.005	0.108±0.003	0.296	0.094	0.023	19.312	135.347
C4	37.241±1.125	0.138±0.004	0.100±0.003	0.278	0.088	0.022	18.0418	127.100
C5	33.944±1.041	0.117±0.004	0.091±0.002	0.257	0.080	0.020	16.477	116.676
C6	24.115±0.797	0.079±0.003	0.065±0.002	0.189	0.059	0.014	12.094	87.269
C7	20.359±0.848	0.077±0.003	0.054±0.002	0.150	0.047	0.011	9.779	68.523
C8	42.193±1.183	0.152±0.004	0.113±0.003	0.317	0.100	0.025	20.479	144.655
C9	51.632±1.308	0.194±0.005	0.139±0.003	0.388	0.123	0.030	25.185	178.013
Min	20.359±0.788	0.077±0.003	0.054±0.002	0.150	0.047	0.011	9.779	68.523
Max	51.632±1.308	0.194±0.005	0.139±0.003	0.388	0.123	0.030	25.185	178.013
Ave	33.449±1.022	0.121±0.004	0.090±0.002	0.253	0.080	0.020	16.321	115.59
W.D ¹⁸	370	<1	<1	<1	<1	<1	55	300

dose of each sample analysed in the current investigation is less than 01 mSv, satisfying the safety requirement. Gonadal dose was also calculated, and all values were within the average of 115.599 Sv/y,²² and they were compared as in Figure 1, within the globally advised limits as well as the ICRP's advised safety level for the general population²³. Therefore, these samples do not provide any health risks to the people.

The results in Table 2 show that the highest risk factors were in the sample C9, the reason for this is the nature of the soil and rocks from which the cement is made and contains radioactive isotopes, while the lowest risk factors were in the sample C7, all results of risk factors were smaller than the limit recommended by UNSCARE (2000) and ICRP.

Conclusion

The radioactivity of long-lived gamma emitters and the results of the annual gonadal equivalent dose risk assessment were compared with the average global activity of raw materials used in the manufacture of cement in order to estimate the radiological dangers to human health. The examined cement may be safe for use in building construction with no adverse effects on workers or residents of all ages, including children and adults (UNSCEAR), according to the results (ICRP). Since just a few varieties of cement used as building materials have been analysed in the current study, it is recommended that the level of naturally occurring radioactive elements in other types of cement and other building materials be investigated. This investigation may serve as a baseline for future research.

Disclaimer: None.

Funding Disclosure: None.

Source of Funding: None.

References

1. Kosmatka SH, Kerkhoff B, Panarese WC. Design and Control of Concrete Mixtures, 14th ed. Illinois, USA: Portland Cement Association, 2002.
2. Yasir MS, Majid AA, Yahaya R. Study of natural radionuclides and its radiation hazard index in Malaysian building materials. *J Radioanal Nucl Chem* 2007;273:539-41. doi: 10.1007/s10967-007-0905-7.
3. Kosmatka SH, Kerkhoff B, Panarese WC. Design and Control of Concrete Mixtures, 13th ed. Illinois, USA: Portland Cement Association, 1988.
4. Gjeçi E, Karaja T, Xhixha G, Shyti M. Characterization of natural radioactivity in building materials. In: The International Physics Conference Tirana 2015. Tirana, Albania: Proceedings Book; 2015.
5. Aswood MS, Alhous SF, Abdulridha SA. Life Time Cancer Risk Evaluation Due to Inhalation of Radon Gas in Dwellings of Al-Diwaniyah Governorate, Iraq. *Nat Environ Pollut* 2022;21:331-7. doi: 10.46488/NEPT.2022.v21i01.040.
6. Makki NF, Kadhim SA, Alasadi AH, Almayahi BA. Natural Radioactivity Measurements in different regions in Najaf city, Iraq. *International Journal of Computer Trends and Technology (IJCTT)* 2014;9:286-9. doi: 10.14445/22312803/IJCTT-V9P154.
7. Hussain H, Hussain R, Yousef R, Shamkhi Q. Natural radioactivity of some local building materials in the middle Euphrates of Iraq. *J Radioanal Nucl* 2010;284:43-7.
8. El-Taher A, Makhluaf S, Nossair A, Abdel Halim AS. Assessment of natural radioactivity levels and radiation hazards due to cement industry. *Appl Radiat Isot* 2010;68:169-74. doi: 10.1016/j.apradiso.2009.09.001.
9. Alhous SF, Kadhim SA, Alkufi AA, Muhmood AA, Zgair IA. Calculation of radioactivity levels for various soil samples of Karbala - Najaf road (Ya- Hussein) / Iraq. *IOP Conf Ser Mater Sci Eng* 2020;928:072076. DOI: 10.1088/1757-899X/928/7/072076.
10. Tomarchio EAG. Evaluation of full-energy-peak efficiencies for a LaBr3:Ce scintillator through a Virtual Point Detector approach. *Radiat Phys Chem* 2024;216:111463. doi: 10.1016/j.radphyschem.2023.111463.
11. Adhab HG, Alshebly SAK, Alsabari EK. Assessment excess lifetime cancer risk of soils samples in Maysan neighborhood adjacent to the middle Euphrates cancer center in Najaf / Iraq. *IOP Conf Ser Mater Sci Eng* 2020;928:072100. DOI: 10.1088/1757-899X/928/7/072100.

12. Alhous SF, Kadhim SA, Alkufi AA, Kadhim BA. Measuring the level of Radioactive contamination of selected samples of Sugar and Salt available in the local markets in Najaf governorate / Iraq. IOP Conf Ser Mater Sci Eng 2020;928:072097. DOI: 10.1088/1757-899X/928/7/072097.
13. Alkufi AA, Kadhim SA, Alhous SF. Comparison of excess lifetime cancer risk for different age groups for selected flour samples. AIP Conf Proc 2022;2437:020070. Doi: 10.1063/5.0093069.
14. Abbas HH, Kadhim SA, Alhous SF, Hussein HH, AL-Temime FA, Mraity HAA. Radiation Risk Among Children due to Natural Radioactivity in Breakfast Cereals. Nat environ pollut technol 2023;22:527-33. doi: 10.46488/NEPT.2023.v22i01.053.
15. Kadhim SA, Alhous SF, Abas HM Hussein HH. Comparison of alpha equivalent dose and equivalent annual reproductive dose in flour / Iraq. AIP Conf Proc 2022;2394:090002. Doi: 10.1063/5.0121404.
16. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources And Effects Of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, 1st ed. New York, United States (US): United Nations; 2000.
17. Radenković MB, Alshikh SM, Andrić VB, Miljanić SS. Radioactivity of sand from several renowned public beaches and assessment of the corresponding environmental risks. J Serb Chem Soc 2009;74:461–70. doi: 10.2298/JSC0904461R.
18. Little MP, Hoel DG, Molitor J, Boice JD, Wakeford R, Muirhead CR. New models for evaluation of radiation-induced lifetime cancer risk and its uncertainty employed in the UNSCEAR 2006 report. Radiat Res 2008;169:660-76. doi: 10.1667/RR1091.1.
19. Al-Jundi J, Salah W, Bawa'aneh MS, Afaneh F. Exposure to radiation from the natural radioactivity in Jordanian building materials. Radiat Prot Dosim 2005;118:93-6. doi:10.1093/rpd/nci332.
20. Harrison JD, Streffer C. The ICRP Protection Quantities, Equivalent And Effective Dose: Their Basis And Application. Radiat Prot Dosim 2007;127:12-8. doi:10.1093/rpd/ncm248.
21. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources And Effects Of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, 1st ed. New York, United States (US): United Nations, 2000; pp 453-87.
22. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2006 Report, Volume I, 1st ed. New York, United States (US): United Nations; 2008.
23. Wrixon AD. New ICRP recommendations. J Radiol Prot 2008;28:161. doi: 10.1088/0952-4746/28/2/R02