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The concentrations of Natural Radioactivity in Fly Ash Released from Al-Dura thermal Power Plant in The south of Baghdad City

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Abstract

The concentrations of naturally radioactive made occurring and technically enhanced radioisotopes of fly ash samples, collected from Al-Dura thermal power Plant- south of Baghdad, have been investigated using the NaI(Tl) gamma-ray spectroscopy. The average Activity concentrations of the radio elements ^{238} U, ^{232}Th and ^{40}K in Fly ash samples are measured accurately and found to be 33.860, 32.6 and 644.64Bq/kg respectively. On the whole the radionuclide's concentrations are still below the global average of 50 Bq/kg for ^{238}U and ^{232}Th, but are much higher in ^{40}K, relative to the global average, about 500 Bq/kg. The absorbed gamma doses in air, due to naturally occurring radionuclides in fly ash samples, are measured and found within the range; from 46.863 to 86.358 nGy h^{-1}, which is higher than the world average, about 43 nGy h^{-1}. As well as Fly Ash samples have had Radium equivalent activity (Ra_{eq}) with an average is about 138.82 Bq/kg. The radiation hazard indexes are calculated based on the above results and found lower than the maximum value. The overall average values of the H_{ex} and H_{in} indices have been found to be 0.37and 0.32 respectively. Also, the overall average value of the representative gamma index ($I_{\gamma r}$) for all fly ash samples is about 1.037, which are greater than the unity (>1). In this case, treatments to the NORM released from that station must be done.

Keywords: Fly Ash, Radioactivity, Thermal Power Plant

تركيز النشاط الاشعاعي الطبيعي ومعاملات الخطورة لبعض عينات الرماد المتطاير من محطة كهرباء الدورة الحرارية في جنوب مدينة بغداد

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الخلاصة

تم البحث عن النظائر المشعة طبيعيا والنظائر المشعة المحسنة تقنيا لعينات من الرماد المتطاير ، والتي جمعت من محطة الدورة الحرارية الواقعة جنوب مدينة بغداد، باستخدام منظومة كاشف اشعة كاما- ايوديد الصوديوم. تم قياس تراكيز النشاط للعناصر المشعة (^{238} U و^{232}Th و ^{40}K) بدقه وكانت على التوالي (33.860 و 32.6 و 644.64 بكرل/كغم). بشكل عام وجد ان تراكيز النوى المشعة في الرماد المتطاير اقل من المعدل العام (50 بكرل/كغم بالنسبة ^{238} U و^{232}Th) ، باستثناء الزيادة في نظير ^{40}K عن المعدل الدولي (500 بكرل/غم).

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كذلك قيست جرع اشعة كاما الممتصة في الهواء نتيجة وجود النوى المشعة في الرماد المتطاير وكانت ضمن الحدود 46.863 الى 86.358 نانوكري/ساعة ، وهي تمثل اعلى من المعدل الدولي والبالغ 43 نانو كري /ساعة . سجل معدل قيم النشاط المكافئ في الرماد المتطاير بحدود 138.82 بكرل/كغم وكذلك المعدل الاجمالي للمعاملات H_{ex} , H_{in} بحدود 0.37 و 0.32 على التوالي. وجد ان معامل كاما $I_{\gamma r}$ لجميع نماذج الرماد المتطاير بحدود 1.037 وهي تمثل اكبر من واحد ، الامر الذي يتطلب معالجة اطلاق المواد ذات النشاط الاشعاعي الطبيعي الذي يرافق الرماد المتطاير من المحطة الحرارية في الدوره.

Introduction

Fly ash is a residue of burning of coal, lignite and crude oil, the organic sources of energy. The macro and micro nutrients contain radionuclides and generally concentrated in the ash. It is also known as flue-ash, which is one of the residues generated in combustion, and comprises the fine particles that rise with the flue. In an industrial context, fly ash usually refers to ash produced during combustion of coal, oil or gas. It is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of power plants. Together with bottom ash removed from the bottom of the furnace in this case jointly known as coal or crude oil ash. Depending upon the source and makeup of the coal/oil being burned, the components of fly ash vary considerably, for instant many coal-bearing rock all fly ash includes substantial amounts of silicon dioxide (Sio2), both amorphous and crystalline, and calcium oxide (CaO), both being endemic ingredients [1]. The constituents depend upon the specific coal/oil bed makeup, but may include one or more of the following elements or substances found in trace quantities, up to hundred ppm, arsenic, beryllium, boron, cadmium, chromium, hexavalent, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium and vanadium, along with dioxins and PAH compounds [2].

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled [3], often used as a Pozzolan to produce hydraulic cement or hydraulic plaster or a partial replacement for Portland Cementin concrete production.

Measurements of radioactivity in technologically enhanced naturally occurring radioactive material (TENORMs) are important from the radiation protection point of view because more than 50% of the total dose to human population from natural sources of radiation is contributed by these materials. The main contribution is due to inhalation of ^{222}Rn, ^{220}Rn and their progeny, which are the most important radioactive and potentially hazardous elements, emitted by primordial radionuclide's present in TENORMs and are released into the environment [3].

Naturally occurring radioactive material (NORM) are ubiquitous in the environment. That is to say NORM is widespread in sands, soil, rocks, etc., although the concentration of NORM in most natural substance (processed by humans) is low, much of the literature suggested in which material is extracted from the earth and processed can potentially concentrate NORM on products, by-product or waste [4, 5].

Natural radioactivity in soil comes from ^{238}U, ^{232}Th and ^{40}K.The evaluation of their concentrations in the samples, with respect to the natural background levels and regulatory control actions, can estimate the environmental potential in transportation to the human, and study the magnitude and extent of deposition, especially for long - term release. That is the reason to carry out radiological characterization of soil and to select the lowest amount of harmful matters.

In the present work fly ash sample of Al-Dura thermal power station was collected and analysed the activity concentration of natural radionuclide's namely ^{238} U, ^{232}Th and ^{40} K using gamma spectrometry -NaI (Tl).

Materials, System and Methods of Calculations

Fly Ash samples are collected from Al-Dura thermal power station, south of Baghdad. The samples are dried for 24 h in electrical oven at 110 ^{0}C. The dried samples were grounded with mortar and pestle and then allowed to pass through a 100- mesh sieve, where further powder, homogeneity are achieved. Sample of 1kg dry-weight are packed in air tight standard cylindrical plastic container, high geometry 7.6cm x 7.6cm, its area suit the detector geometry. Then, it is stored for a period of four

weeks before counting, so that secular equilibrium can be attained, after attained of secular equilibrium the samples are subjected to gamma -ray spectrometric analysis. Gamma spectroscopy system is used in analyzing the samples. A High level shielding against the environmental background radiation was built by using 100mm thick lead castle [6], The counting is accomplished by using a thallium activated Canberra vertical high purity 3"x 3" Sodium iodide [NaI(TI)] detector, and then, matched gamma energies via library of possible isotopes, through program MAESTRO window. The energy resolution of the detector is 8% from ^{137}Cs energy line at 662keV, while the activity of the standard at the time of calibration is 25.37kBq.The background spectrum measured under the same conditions for both the standard and sample measurements to correct the calculated sample activities concentration[7, 8].

After the arrangements of the counting systems with samples, the concentration of ^{232}Th is determined, from the average concentrations of ^{212}pb (238.6 keV) and ^{228} Ac (911.1keV) in the samples, and also the average concentration of ^{214}pb (351.9 keV) and decay product of ^{40}k (1460 keV) are determined.

Since the activity index provides a useful guideline in regulating the safety standard dwellings, therefore, different known radiation health hazard indices analyses have been measured in present study to arrive at a better and safer conclusion on the health status of a radiated or irradiated person and environment in the present of fly ash area. Among them is the Radium equivalent (Ra_{eq}), which is a common index used to compare the specific activities of materials containing ^{226}Ra, ^{232} Th, ^{40}K by a single quantity, which takes into account the radiation hazards associated with them [9]:
This equations taken from the source and the figures is a theory which is already in place[10];

$$Ra_{eq}(Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_K \text{ [10]}$$

where A_{Ra}, A_{Th} and A_k are the radioactivity concentration of ^{226}Ra , ^{232} Th and ^{40}K respectively.
Also, since many radionuclides occur naturally in terrestrial soils and rocks and upon decay, therefore, these radionuclides could produce an external radiation field to which all human beings are exposed. An example of the primordial radionuclides, which are of distinguish activities natural radionuclides, are ^{226}Ra, ^{232} Th, ^{40}K Thorium and uranium head series of radionuclides that produce significant human exposure. Therefore, the external and internal hazards indices are respectively:

$$H_{ex}(Bq/kg) = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810}$$

and

$$H_{\text{int}}(Bq/kg) = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810}$$

where A_{Ra}, A_{Th} and A_k are the radioactivity concentration in ^{226}Ra , ^{232} Th and ^{40}K.
They should be less than unity for the radiation hazard to be negligible.

The internal exposure to radon is very hazardous which can be lead to respiratory diseases like asthma and cancer. The γ- radiation hazard associated with the natural radionuclide, in specific investigated samples, can be estimated by gamma index (I_{yr}), (I_{yr}) Representative Gamma Index This is used to estimate the γ- radiation hazard associated with the natural radionuclide in specific investigated samples[11,12], These numbers are originally from the source.

$$I_{yr} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \text{ [10]}$$

This index is also used to correlate the annual dose rate due to the excess external gamma radiation caused by superficial materials. It is a screening tool for identifying materials that might become health of health concern when used for construction [13]. Values of Iyr ≤ 1 corresponds to an annual effective dose of less than or equal to 1mSv, while Iyr ≤ 0.5 corresponds to annual effective dose less or equal to 0.3mSv [14]. The absorbed gamma dose rate in air above the ground surface for uniform distribution of radionuclides ^{238} U ^{232}Th and ^{40} K was computed on the basis of guide-lines provided by UNSCEAR[15] . The conversion factors used to compute absorbed gamma dose rate (D) in air per unit activity concentration in (1Bq/kg) is [10]:

$$D(nGy/h) = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_k \text{ [10]}$$

where: A_{Th}, A_{Ra} and A_k are the radioactivity concentration in ^{226}Ra , ^{232} Th , ^{40}k respectively

Results and Analysis:

Table-1 present the three(^{238}U, ^{232} Th , ^{40}K) natural radionuclide isotopes present in the power station , The radioactivity concentration values obtained in the power station are below the world average value of 400Bq/kg for ^{40}k, 35Bq/kg for ^{238} U, 30 Bq/kg for ^{232}Th The relatively high values of ^{40}k are comparable with the values reported by and maybe as a result of its abundance in the earth crust ,The average concentrations of ^{238} U in the power station are slightly higher compared to that of ^{232} Th. This may be attributed to the fact that ^{238}U is moderately soluble in water and is found more abundant than ^{232}Th in atmosphere Also, external and internal hazard indices with the representative gamma index are less than the world permissible value of unity. This indicates that the values will not lead to respiratory diseases such as asthma and cancer and external diseases such as erythema, skin cancer and cataracts.

Table 1- The overall results for the investigated samples of fly ash isotopes and Hazard indices

Station Name	Sample Code	*U-238 Bq/Kg*	*TH-232 Bq/Kg*	Cs-*137* Bq/Kg	*K-40 Bq/Kg*	*Raeq (Bq/Kg)*	*D (nGy/h)*	*H-ext*	*H-int*	*Iyr*
Al-Dura	S1	*28.74*	*27.61*	1.21465	*951.43*	*141.47*	*70.09*	*0.382*	*0.460*	*1.102*
	S2	*36.77*	*20.33*	27.1953	*689.67*	*118.94*	*58.37*	*0.321*	*0.421*	*0.908*
	S3	*79.01*	*54.49*	72.3348	*406.29*	*188.22*	*87.29*	*0.508*	*0.722*	*1.343*
	S4	*24.46*	*30.77*	18.7982	*776.40*	*128.25*	*62.79*	*0.346*	*0.412*	*0.988*
	S5	*30.39*	*30.59*	4.18494	*551.37*	*116.59*	*56.03*	*0.315*	*0.397*	*0.876*
	S6	*28.47*	*27.61*	3.75624	*951.43*	*141.47*	*70.09*	*0.382*	*0.460*	*1.102*
	S7	*83.99*	*32.52*	45.279	*494.58*	*168.57*	*79.62*	*0.455*	*0.682*	*1.215*
	S8	*56.76*	*34.40*	10.7618	*436.88*	*139.59*	*65.80*	*0.377*	*0.530*	*1.014*
	S9	*36.10*	*45.98*	40.8219	*642.59*	*151.33*	*72.03*	*0.40 9*	*0.506*	*1.129*
	S10	*3.87*	*19.89*	3.83789	*792.89*	*93.36*	*47.20*	*0.252*	*0.263*	*0.753*
	S11	*15.58*	*48.63*	3.69159	*797.56*	*146.52*	*70.65*	*0.396*	*0.438*	*1.122*
	S12	*24.76*	*58.38*	14.8616	*653.48*	*158.56*	*74.94*	*0.428*	*0.495*	*1.185*
	Ave=	37.70	33.39	20.55	678.88					

Conclusion:

The gamma spectroscopy method NaI(Tl) was used for assessment of the ^{238} U and ^{232}Th series and $Cs^{137}$and ^{40}k concentration in many fly ash samples collected from Al-Dura thermal Power Plant in the southern of Baghdad city. The average activity concentrations ^{238}U ^{232}Th and ^{40}k in Fly ash samples are found to be 37.70, 33.39 and 678.88 Bq/kg respectively. On the whole the radionuclide's concentrations are still below the global average of 50 Bq/kg, 50 Bq/kg for ^{238}U, ^{232}Th, but is much higher in ^{40}k because the global average is about 500 Bq/kg for ^{40}k .

There is a rapprochement in results between the present work and the data measured from different countries listed in Table-2 like, India,. But, the comparisons also show some variations with values from other countries. These indicate considerable variations in the activity concentration due to the varying amounts of Uranium, Thorium and **k** contents as a result of different geological formations under the earth crust from where the raw material for particular kind of sand was obtained.

Table 2-The overall results of fly ash Indian Samples

Sample Code (Indian)	*U-238 Bq*/kg	*TH-232 Bq*/kg	*K-40 Bq*/kg
S1	202	288	BDL
S2	164	197	355
S3	203	197	BDL
S4	149	232	BDL
S5	158	236	BDL
S6	114	165	BDL
S7	110	145	BDL

From this work one can deduce the evaluation of radiation hazard indices are found to be below the standards for such environment and as such exposure to the drilling mud by the drillers and other workers will pose no significant health threat to human lives and the environment is said to be radio logically hazard safe.

Figure-1 shows us some Radioactive isotope in the first and tenth samples of fly ash by using Nuclear Detector (NaI(Tl)) To show us some radioactive isotopes like ^{238}U,^{232}Th,^{40}K,^{137}Cs In the value of the specific energies.

This Figure-1 was obtained through the system existing in the laboratory It also shows us the radioactive isotopes through its energies known like ^{40}K from 1460Kev and ^{137}Cs from 661.7Kevand etc This form is the relationship between the count for a full hour and energies.

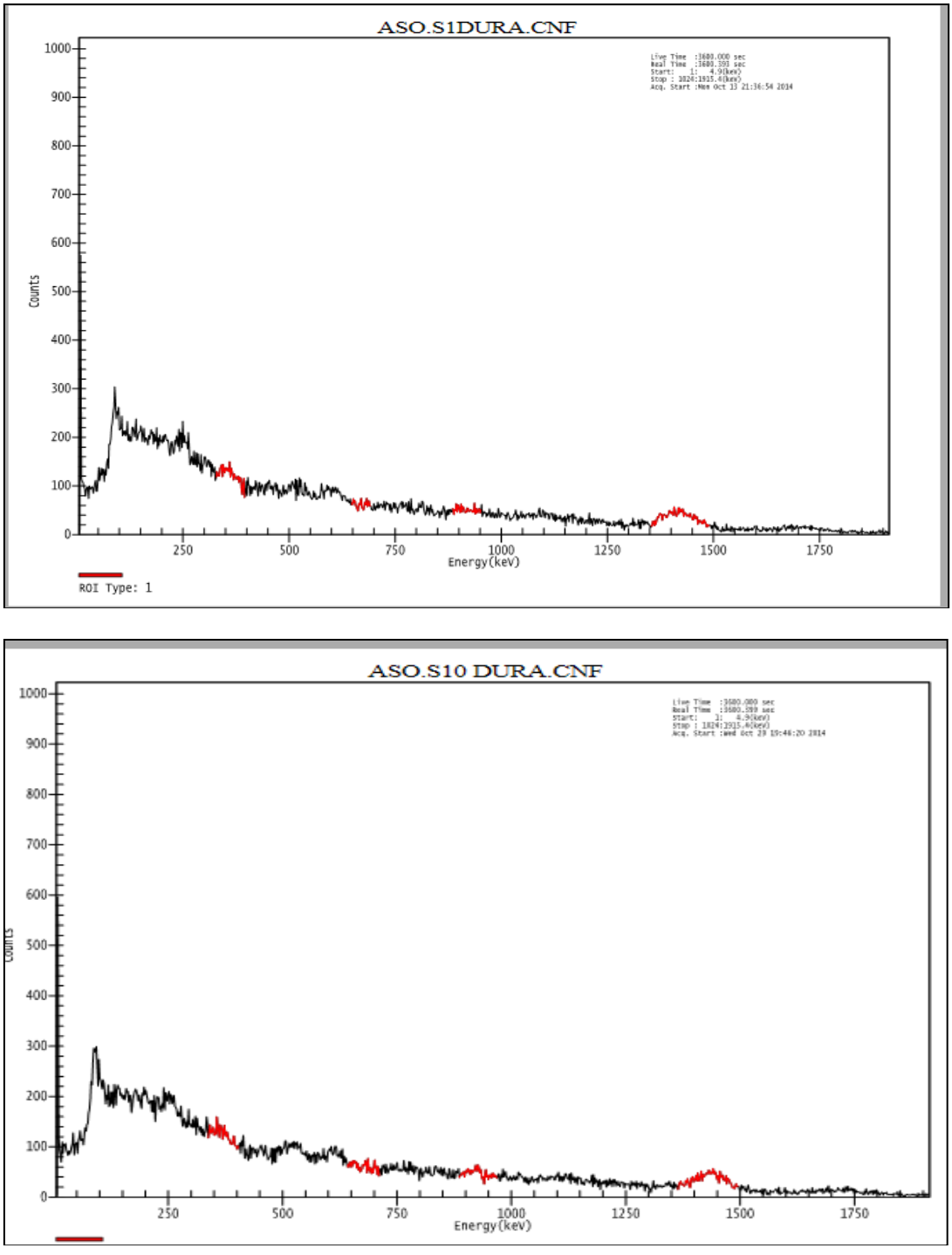

Figure 1- The Activity concentration in Fly Ash samples (1&10) by using the NaI(Tl) Gamma spectrometer

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