



ASSESSMENT OF NATURAL RADIOACTIVITY LEVELS AND RADIATION HAZARDS FOR BUILDING MATERIALS USED IN SOME SELECTED PROVINCES IN IRAQ

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ABSTRACT

The radioactive properties of building materials used for the construction of habitable structures in Iraq were investigated in this study. In the framework of this paper, ten samples of commonly used building materials (bricks and rocks used for incasing) were collected from ten Iraqi provinces for radiometric analysis. The activity concentrations of natural radionuclides in the selected samples were determined by gamma ray spectrometry using sodium iodide (NaI) detector. Based on the results of this study, the use of rocks for incasing manufactured in Al-Rumadi is considered to be unsafe for human habitation from radiological points of view due to relatively high background radioactivity. The radioactivity levels for building materials for the remaining investigated areas were well within the permissible limits.

تقييم مستويات النشاط الإشعاعي الطبيعي والمخاطر الإشعاعية لمواد البناء المستخدمة في بعض المحافظات العراقية

الكلمات المفتاحية

النشاط الإشعاعي الطبيعي، المخاطر الإشعاعية، مواد البناء

الخلاصة

تم في هذه الدراسة تقييم مستويات النشاط الإشعاعي الطبيعي في مواد البناء المستخدمة في تشييد المباني السكنية في العراق. جرى تجميع عشرة نماذج لمواد البناء الشائعة الاستخدام في العراق (الطابوق وحجر التغليف) من عشرة محافظات عراقية لأغراض التحليل المختبري. تم قياس مستويات النشاط الإشعاعي الطبيعي في النماذج المنتخبة باستخدام كاشف يوديد الصوديوم. بناءً على النتائج المستحصلة من هذه الدراسة، تعتبر أحجار التغليف المستخدمة في مدينة الرمادي غير صالحة لأغراض تشييد المباني السكنية من النواحي الإشعاعية نظراً لارتفاع مستويات النشاط الإشعاعي الطبيعي فيها، وكانت مستويات النشاط الإشعاعي لمواد البناء في بقية المناطق ضمن الحدود المسموح بها.

Introduction

All building raw materials and products derived from rock and soil contain various amounts of mainly natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and the radioactive isotope of potassium (^{40}K). In the ^{238}U series, the decay chain segment starting from radium (^{226}Ra) is radiologically the most important and, therefore, reference is often made to ^{226}Ra instead of ^{238}U . These radionuclides are sources of the external and the internal radiation exposures in dwellings. The external exposure is caused by direct gamma radiation while the inhalation of radioactive inert gases radon (^{222}Rn , a daughter product of ^{226}Ra) and thoron (^{220}Rn , a daughter product of ^{224}Ra), and their short-lived secondary products lead to the internal exposure of the respiratory tract to alpha particles. The specific activities of ^{226}Ra , ^{232}Th and ^{40}K in the building raw materials and products mainly depend on geological and geographical conditions as well as geochemical characteristics of those materials [1].

The radiological impact from the natural radioactivity is due to radiation exposure of the body by gamma-rays and irradiation of lung tissues from inhalation of radon and its progeny. From the natural risk point of view, it is necessary to know the dose limits of public exposure and to measure the natural environmental radiation level provided by ground, air, water, foods, building interiors, etc., to estimate human exposure to natural radiation sources [2]. Low level gamma-ray spectrometry is suitable for both qualitative and quantitative determinations of gamma-ray-emitting nuclides in the environment. The concentration of radioelements in building materials and its components are important in assessing population exposures, as most individuals spend 80% of their time indoors. The average indoor absorbed dose rate in air from terrestrial sources of radioactivity is estimated to be 70 nGy/h [3]. Great attention has been paid to determining radionuclide concentrations in building materials in many countries [4].

The objectives of this study are:-

- Assess natural radioactivity levels in the most commonly used building materials in Iraq (i.e. clay brick, rocks used for incasing),
- Estimate the radiological parameters (radium equivalent activity, external and internal hazard indices and annual effective dose) to assess the radiological hazards to human health from building materials.

Materials and Methods

Sampling and Sample Preparation

A total of 10 samples of bricks and rocks used for the construction and incasing of dwellings in some provinces in Iraq have been collected from local suppliers and under construction sites for the period from January to June 2014. The collected samples have been prepared for radiometric analysis in accordance with the procedures recommended by the International Atomic Energy Agency (IAEA). The collected sample each about 1 kg in weight were crushed, dried in an oven at about 105°C to ensure that moisture is completely removed. The samples were homogenized, and sieved through a 200 mesh. Weighted samples were placed in polyethylene beaker. The beakers were completely sealed for 4 weeks to reach secular equilibrium where the rate of decay of the daughters becomes equal to that of the parent [5,6,7]. This step is necessary to ensure that radon gas confined within the volume and the decay products will also remain in the sample.

Radiometric Analysis

Radioactivity measurements for the collected samples were performed in the laboratories of the Ministry of Science and Technology for the period July-August 2014 by high-resolution gamma ray spectrometer (Canberra Inc.), employing a sodium iodide (NaI) detector, dimensions $3''\times 3''$, efficiency 65% for all radionuclides.

Radiological Hazards Assessment

In this study, the radiological parameters such as indices of radium equivalent activity, external hazard index, and indoor absorbed gamma dose rate were calculated to estimate the exposure risk for building materials used in Iraq.

- Absorbed dose rate at 1 m above the ground are calculated by Monte Carlo method [8,9]:

$$D \text{ (nGy/h)} = 0.0417 (A_{\text{K}}) + 0.462 (A_{\text{Ra}}) + 0.604 (A_{\text{Th}}) \dots (1)$$

where A_{Ra} , A_{Th} and A_{K} are the specific activities of ^{226}Ra , ^{232}Th and ^{40}K in Bq/kg.

In order to estimate the annual effective dose rate in air, the conversion coefficient from absorbed dose in air to effective dose received by an adult has to be taken into consideration. This value is published in UNSCEAR 2000 report [10] to be 0.7 Sv/Gy for environmental exposure to gamma rays of moderate energy. The indoor occupancy factor is about 0.8 [10]. The annual effective dose equivalent (AEDE) originating from the building materials is assessed using the following equation:

$$AEDE \text{ (mSv/y)} = D \text{ (nGy/h)} \times 8760 \text{ (h/y)} \times 0.8 \times 0.7 \text{ (Sv/Gy)} \times 10^{-6} \dots (2)$$

Radium equivalent activity (Raeq) is used to assess the hazards associated with materials that contain 226Ra, 232Th and 40K in Bq/kg. This index is calculated with the assumption that 370 Bq/kg 226Ra or 260 Bq/kg 232Th or 4810 Bq/kg 40K produce the same dose rate. The Raeq of the sample in (Bq/kg) can be determined using the following equation [6]:

$$Raeq = 0.077 \text{ (AK)} + \text{(AU)} + 1.43 \text{ (ATh)} \dots (3)$$

The published maximal admissible Raeq is 370 Bq/kg [10].

The external hazard index is an evaluation of the hazard of the natural gamma radiation [11]. The prime objective of this index is to limit the radiation dose to the admissible dose equivalent limit of 1 mSv/y. This index can be evaluated using the following equation [12,13,14]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \dots (4)$$

The external hazard index should be below unity for the radiation hazard to be negligible.

Inhalation of alpha particles emitted from the short-lived radionuclides radon (222Rn, the daughter product of 226Ra) and thoron (220Rn, the daughter product of 232Th) is also hazardous to the respiratory organs. This hazard can be quantified by the internal hazard index (Hin) [13,14,15,16], which is given by the following equation:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \dots (5)$$

The internal hazard index should be below unity in order to provide safe levels of radon and its short-lived daughters for the respiratory organs of individuals living in the dwellings.

3. Results and Discussion

Bricks is an important construction material for houses and buildings in urban areas of Iraq. The mean measured activity concentrations together with their respective standard deviation of the natural radionuclides are presented in table 1. As shown in figures 1-5, the radioactivity in building materials varied from one province to another due to variation in background radioactivity. Higher natural radioactivity were detected in the western region of Iraq (Al-Rumadi) due to naturally elevated concentrations of radionuclides in the soil. It was important to

point out that these values were not the representative values for the provinces mentioned but for the regions from where the samples were collected. Radium, thorium, uranium and potassium are not uniformly distributed in soil or rocks, from which building materials are derived, but the radioactivity varies, often greatly, over a distance of some meters.

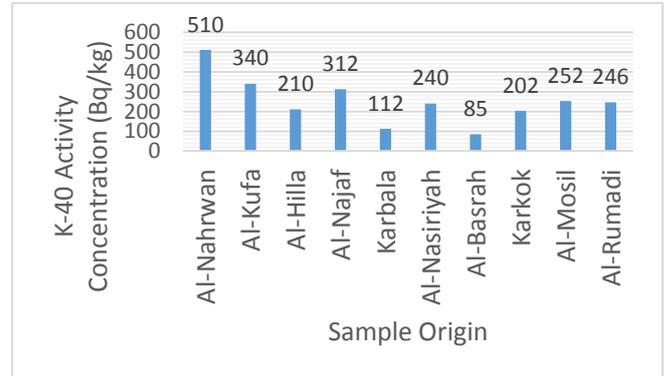


Figure 1: Mean values of 40K activity concentration in bricks used in the construction of dwellings in some selected provinces in Iraq.

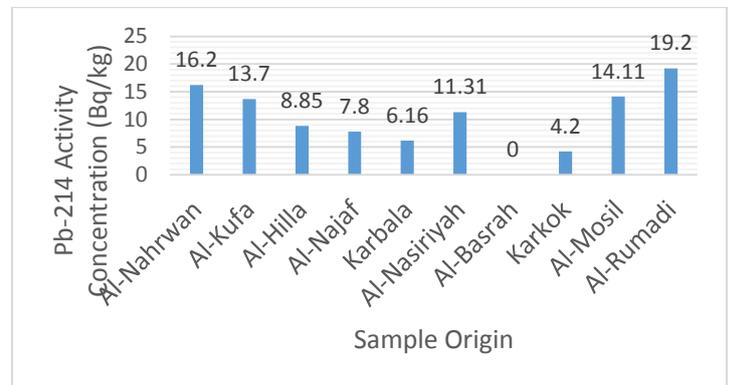


Figure 2: Mean values of 214Pb activity concentration in bricks used in the construction of dwellings in some selected provinces in Iraq.

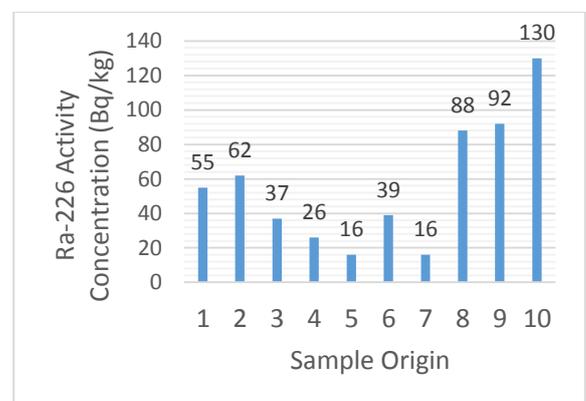


Figure 3: Mean values of 226Ra activity concentration in bricks used in the construction of dwellings in some selected provinces in Iraq.

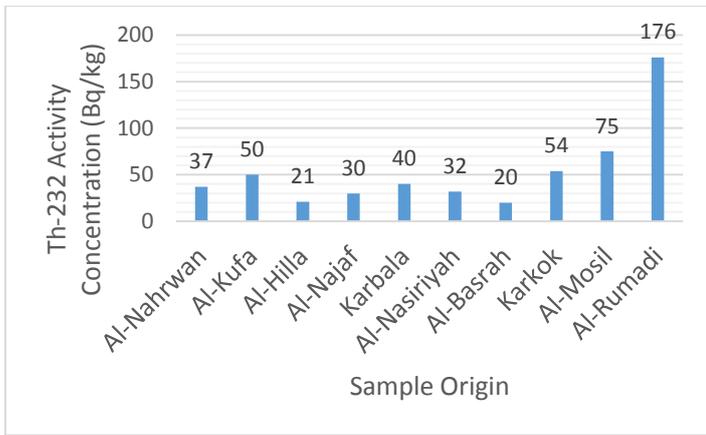


Figure 4: Mean values of ^{232}Th activity concentration in bricks used in the construction of dwellings in some selected provinces in Iraq.

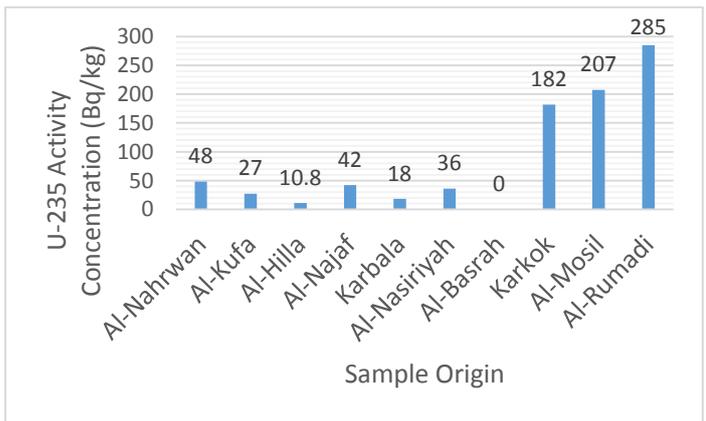


Figure 5: Mean values of ^{235}U activity concentration in building materials used in the construction of dwellings in some selected provinces in Iraq.

Figures 6-8 presents the calculated values of annual effective dose rate, radium equivalent activity, external and internal hazard indices. From Fig.(6), the average values of calculated effective dose rates in samples under investigation are ranged between 0.11 to 0.86 mSv/y. The mean observed radium equivalent activity (Raeq) values for all building materials under investigation is 181 Bq/kg, ranged from 35 to 556 Bq/kg. The mean Raeq value is less than the permissible limit of 370 Bq/kg, which is considered acceptable for safe human use. Lowest Raeq value was found for bricks sample collected from Al-Basrah (35 Bq/kg), while the highest Raeq value was observed in rocks sample used for incasing collected from Al-Rumadi (556 Bq/kg). From these results it is evident that there are considerable variations in the Raeq of the different materials and also within the same type of materials originating from different areas. This fact is important from the point of view of selecting suitable materials for use in building and construction especially concerning those which have large variations in their activities.

Large variation in radium equivalent activities may suggest that it is advisable to monitor the radioactivity levels of materials from a new source before adopting it for use as a building material

The calculated values of external and internal hazard indices obtained in this study ranged from 0.09 to 1.5, and 0.09 to 2.27, respectively. Since the calculated values of external and internal hazard indices for rocks sample collected from Al-Rumadi are greater than unity, it can be say that the radiation hazard is significant for the population living in this investigated area.

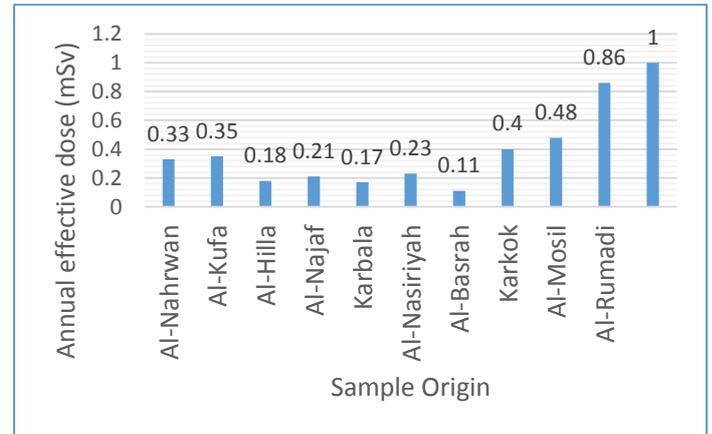


Figure 6: Comparison between the estimated annual effective dose equivalent of inhabitants at 1 m above the ground level in dwellings with the permissible limit.

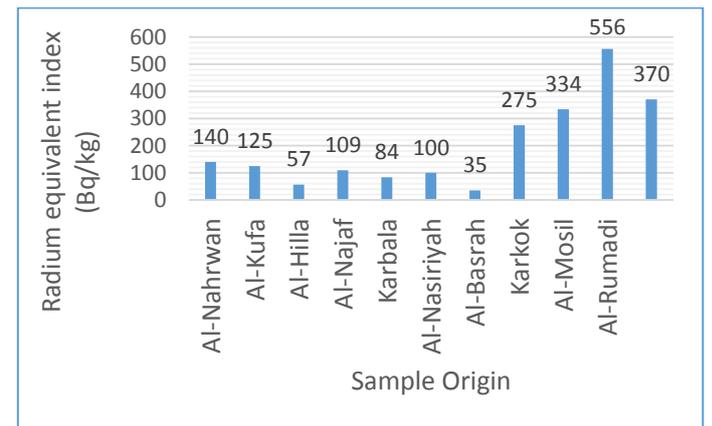


Figure 7: Comparison between the estimated radium equivalent index with the permissible limit.

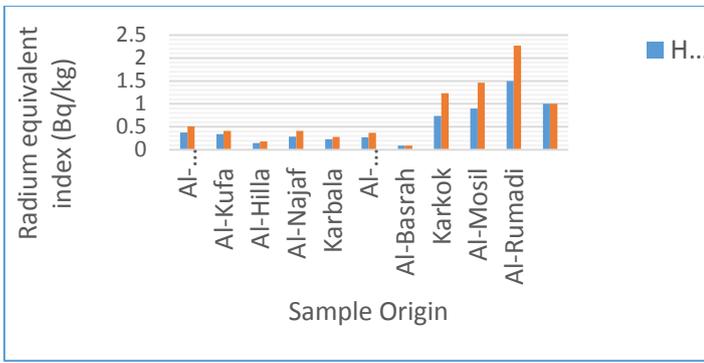


Figure 8: Comparison between the estimated hazard index with the permissible limit.

Conclusions

Materials derived from rock and soils contain mainly natural radioisotopes of the ^{238}U , ^{235}U and ^{232}Th series and radioactive isotope of ^{40}K . Gamma ray spectrometry is powerful experimental tool in studying natural radioactivity and determining elemental concentration in various building materials. The radium-equivalent activities and hazard indices assessed for about 90% of the building materials investigated in this study were satisfy the radiation protection limits established in the literature. Therefore, the use of these building materials in the construction of dwellings in Iraq is considered to be safe for human habitation, except for rocks used for incasing manufactured in Al-Rumadi which shows excessive radioactivity levels.

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