Assessment of radioactivity and radiological hazards in some flooring materials used in Karbala governorate, Iraq.

1Auras Muse Omron, 2Manar Dheyaa Salim
1Karbala University, College of Sciences, Physics Dep., Karbala, Iraq.
2Thi-Qar University, College of Education for Pure Sciences, Physics Dep., Thi-Qar, Iraq.
oras.m@uokerbala.edu.iq

Abstract
The radioactivity concentrations of $^{40}$K, $^{232}$Th and $^{238}$U in 20 specimens of commercial flooring materials used in Karbala governorate, were measured using (HPGe) system. The results of measurements have shown that highest value of specific activity of for $^{238}$U which was 294.570Bq/kg (granite; Vietnamese origin), $^{232}$Th which was 88.808Bq/kg (granite; Italian origin) and $^{40}$K which was 284.580Bq/kg (marbles; Iranian origin), which were less than the worldwide average (UNSCEAR,2000). The various hazard indices were also calculated to assess the radiation hazard. It was found that none of the results exceed the recommended limit value. All specimens in this paper are within the recommended safety limit and do not present huge radiation dangers.

Keyword: Radiation hazard indices, flooring materials, (HPGe) detector.

1. Introduction
Humans are continuously exposed to ionizing radiation from naturally occurring radioactive materials (NORM)[1]. Although the origin of these materials is the earth crust, they find their way into building-materials, air, water, food, and the human body itself[2,3]. Measuring the activity concentrations of radionuclides in building materials is important for the assessment of population exposures, as most individuals spend 80% of their time indoors.

All building materials are mostly made from soil and rock ,the materials contain natural radioactive isotopes[1,4]. For example, thorium-232 series, uranium-238 series and potassium-40. Gamma radiation emitted from naturally occurring radioisotopes, for example, the radionuclides from potassium-40, Uranium-238 series and Thorium-232 series and their decay products which exist at trace levels in all ground formations. All of these natural sources of radioactivity can be sources of both internal and external radiation exposure[5]. Internal exposure occurs through the inhalation of radon gas, and external...
exposure occurs through the emission of penetrating gamma rays from radioactive sources[6]. The decorative and flooring building materials for example marbles, granite, ceramic tiles and so on are utilized usually in the world[3,7]. There are increasing interest of the public in knowing information about the presence of naturally occurring radionuclides , we use (HPGe) detector to determine the radiation hazard indices and specific activity concentrations for some flooring materials utilized in Karbala governorate, which is the aim of this work [8,9].

2. Materials and Method

All flooring materials specimens were gathered from various markets and factories. The specimens were chosen in terms of the widely and most common type Karbala governorate markets, see Fig.(1). Every one of the specimens were pulverized into tiny pieces, then into fine powder using the utilizing jaw crusher. The specimens were dried at 90 °C for two hours to ensure that any moisture was removed from the specimens and after that to acquire uniform particle sizes, approximately (600μm) mesh was used to sieve the specimens after that specimens were weighted approximately (onekg) and transferred to a Marinelli beaker. In the present work a (3”×3”) (HPGe) system, see Fig.(2) basic prerequisite for the estimation of gamma producer is the careful character of photo peaks presents in the spectrum produced by the detector system.

Fig. (1): Random specimens of flooring materials
3. Determination of some Gamma Radiation Parameters

3.1. Activity Concentration (A)[3]:

\[ A = \frac{\text{NET}}{\varepsilon \cdot \gamma \cdot m \cdot t} \] .......................... (1)

Where A: activity concentrations, \( \varepsilon \): Energy efficiency, m: the mass and t: the time (3600s).

3.2. Radium Equivalent (Ra_{eq})[3]:

\[ \text{Ra}_{eq} = A_K \times 0.077 + A_{Th} \times 1.43 + A_U \] .......................... (2)

Where \( A_K, A_{Th}, A_U \) activity concentration of a \(^{40}\)K and series of (thorium-232 and uranium-238) respectively.

3.3. Absorbed Dose Rate \( (D_\gamma)[4] \):

\[ D_\gamma = A_{Th} \times 0.604 + A_K \times 0.0417 + A_U \times 0.462 \] .......................... (3)

3.4. The Annual Effective Dose (AED_{in}, AED_{out})[5]:

\[ (\text{AED})_{in} = 0.80 \times (0.7 \text{ Sv/Gy}) \times D_\gamma \times (\text{nGy/h}) \times 10^6 \times 8760 \text{ h/y} \] .......................... (4)
\[ (\text{AED})_{out} = 0.20 \times (0.7 \text{ Sv/Gy}) \times D_\gamma \times (\text{nGy/h}) \times 10^6 \times 8760 \text{ h/y} \] .......................... (5)

3.5. Internal and External Hazard Index (H_{in}, H_{ex})[6]:

\[ H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \] .......................... (6)
\[ I_{in} = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \leq 1 \] .......................... (7)
\[ I_{ex} = \frac{A_{Ra}}{200} \leq 1 \] .......................... (8)
4. Results and Conclusions

In total, twenty flooring materials' specimens were collected from different markets and factories. The specimens were chosen in terms of the widely and most common type in Karbala governorate markets. The types of materials for each sample of (ceramic, marbles, mosaic tile and granite) for different originators.

The results of the specific activity for $^{40}$K, $^{232}$Th and $^{238}$U radionuclides for twenty flooring materials' specimens are displayed in Table(1). From Table (1), it can noted that:

$A_{U}$ was observed to be extended from 11.760Bq/kg (ceramic; Egyptian origin) to 294.570Bq/kg (granite; Vietnamese origin), see Fig.(3). These qualities were not as much as the world normal estimation of (35Bq/kg).

$A_{Th}$ was observed to be extended from 18.270Bq/kg (marbles; Chinese origin) to 88.808Bq/kg (granite; Italian origin), see Fig.(4). These qualities were not as much as the world normal estimation of (30Bq/kg).

$A_{K}$ was observed to be extended from 28.392Bq/kg (granite; Turkish origin) to 284.580Bq/kg (marbles) (Iranian origin), see Fig. (5).These qualities were not as much as the world normal estimation of (400Bq/kg) [10].

$(Ra_{eq})$ was observed to be gone from 0.139Bq/kg (granite; Turkish origin) to 88.721Bq/kg (marbles; Iranian origin), these qualities were not as much as the world normal estimation of (370Bq/kg).

$(D_{\gamma})$ was observed to be extended from 0.035nGy/h (granite; Turkish origin) to 41.145nGy/h (marbles; Iranian origin), these qualities were not as much as the world normal estimation (55nGy/h).

$(AEDE)_{in}$ was observed to be run from 0.127mSv/y (ceramic; Egyptian origin) to 0.322mSv/y (granite; Italian origin), these qualities were not as much as the world normal estimation of (1mSv/y)[11,12].

$(AEDE)_{out}$ was observed to be extended from 0.032mSv/y (ceramic; Egyptian origin) to 0.312mSv/y for (granite; Italian origin), these qualities were not as much as the world normal estimation of (1mSv/y)[13].

$I_{\gamma}$ was observed to be gone from 0.166 (granite; Turkish origin) to 0.324 (marbles; Iranian origin), these qualities were not as much as the world normal estimation of (1)[14].

$H_{in}$ was observed to be gone from 0.186 (ceramic; Egyptian origin) to 294.57 (granite; Vietnamese origin), these qualities were not as much as the world normal estimation of (1)[15].

$H_{out}$ was observed to be extended from 0.154 (ceramic; Egyptian origin) to 88.808 (granite; Italian origin), these qualities were not as much as the world normal estimation of (1)[16].

5-Conclusion

The natural radionuclide content, specific activity for (K-40, Th-232 and U-238) and various hazard indices of some flooring building materials commonly used in Karbala governorate were...
determined. The specific activity for (K-40, Th-232 and U-238) for building materials in this work were all below the criterion limit of radiation dose. Values of parameters hazard indices for all specimens investigated are below the criterion limit of radiation dose, all the specimen investigated are within the recommended safety limit specified for materials used for building construction and hence do not pose any radiation hazards to the dwellers.

Fig.(3): specific activity of $^{238}\text{U}$ for all flooring materials' specimens studied in the present work.
Fig. (4): specific activity of (Th-232) for all flooring materials' specimens studied in the present work.

Fig. (5): specific activity of (K-40) for all flooring materials' specimens studied in the present work.
Table (1) specific activities of U-238, Th-232 and K-40 with some other parameters in flooring materials used in Karbala governorate.

| types of Sample | Origin Sample | $^{238}\text{U}\!$ (Bq/kg) | $^{232}\text{Th}\!$ (Bq/kg) | $^{40}\text{K}\!$ (Bq/kg) | $D_{\gamma}$ (nGy/h) | Annual effective dose (mSv/y) | $I_{\gamma}$ | Hazard index |
|-----------------|---------------|-----------------|-----------------|-----------------|-----------------|-----------------------------|---------|-------------|
|                 |               |                 |                 |                 |                 | (AED) in                  | (AED) out |             |
| ceramic         | Egypt         | 11.760          | 23.430          | 153.570         | 57.090          | 25.989                    | 0.127    | 0.032       | 0.208       | 0.186       | 0.154       |
| ceramic         | Vietnam       | 18.070          | 22.570          | 166.820         | 63.190          | 28.937                    | 0.142    | 0.035       | 0.229       | 0.220       | 0.171       |
| ceramic         | Iran          | 27.580          | 28.060          | 254.580         | 87.308          | 40.306                    | 0.198    | 0.049       | 0.317       | 0.310       | 0.236       |
| ceramic         | Turkey        | 22.490          | 22.230          | 273.290         | 75.322          | 35.213                    | 0.173    | 0.044       | 0.277       | 0.264       | 0.203       |
| ceramic         | China         | 21.330          | 19.530          | 163.770         | 61.868          | 28.480                    | 0.140    | 0.035       | 0.223       | 0.225       | 0.167       |
| Average         |               | 20.246          | 23.164          | 202.406         | 68.956          | 31.785                    | 0.156    | 0.039       | 0.251       | 0.241       | 0.186       |
| granite         | India         | 143.580         | 65.613          | 29.694          | 0.146           | 0.036                     | 0.236    | 0.222       | 0.177       | 143.580     | 65.613      |
| granite         | Iran          | 168.820         | 64.806          | 29.697          | 0.146           | 0.036                     | 0.234    | 0.228       | 0.175       | 168.820     | 64.806      |
| granite         | Vietnam       | 294.570         | 83.151          | 38.912          | 0.191           | 0.048                     | 0.305    | 0.299       | 0.225       | 294.570     | 83.151      |
| granite         | Italy         | 253.260         | 88.808          | 40.898          | 0.201           | 0.050                     | 0.322    | 0.312       | 0.240       | 253.260     | 88.808      |
| granite         | Turkey        | 179.560         | 61.348          | 28.392          | 0.139           | 0.035                     | 0.223    | 0.222       | 0.166       | 179.560     | 61.348      |
| Average         |               | 207.958         | 72.745          | 33.519          | 0.164           | 0.041                     | 0.264    | 0.257       | 0.196       | 207.958     | 72.745      |
| mosaic          | China         | 18.720          | 25.430          | 133.570         | 65.370          | 29.578                    | 0.145    | 0.036       | 0.234       | 0.227       | 0.177       |
| mosaic          | India         | 21.070          | 26.520          | 148.820         | 70.453          | 31.958                    | 0.157    | 0.039       | 0.252       | 0.247       | 0.190       |
| mosaic          | Iraq          | 24.590          | 23.020          | 234.550         | 75.569          | 35.045                    | 0.172    | 0.043       | 0.275       | 0.271       | 0.204       |
| mosaic          | Iran          | 23.850          | 25.290          | 243.250         | 78.745          | 36.437                    | 0.179    | 0.045       | 0.287       | 0.277       | 0.213       |
| mosaic          | Turkish       | 27.810          | 19.530          | 159.760         | 68.039          | 31.306                    | 0.154    | 0.038       | 0.244       | 0.259       | 0.184       |
| Average         |               | 23.208          | 23.958          | 183.990         | 71.635          | 32.865                    | 0.161    | 0.040       | 0.258       | 0.256       | 0.193       |
| marbles         | Egypt         | 21.430          | 27.460          | 163.770         | 73.308          | 33.316                    | 0.163    | 0.041       | 0.263       | 0.256       | 0.198       |
| marbles         | Vietnam       | 21.940          | 28.080          | 158.710         | 74.315          | 33.715                    | 0.165    | 0.041       | 0.266       | 0.260       | 0.201       |
| marbles         | Iran          | 26.740          | 28.020          | 284.580         | 88.721          | 41.145                    | 0.202    | 0.050       | 0.324       | 0.312       | 0.240       |
| marbles         | China         | 27.490          | 18.270          | 263.740         | 73.924          | 34.733                    | 0.170    | 0.043       | 0.271       | 0.274       | 0.200       |
| marbles         | Spain         | 22.010          | 23.030          | 169.160         | 67.968          | 31.133                    | 0.153    | 0.038       | 0.245       | 0.243       | 0.184       |
| Average         |               | 23.922          | 24.972          | 207.992         | 75.647          | 34.808                    | 0.171    | 0.043       | 0.274       | 0.269       | 0.204       |
| Global limit    |               | 35              | 30              | 400             | 370             | 55                        | 1        | 1           | 1           | 1           | 1           |

References

[1] El-Taher, S. Makhlufl, A. Nossair, A.S. Abdel Halim, Assessmentof natural radioactivity levels and radiation hazards due to cementindustry, J. Appl. Radiat. Isot. 68 (2010) 169–174.

[2] L. Merle, R. Enn, Assessment of natural radiation exposure from building materials in Estonia, Proc. Estonian Acad. Sci. 61 (2)(2012) 107–112.
[3] G. Viruthagiri, K. Ponnarasi, Measurement of natural radioactivity in brick samples, Adv. Appl. Sci. Res. 2 (2) (2011) 103–108.

[4] K. Prasong, A. Susaira, Natural radioactivity measurement in soil samples collected from municipal area of Hat Yai District in Songkhla Province, Thailand, Knitl Sci. J. 8 (2) (2008).

[5] Malanca, V. Pessina, G. Dallara, Radionuclide content of building materials and gamma-ray dose rates in dwellings of Rio-GrandeDo-Norte Brazil, Radiat. Prot. Dosim. 48 (2) (1993) 199–203.

[6] A. El-Taher, Gamma spectroscopic analysis and associated radiation hazards of building materials used in Egypt, Radiat. Prot. Dosim. 138 (2) (2010) 166–173.

[7] UNSCEAR United National Scientific Committee on the Effects of Atomic Radiation Sources and Risks of Ionizing Radiation. Report to the General Assembly with Annexes, United Nations, New York, 2000.

[8] NEA-OECD, Nuclear Energy Agency. Exposure to Radiation from Natural Radioactivity in Building Materials. Report by NEAGroup of Experts, OECD, Paris, 1979.

[9] M.S. El-Tahawy, R.H. Higgy, Natural radioactivity in different types of bricks fabricated and used in Cairo region, Appl. Radiat. Isot. 46 (12) (1995) 1401–1406.

[10] (UNSCEAR), United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly. Anex B: Exposures from Natural Radiation Sources, New York, 2000.

[11] Righi, S., & Bruzzi, L. Natural radioactivity and radon exhalation in building materials used in Italian dwellings, (2006).

[12] Dia H.M.; Nouh S.A.; Hamdy A.; EL-Fiki S.A. Evaluation of Natural Radioactivity in a Cultivated Area around A Fertilizer Factory. Nuclear and Radiation Physics. 2008, 3,1,53-62.

[13] Nashwan Shawkat. Radioactive pollution and environmental sources in the province of Nineveh. M.Sc. Thesis. Wasit University. 2000.

[14] El-Arabi A.M. Gamma activity in some environmental specimens in south Egypt. Indian Journal of Pure & Applied Physics., 43, 422-426, 2005.

[15] Al-Taher A.; Makhluf S. Natural radioactivity levels in phosphate fertilizer and its environmental implications in assuit governorate, Upper Egypt. Indian Journal of Pure & Applied Physics., 48, 697-702. 2010.

[16] Arman E. An Investigation on the Natural Radioactivity of Building Materials, Raw Materials and Interior Coatings in Central Turkey. Brazilian Journal of Medical Sciences, 37, 4, 199-203, 2007.