External and Internal Hazard indices in fly ash samples from Al-Hartha thermal power station

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Abstract
In the presented study, internal and external hazard indices for fly ash’s samples were measured from Al-Hartha thermal power station in the south part of Al-Basra province in Iraq. Eight samples were taken from different places inside the station. The samples were collected at year 2018 and compared with a previous study at 2014. The range of total values (highest value and lowest value) related to the internal and external hazard indices was $H_{in} = 1.374 - 0.612$ and $H_{ex} = 1.003 - 0.529$, respectively. Therefore, it is noted that some $H_{in}$ and $H_{ex}$ values are considered higher than the permissible limits set by international organizations, especially the S4 sample, taking into account that the values of radiation risk factors should be less than one ($\leq 1$) to be negligible. Therefore, the results of the measurements showed that the values of hazard indices related to some samples of fly ash that were taken from Al-Hartha thermal electric power station in Al-Basra are higher than the internationally permissible limits.

Keywords: hazard indices, fly ash, thermal power station.

Introduction
Fly Ash is made of crude oil such as fly ash from electrical power stations (thermal or gas), phosphor gypsum and certain slags etc. Materials containing little quantities of natural radionuclides.

The presence of radionuclides in crude oil or in fly ash may cause individuals living in residences to be exposed to internal and external radiations, that could vary according to the oil’s geochemical features and the area’s geology. External radiation is caused majorly because of the gamma radiation from natural radioactivity, while the internal radiation emerges from breathing in the $\alpha$- particles, that are discharged by the short lived gaseous radionuclide's thoron ($^{220}$Rn
which is the daughter product of $^{224}$Ra) and radon ($^{222}$Rn which is the daughter product of $^{226}$Ra). [1].

Many quantities of natural radioactive nuclides are included in the fly ash; derived materials either from the crude oil or from oil that consist of natural radionuclide's regarding the thorium ($^{232}$Th) and the uranium ($^{238}$U) series, as well as the radioactive isotope regarding the potassium ($^{40}$K). In the series of uranium, the chain segment of decay is initiated from radium ($^{226}$Ra), that is radio logically of high importance. Thus, radium is always considered instead of uranium by researchers. Globally, the radium’s, thorium’s, potassium’s concentrations average in fly ash from the power stations are approximately 1000, 1000 and 10000 Bq/kg[2].

Internal and external exposures are the two types of exposures happening because of fly ash. Internal radiation result from breathing in thoron ($^{220}$Rn), radon ($^{222}$Rn) and their short decay products, while the external radiation result from direct gamma radiation. Radon can be defined as a part of the radioactive uranium’s decay series that is in fly ash, due to the fact that radon is inert gas and it could freely move through porous media. Though, just a portion of the gas reach the oil’s surface and enter the indoor air [3].

Nevertheless, the concentrations of thoron are generally at low-level, also indoor thoron could be a significant exposure cause taking into account some rare situations where crude oil consist of high thorium concentrations.

Some widespread studies were being conducted in various countries because of the increasing awareness in approximating a baseline level of terrestrial gamma radiation. Estimating the external exposures resulting from gamma-ray radiation is significant as it could be very helpful in evaluating the total yearly dose for individuals. Depending on the $^{232}$Th, $^{238}$U, and their daughter products, and $^{40}$K concentrations in local geology the doses could vary noticeably [4].

Additional cause of individual’s exposure to radiation is their activity concerning the application of radiation. Some activities could result in a great exposure level from natural sources like nuclear power plants that discharge radioactive materials in the environment, the global dispersion of radionuclide's from testing nuclear weapons or the nuclear reactor accidents which cause atmospheric fall-out such as Fukushima recently and Chernobyl before [5]. Nevertheless, using radiation for medical motives is the leading artificial source of yearly dose that is received via people all over the world. Some groups of people working in industrial
medicine or research field could be exposed to radiation from their work. The taken dose from natural radiation exposure is higher than of the occupational exposure [6].

**Experimental Method**

1. **External and internal hazard indices**

   External hazard indices $H_{ex}$ (representing external exposures) is what is used often to refer to hazard indices, $H_{ex}$ can be estimated as below.

   $$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_{k}}{4810} \ldots \ldots \ldots \ldots (1)$$

   As well as the external hazard index, radon along with its related short-lived products is considered to be harmful to respiratory body parts. Internal exposure to radon along with its daughter product is measured through the internal hazard index $H_{in}$ that is specified via:

   $$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_{k}}{4810} \ldots \ldots \ldots \ldots (2)$$

   For the radiation hazard to be insignificant, the values of $H_{in}$ and $H_{ex}$ should be less than unity ($\leq 1$) [7].

2. **Radiation hazard indices**

   As interaction happens between the radiation energy and the living cell’s molecules via exposure and deposition, then the biological effects of ionizing radiation could begin. The symptoms which are related to severe radiation injury is likely to occur in the first few hours or days when a substantial dose is carried in short-time (i.e. $> 20$ Gy full body). Nevertheless, the biological impact of the exposure could not happen for several decades or could not happen at all when the given dose is considerably less and recurring through many years [8].

   This work focuses on natural radioactivity $\text{^{40}K}$, $\text{^{232}Th}$ and $\text{^{226}Ra}$ in fly ash from thermal power stations and considers the radiation hazards related to them, a typical radiological index was presented; this index is referred to as the radium equivalent activity ($\text{Ra}_{eq}$) [8].
3. **Samples collection**

A collection of samples in this research have been taken from Al-Hartha thermal electrical power station in southern part of Al-Basra province in Iraq. These samples were taken randomly from differences Units in the station. The details of samples, which are collected, are presented in Table (1). Figures (1) show that the area where the fly ash is collected near the boiler and from economizer of Al-Hartha thermal power station, respectively.

**Table (1): the details of samples which are collected**

| S.No | Al-Hartha Station                                      |
|------|-------------------------------------------------------|
| S1   | From inside the oven below                           |
| S2   | From the bottom of the oven                          |
| S3   | From the bottom of the inside of the oven            |
| S4   | From the bottom of the oven from Externally          |
| S5   | A sample of the area 1,2,3                           |
| S6   | Floor furnace                                        |
| S7   | The bottom of the oven from abroad                   |
| S8   | A sample of the area super heater (SH)               |

Through the use of NaI(Tl) gamma spectroscopy with standard system setup, the activity concentration of the radionuclides $^{40}$K, $^{232}$Th and $^{226}$Ra of samples in Iraq were measured. The places of the collection samples in stations are: chimney, boiler, and super heater, economizer, walking line, units, filters and generator. Each Sample was packed into secure bag and gave code's number S and A refers to Fly ash Samples.
4. Samples preparation

The sample preparation depends on the type of samples under research. The Fly ash samples were converted into powder and the homogenized samples with the size, about 1kg, were put in a Marinelli beakers to measure the activity concentration of radionuclides using NaI(Tl) detector. All samples were weighted using a fine balance ± 0.01g error. All Fly ash samples crushed, milled, grinded and dried by placing each sample at room temperature, removing any residual moistures and ensure reaching a constant weight. Then, the dried samples were pulverized into a fine powder Fig. (1) shows the location which samples collected from Al-Hartha thermal electric power station.

Figure (1): Fly ash from air heater & economizer and walking line from Al-Hartha thermal electrical power station
Results and Discussion

The results for this research have been presented in Table (2).

From Table (2), it can be shown that the maximum value regarding the specific Activity (SA) of radioactive nuclide $^{226}$Ra or $^{238}$U is 176.43 Bq/kg in S3 whereas the minimum value is 23.97 Bq/kg in S6.

For the isotope $^{228}$Ac or $^{232}$Th the maximum value of the SA is 143.48 Bq/kg in S6, and the minimum value is 51.87 Bq/kg in S2, the maximum value of the SA of $^{40}$K is 1208.0 Bq/kg in S7, the minimum value is 389.07 Bq/kg in S6. Figure (2) shows summary for the maximum & minimum value of SA for all samples.

The overall average values related to the internal ($H_{in}$) and external ($H_{ex}$) hazard indices, which calculated using equations (1 and 2) are 0.78 and 1.01, The maximum value of $H_{ex}$ is 1.003 in S4 and the minimum value is 0.529 in S8, and the maximum value of $H_{in}$ is 1.410 in S2 station and the minimum value is 0.612 in S8 station. For the full samples set of fly ash, it is found that all $H_{ex}$ and $H_{in}$ had the up normal range and below unity. For the radiation hazard to be insignificant, the $H_{ex}$ and $H_{in}$ values should be less than unity ($<1$) [9] but in some samples the value of these indices were greater than the unity ($>1$) In this case, treatments to the NORM released from that stations must be done.

| Sample Code | $^{238}$U Bq/kg | $^{232}$Th Bq/kg | $^{40}$K Bq/kg | $H_{ex}$ | $H_{in}$ |
|-------------|-----------------|-----------------|----------------|---------|---------|
| S1          | 68.76           | 96.84           | 1124.35        | 0.793   | 0.979   |
| S2          | 187.41          | 51.87           | 946.02         | 0.903   | 1.410   |
| S3          | 176.43          | 63.19           | 849.76         | 0.897   | 1.374   |
| S4          | 114.83          | 130.80          | 451.26         | 1.003   | 1.313   |
| S5          | 43.65           | 76.98           | 1146.97        | 0.6540  | 0.772   |
| S6          | 23.97           | 143.48          | 389.07         | 0.700   | 0.764   |
| S7          | 58.59           | 93.55           | 1208.52        | 0.771   | 0.929   |
| S8          | 32.94           | 58.87           | 1022.59        | 0.529   | 0.612   |
| Overall average | 88.32 | 89.44 | 892.31 | 0.78 | 1.01 |
if its compare the average activity concentration levels in Fly Ash from Al-Hartha thermal electric power station for $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in Bq/kg and $H_{ex}$, $H_{in}$ for the same study but in 2014 we notice have a high concentration of radionuclide's us we shown in Table (3).

It is possible to note the increase in the concentrations of radioactive elements or internal and external hazard indices cores because of fuel type utilized in the thermal power station or because of the exposure of radioactive elements to pollution the Al- Basra city

Table (3): a comparison of average activity for $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ [10]

| Sample Code | $^{238}\text{U}$ Bq/kg | $^{232}\text{Th}$ Bq/kg | $^{40}\text{K}$ Bq/kg |
|-------------|------------------------|------------------------|------------------------|
| S1          | 241.90                 | 94.83                  | 1114.27                |
| S2          | 92.57                  | 21.61                  | 1034.22                |
| S3          | 286.17                 | 220.34                 | 506.30                 |
| S4          | 87.37                  | 34.89                  | 928.16                 |
| S5          | 32.94                  | 58.87                  | 1022.59                |
| S6          | 22.10                  | 41.47                  | 947.40                 |
| S7          | 10.94                  | 27.94                  | 664.20                 |
| S8          | 200.89                 | 173.90                 | 742.24                 |
Conclusion:

From the results presented in this work, which included measuring the activity related to gamma-emitting radionuclides in the samples of fly ash I can conclude:

1) The results show that there is weirdly disparity in the values of S.A for measured samples and it is due to the differences in the kind and differences in the origin.

2) Any hazard indices can be calculated without measurement of any S.A of terrestrial radionuclides. There is weirdly disparity in the values of hazard indices external or internal due to the concentration of radioactive nuclides in some samples, or due to increased concentrations of radionuclides from military operations in Al-Basra city especially in (2003)

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