Natural radioactivity and radiation risk assessment in fly ash Soil and Water Samples Collected from and around of the AL-Zubaydiyah Thermal Power Plant, wasit, Iraq

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تقييم النشاط الإشعاع الطبيعي والمخاطر الإشعاعية في عينات الرماد المتطاير و التربة والمياه المجمعة من داخل وحول محطة الزبيدية الحرارية ، واسط ، العراق

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المستخلص

تم حساب تراكيز النظائر المشعة طبيعية المنشأ للراديوم -226(Ra^{226}) , اكتينيوم-228(Ac^{228})و البوتاسيوم -40(K^{40}) للرماد المتطاير ,في محطة كهرباء الزبيدية الحرارية في محافظة واسط في العراق . تم تحديد تراكيز هذه النظائر باستخدام التحليل الطيفي لاشعة كاما باستخدام كواشف الجرمانيوم عالي النقاوة (HPGe) و أيوديد الصوديوم المطعم بالثاليوم ((NaI(TI)) .أُستخدمت منظومة كاشف ايوديد الصوديوم ذات طيف كاما والمحاط بدرع من الرصاص لتقليل الخلفية الاشعاعية ولقياس النماذج وحساب تراكيز النظائر المشعة الطبيعية لسلسة اليورانيوم -238 ,وسلسلة الثوريوم-232,وكذلك نظير البوتاسيوم-40 الطبيعي. بصورة عامة كانت نتائج اليورانيوم اعلى من نتائج الثوريوم بحدود 3 الى 4 مرات و هذه هي من النتائج الطبيعية التي تؤكد بانه لا توجد ملوثات سابقة أو قديمة في مناطق الدراسة. تم حساب معاملات الخطورة في الدراسة الحالية , والتي تشمل مكافئ الجرعة الفعالة للراديوم (R_{aeq}) , و معدل الجرعة الممتصة لاشعة كاما (D) ,و معامل الخطورة الخارجية (H_{ex}),و معامل الخطورة الداخلية (H_{in}), و الجرعة السنوية المؤثرة و التي تشمل نسبة الجرع الفعالة الداخلية و الخارجية (E) و تقاس بوحدة mSv/y ومعدل مستويات الخطورة لاشعة كاما ($I_{\gamma r}$), على التوالي.

الكلمات المفتاحية :المواد المشعة الطبيعية,الرماد المتطاير,النشاط المكافئ للراديوم ,المخاطر.

Abstract

In this study, the activity concentrations of radium -226 (236Ra),actinium-228 (238Ac) and potassium -40 (40K) of fly ash , in the Zubaidiyah thermal power station in Wasit province in Iraq were determined using gamma-rays spectroscopy with a hyper -pure germanium (HPGe) and sodium iodide (NaI(TI)) detectors. Reagent system used sodium iodide gamma spectrum and is surrounded by a shield of lead to reduce background radiation and measuring models and calculate the concentrations of natural radioactive isotopes of uranium -238 series, and a series of thorium-232, as well as potassium isotope -40 natural . In general, the results of uranium were higher than the results of thorium with a limit of 3 to 4 times. These are normal results that confirm that there are no previous or old pollutants in the study areas. The risk factors have been calculated in the present study, which include radium equivalent activities (Ra_{eq}), gamma dose rate (D), external hazard index (H_{ex}), internal hazard index (H_{in}), annual effective dose which comprise indoor and outdoor effective dose rate (E) It is measured by unit mSv/y and representative level index ($I_{\gamma r}$), respectively.

Key words: natural occurring radioactive material , fly ash, Radium equivalent activity, hazard .

Introduction

NORMs (Naturally Radioactive Materials *)* is the radioactive material found in nature. NORMs can be found everywhere in soil, air, oil, regular water supply and irradiated potassium from our bodies. NORMs are part of our world [1].Naturally occurring radioactivity found in industrial materials such as ores and metals[2] . These materials ,in the past, were known as Low Specific Activity (LSA), and Technologically Enhanced Naturally Occurring Radioactive Materials (TE-NORM), but now described in a simplified manner "NORM", Which means Naturally Occurring Radioactive Materials. NORM occurs in minerals, coal, oil and gas, mineral sands and bauxite [3]. Mining and processing of raw materials for the extraction of metals can alter the concentration of the radioactivity of products, by-products, residues and wastes from these materials [4]. Examples of bulk materials include: red mud (from bauxite processing), bricks [5], sludge and scales (from oil and gas production), phosphate rocks [6], and fertilizers [7].

Radiation hazard indices

1. Radium equivalent activity (Ra_{eq})

The value of the equivalent concentration of the radium element (Ra_{eq}) used to estimate the hazards associated with substances containing ^{226}Ra, ^{232}Th and ^{40}K radioactive elements is the most widely used indicator for radiation risk assessment and calculated by equation of Beretka and Mathew[8].

Ra_{eq} $(Bq.Kg^{-1})= A_{Ra} + 1.43A_{Th} + 0.077A_K$ ……………………..…..…(1)

Where A_{Ra} , A_{Th} and A_K is the efficacy of of Ra- 226, Th-232 and K-40 respectively and measured by peckerels per kilogram (Bq/Kg) [9]. The maximum permissible value of the radium equivalent activity is 370 Bq.Kg^{-1} [10].

2. Dose Rate (D)

Due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclide's (^{226}Ra, ^{232}Th and ^{40}K) were calculated, we assumed The contributions from other naturally occurring radionuclides were insignificant.so, D can be calculated according to [11].

.. …(2)

$$\mathbf{D(nGy/h)=0.462+0.621}A_{Th}\mathbf{+0.417}A_K\ A_{Ra}$$

3. External and internal hazard indices

The purpose of this factor is to ensure that the effective dose of this radiation does not exceed out the permissible limits. The external risk factor is calculated using the following equation[12]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1$$ ……………………………….…(3)

where H_{ex} is the external risk factor and A_{Ra} , A_{Th} and A_K are the concentrations of radiation activity of ^{226}Pa , ^{232}Th and ^{40}K respectively , measured in bicerel per kilogram (Bq/Kg) [13].

The internal risk factor is a measure of radiation dose and is given by the following relationship:

$$\boldsymbol{H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1}$$ ……………………………………..…(4)

Where H_{ex} is the external risk factor and A_{Ra} , A_{Th} and A_K are the concentrations of radiation activity of radium-226, thorium-232 and potassium-40, respectively, Internal risk factor values should be less than one in the ideal environment for the respiratory organs to work properly because they have serious respiratory effects [14].

4. Indoor and outdoor annual effective Dose

The conversion constant has been adopted 0.7 $SvGy$ as a factor of conversion from the air-absorbed dose to the annual effective dose received by adults, and 0.8 for the interior possessive factor including that 20% of time is spent outdoors . and 0.8 for the indoor occupancy factor and implying that 20% of time is spent outdoors. Outdoor occupancy factor of 0.2 proposed by UNSCEAR 2000 were used

The annual effective dose equivalent (AEDE) in units of $mSvy/$ was calculated by the following formulae [15].

Indoor effective dose:

$$\mathbf{E_{ied}\ (msv/y) = D(nGy/h) * 8760h * 0.8 * 0.7\ sv/Gy * 10^{-6}} \quad \ldots(5)$$

Outdoor effective dose:

$$\mathbf{E_{oed}\ (msv/y) = D(nGy/h) * 8760h * 0.2 * 0.7\ sv/Gy * 10^{-6}} \quad \ldots(6)$$

5. Gamma level index ($I\gamma r$)

The indicator is used to estimate the radiation risk of gamma rays associated with natural radionuclides in measured models. It can be calculated from the following equation [16].

$$\mathbf{I_{\gamma r} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where A_{Ra} , A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively.

The value of $\boldsymbol{I_{\gamma r}}$ should be ≤ 1 for the radiation risk to be insignificant [17].

Results and Discussion

The overall results for the achieved samples for NORM isotopes have been presented in Table (1) Starting with samples of fly ash taken from the chimney in the boilers available at the station. Radiometric tests were conducted in the Department of Physics, Faculty of Science, University of Baghdad. in Table (1) shown as NORM isotopes in samples.

Table (1): NORM isotopes in samples.

Code sample	U-238 Bq/kg	Th-232 Bq/kg	K-40 Bq/kg	U-238 / Th-232
S1	56.17	20.35	269.62	2.76
S2	73.96	23.86	310.63	3.09
S3	87.37	28.18	365.03	3.10
S4	37.92	17.44	177.53	2.17
S5	17.64	10.07	79.33	1.75
S6	95.27	31.03	472.51	3.07
S7	35.95	15.88	178.33	2.26
S8	32.85	13.06	167.67	2.51
S9	23.39	11.98	91.35	1.95
Ave	51.17	19.09	234.67	2.517

Fig. (1) we can view The concentration activity of NORM in the samples

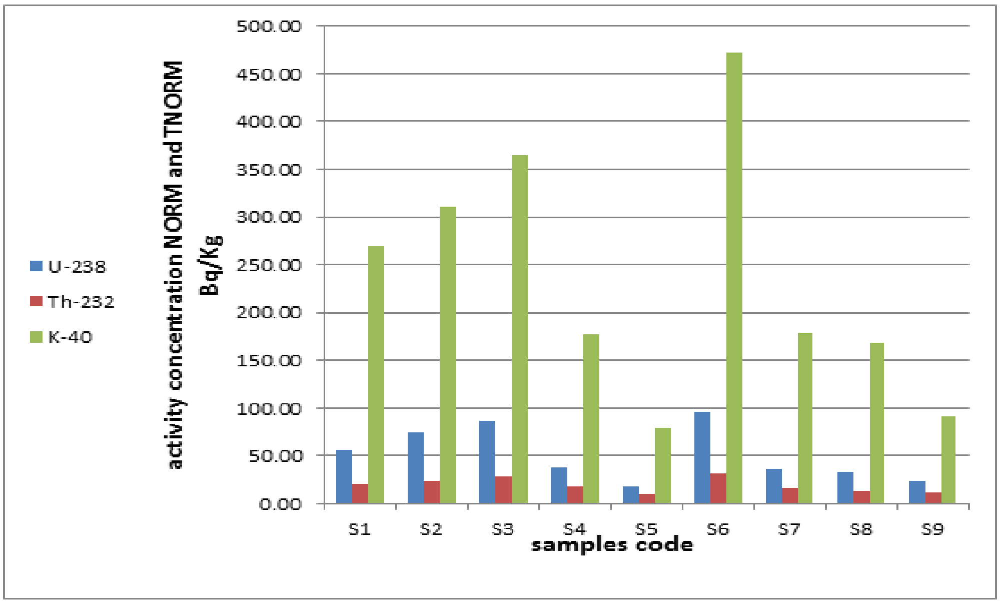


Fig. (1): The concentration activity of NORM in the samples.

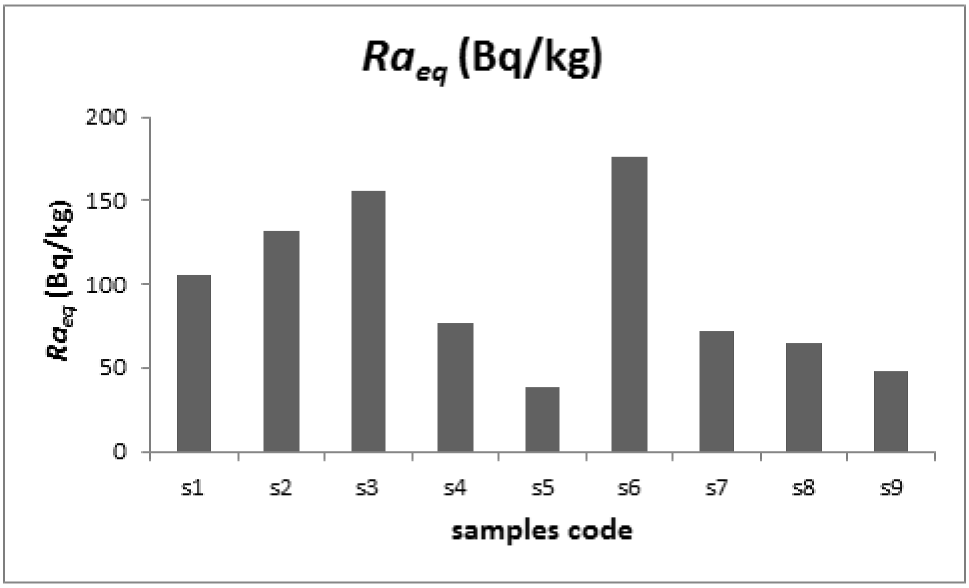
Table (2):hazard indices for all samples

Sample Code	*Ra_{eq} (Bq/kg)*	*D (nGy/h)*	*H-ext*	*H-int*	*Iyr*	*AEDR (indoor) (mSv/y)*	*AEDR (outdoor) (mSv/y)*
S1	106.03	49.83	0.29	0.44	0.76	0.244	0.061
S2	132.00	61.94	0.36	0.56	0.94	0.303	0.075
S3	155.78	73.08	0.42	0.66	1.11	0.358	0.089
S4	76.53	35.75	0.21	0.31	0.54	0.175	0.043
S5	38.15	17.71	0.10	0.15	0.27	0.086	0.021
S6	176.03	82.99	0.48	0.73	1.26	0.407	0.101
S7	72.39	33.91	0.19	0.29	0.515	0.166	0.041
S8	64.44	30.28	0.17	0.26	0.46	0.148	0.037
S9	47.55	22.05	0.13	0.19	0.334	0.108	0.027
Minimum	38.15	17.71	0.10	0.15	0.27	0.086	0.021
Maximum	176.03	82.99	0.48	0.73	1.26	0.407	0.101
Average	96.5444	45.2822	0.2611	0.3988	0.6876	0.2216	0.055

Hazard Indices

1. Radium equivalent activity

Table (1) explains all the calculated danger indices, However, the overall average value of radium equivalent activities (Ra_{eq}) of gamma dose rate for the full samples set were determined using equation (1) to be 96.5444Bq/kg. This value is normal, while the maximum value of Ra_{eq} is 176.03 Bq/kg and the minimum value of Ra_{eq} is 38.15 Bq/kg.



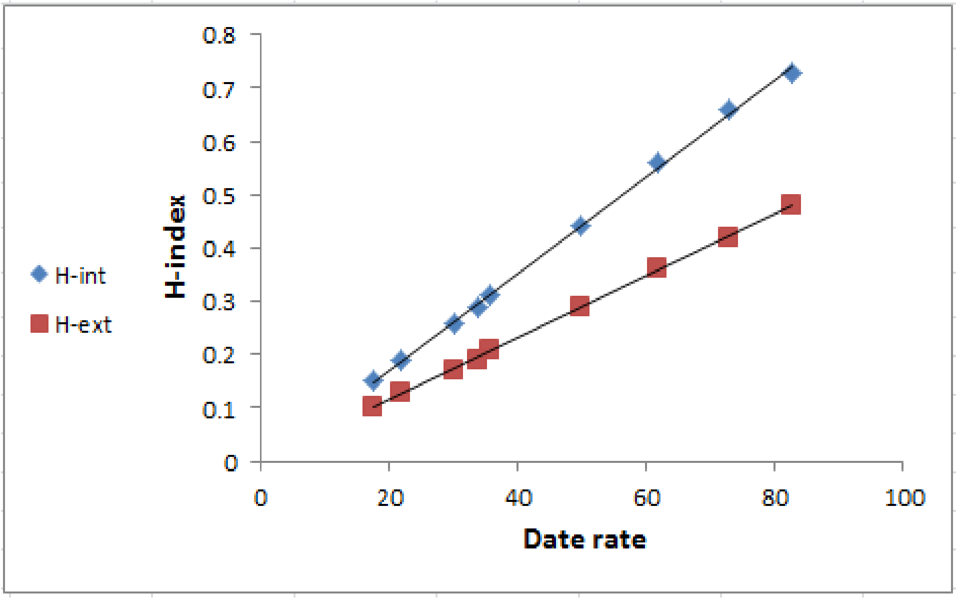
Fig(2): the radium equivalent activity in sample

2. Dose Rate (D)

The overall average value of the gamma dose rate (D) for the total samples were found to be 45.2822nGy/h, which is calculated using eq.(2).The extreme value is 82.99 nGy/h and the minimum value is 17.71 nGy/h.

3. External and internal hazard indices

The overall average values of the external and internal hazard indices (H_{ex}, H_{in}) are 0.2611and 0.3988. The extrreme value of H_{ex} is 0.48 and the minimum value is 0.10 , and the extreme value of H_{in} is 0.73 and the minimum value is 0.15 . The values of the H_{ex} and H_{in} indices must be less than unity (<1) for the radiation danger to be negligible [18]. External and internal hazard indices for all the samples were shown in this Fig. (2)



Fig(3): $H_{ex}$and H_{ex}as a function of D (nGy/h) in samples

4. Indoor and outdoor annual effective Dose

The overall average values of the annual effective dose equivalent (AEDE) due to terrestrial gamma radiation indoors and outdoors gained for all samples set were 0.2216 and 0.055 mSv/y. The extreme value of AEDE (Indoor) 0.407mSv/y and the minimum value is 0.086, and the extreme value of AEDE (Outdoor) 0.101mSv/y and the minimum value is 0.021 .

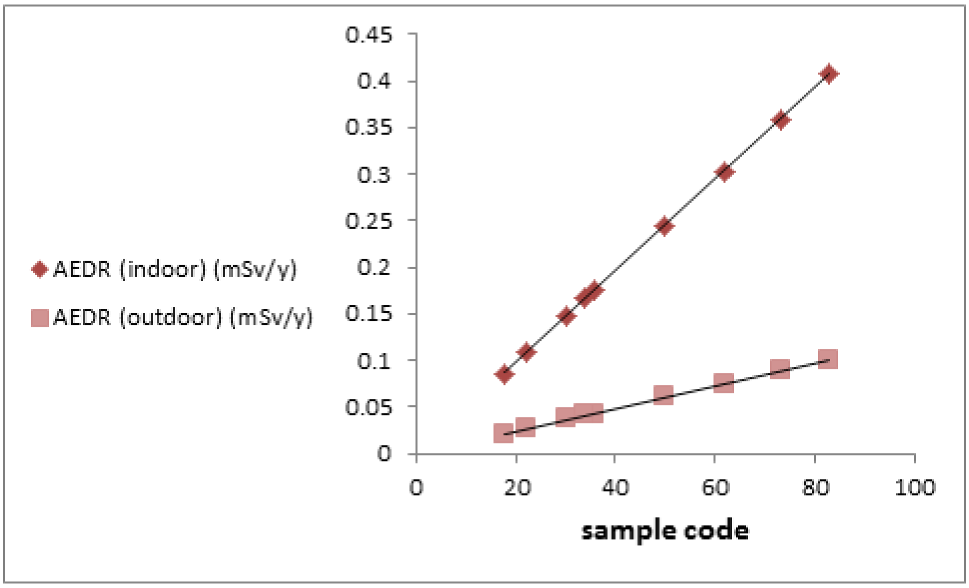
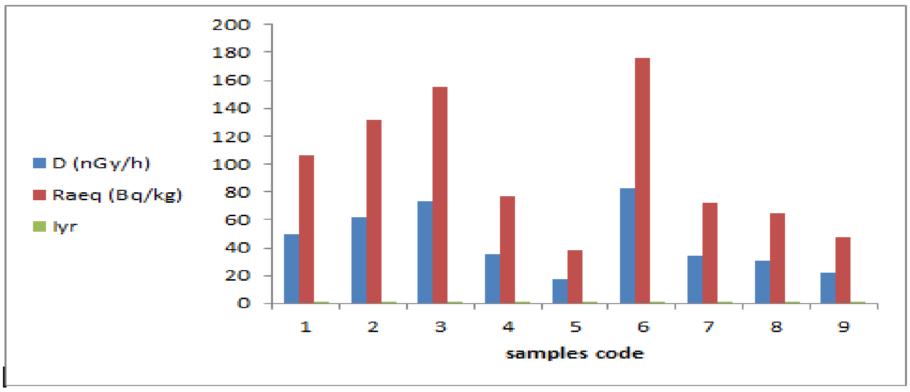


Fig. (4): AEDE (Indoor) and AEDE (Outdoor) in (mSv/y) as a function of D (nGY/h) in sample

5. Gamma level index (*Iγr*)

The extreme value is 1.26 and the minimum value is 0.94, Figure (4) shows the dose rate values in nGy/h with representative level index, (Iγr), and radium equivalent activities (Ra_{eq}) gained in the present study.



Fig(5)： Ra_{eq} (Bq/kg) and $I_{\gamma r}$ as a function of D(nGy/h) samples

Conclusion

The middle value of radium equivalent activities (Ra_{eq}) of gamma dose average for the full measured samples, considered to be normal. thus, all hazardous radiation indicators for all samples are less than the permitted global ranges of hazard radiation indicators.

The results confirm that there are no previous or old contaminants in the study area, as the total uranium Rn^{222} concentrations are higher than the results of Thorium by about 3-4 times.

The total concentration of heavy elements for all samples is higher permissible international level but the raise lung cancer hazard increases with the increasing heavy elements concentrations.

Follow the basic safety conditions such as work clothes, gags and paws and avoid injury at the workplace should not be neglected.

Finally, the total average radiation background of Kut city in air is within the recommended limits of the Iraqi Ministry of Environmental and the international proxies but in some places have higher values.

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