Radiological Impact from Airborne Routine Discharges of Coal-Fired Power Plant

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Abstract

Radioactivity exists everywhere in nature. We are exposed to intense and continuous natural radiation coming from the sun, cosmic radiation, telluric radiation and even to the internal radiation of our own body. The fly ash emitted from burning coal for electricity by a power plant carries into the surrounding environment 100 times more radiation than a nuclear power plant producing the same amount of energy. This paper presents the information of studies on the radiological impact from airborne routine discharge of coal-fired power plants.

1.0 Introduction

Radioactivity exists everywhere in nature. We are exposed to intense and continuous natural radiation coming from the sun, cosmic radiation (from stars other than the sun), telluric radiation (from the ground), and even to the internal radiation of our own body (about 10 000 Becquerel for an average individual). The amount of natural radioactivity can vary, from one region to another. The average background radiation on Earth is by the order of 0.2 µSv/h, or about 2 mSv/year.

As for Malaysia, the average outdoor dose rate is 92 nGy/hr, (measurement range 55-130 nGy/h). Malaysia with a population of about 25 million, about, 5% of the people are exposed to 50-59 nGy/hr, 1.08% people at 60-69 nGy/hr, 61.8% at 70-79 nGy/hr, 12.72% at 0-89 nGy/hr, 43.2% at 90-99 nGy/hr and 31.82% at 100-199 nGy/hr. The external exposure is comparable to the indoor exposure, averagely measured to be about 96 nGy/hr. The external terrestrial exposure is derived from the soil (concentration of K-40, U-238, Ra-226 and Th-232 were determined) and also from the direct exposure, but the ratio of distribution from soil to direct exposure were found to be 1.00. (source: UNSCEAR, Report to General Assembly, 2000).

In 2007, Malaysia increased its coal share of electricity generation to 34.2% (National Energy Balance 2007). Two mega projects of Independent Power Producers were Paremba-Alstom Plant in Manjung, Perak and SKS Power-Sumitomo for plant in Tanjung Bin, Johor. Each of these plants has the capacity of generating 2100MW electricity. The Manjong plant operates using low sulfur, low bitumen pulverized coal while the Tanjung Bin plant is designed to burn either entirely bituminous coals or blended with up to 80% sub-bituminous coals. The combustion of coal releases trace elements, including naturally occurring radionuclide, to the atmosphere as vapors and particles. Attempts have been made to use coal ash as landfill or raw material for cement. This paper explores the information on the radiological impact from air borne discharge of coal-fired power plants for future studies.

2.0 Natural Radioactivity Content of the Coal

The natural radionuclides present in coal consist mostly of members of the U-238 and Th-232 decay chains, which are considered to be in equilibrium with their parent radionuclides. They occur in such trace amounts in the natural environment. As for low quality coal such as lignite, Ra-226 concentrations of 310-350 Bq/kg has been reported [1].

Table 1: Concentrations Of Natural Radionuclide In Coal

Description	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
Fine coal, South Africa	25	30
Coarse coal, china	15	20
Coarse coal, Australia	15	15
Coarse coal, South Africa	25	15
Coarse coal, USA	15	20
Average	20	20

In comparison, Slovenia has an average content of radionuclies in the coal ash as follows; Uranium and Radium (350Bg/kg), Th-232 (45 Bq/kg), K-40 (450 Bq/kg) [9].

During combustion, due to the volatilization of the components that are being combusted, the radionuclides that are contained within these components are separated into the gas phase (air emission) and the solid phase (ash), depending on the volatility of the elements. The solid phase, which contains an average of 10-15% of the original weight of the coal and nearly all the radioactivity except for radon, is composed of bottom ash (15%) and fly ash (85%). With respect to the discharges of the other radioelements through the chimney (air emission), uranium and thorium are assumed to behave the same as radium. Lead and polonium are more volatile and will condense preferably on finer ash particles, against which the electro filters are less effective. Table 2 summarized the specific activity of radionuclides in coal and fly ash (12).

Table 2: Specific activity in coal and fly ash (nCi/kg)

Radionuclide	Coal	Fly ash
U-238 (U-234, Th-230)	<1	8
Ra-226	0.5	8
Pb-210	0.7	80
Po-210	0.8	150
Th-232 (Th-228)	<0.5	3

Uranium in the Fly Ash has the capability to leach into the soil and water where the ash is disposed off, affecting the cropland and, in turn, food. People living within a "stack shadow" the area within a half- to one-mile (0.8- to 1.6-kilometer) radius of a coal plant's smokestacks might then ingest small amounts of radiation. Fly ash is also disposed of in landfills and abandoned mines and quarries, posing a potential risk to people living around those areas through ground water contamination.

3.0 Radiological Impact

Technically enhanced natural radiation in the vicinity of large industrial plants resulting in an additional exposure of the local population is becoming an issue of concern. Fly ash from the stack of power plants containing radionuclides that are concentrated a few times more that their content in coal or surface soil has played a big role in the phenomena. Apart from inhalation, the main additional radiation hazard can be solid fallout resulting in elevated concentration of natural radionuclide in surface soils around the power plant [8]. The collected fly ash has also become the subject of interest because of the usage in the building materials and for filling underground cavities.

Table 2: Airborne discharges of ^{226}Ra from coal fired power plants

Literature Source	^{226}Ra content in fly ash (Bq/kg)
Karangelos et. al (2004)	800-1000
Zeevaert et. al (2006)	700

Study by Harold L. Beck showed that potential exposure due to fossil fuel combustion to most individuals from any pathway is insignificant. This is true in the case of modern power plant with fly ash removal efficiency of 99.5%. However, this is very much dependent of the coal type and the flue gas cleaning system. In India, it was reported that the usage of poor quality coal and lignite (low CV, high ash content), combined with high fly ash emission has resulted in the radiological impact from the thermal power plant being much higher than emission from its nuclear power plant [3].

Table 3: Typical Radioactivity Content in Coal and its byproducts in India

Radionuclide	**Activity (Bq/kg)**			
	Coal	Fly Ash	Slag	Soil
Ra-226	24.1	77.7	88.8	37.0
Ra-228 + Th -228	38.5	125.8	136.9	69.6
K-40	82.5	373.8	377.5	396.0

A study in Lodz area of Poland, a place comprising of 4 power plants, operating for more than 30 years, with annual fly ash load of 8 x 10^6 kg, showed that there was an increased of Ra-226 and Th-232 in the top layer of the soil is at 21% and 17% respectively. However, the effective dose from the natural terrestrial was only 0.28 mSv, lower than average values of 0.45 mSv for Poland [5].

A study of coal fired modern power plants in Belgium, using coal with radioactivity content of 20 Bq/kg of Ra-226, and 20 Bq/kg of Th-232, revealed that the operation of the power plant resulting in Ra-226 content in the air 4.5 nBq/m^3, with total deposition of 1.5 mBq/m^3. This correlates to an exposure of 0.05µSv/yr, an insignificant contribution of radiation exposure [2].

A study in Slovenia revealed an increas in Pb-210 in the upper layer of the soil, specifically in the prevailing wind direction area. Other impacts include water contamination and external radiation within fly ash disposal site. However, the public may only be exposed to less than 10 µSv/yr .

Finally, a study by J. P. McBride at Oak Ridge National Laboratory (ORNL) 1978 in Tennessee and Alabama, looked at the uranium and thorium content of fly ash from coal-fired power plants. The scientists estimated fly ash radiation in individuals' bones at around 18 millirems (thousandths of a rem, a unit for measuring doses of ionizing radiation) a year. Doses for the two nuclear plants, ranged from between three and six millirems for the same period. And the radiation doses were 50 to 200 percent higher around the coal plants.

4.0 Methods Application

For undertaking radiological impact study, the flue gas discharged natural radioactivity of coal and the fly ash need to be measured. For example content of Ra-226, Pb-210 and K-40 in the solid materials were determined using HPGe gamma spectrometry. Radon concentrations in the atmosphere were measures by nuclear track detectors and charcoal absorbers. Then the atmospheric transport, dispersion, and deposition of the discharged radionuclides need to be modeled. This is calculated using Gaussian Plume Model. The model used to estimate external radiation exposures from gaseous emissions following an underground nuclear explosion. Input like stack height, diameter, discharged temperatures, and flow rate is needed. Next, the transfers of the radionuclides to the air and soil are established. The equations for the calculation of the concentrations in the relevant biosphere compartments can utilize various model software packages like Orion-Win code (Japan) and Generic Model (IAEA).

5.0 Conclusion

Coal contains Uranium and Thorium and they occur in such trace amounts in natural, but when coal is burned, Uranium and Thorium are concentrated at up to a few times their original levels. In fact, the fly ash emitted from burning coal for electricity by a power plant, carries into the surrounding environment, 100 times more radiation than a nuclear power plant producing the same amount of energy. The conclusion is the waste produced by coal plants is actually more radioactive than that generated by nuclear power plant. Thus, Malaysia needs to consider the possible future study of radiological impact from airborne routine discharges of coal-fired power plant.

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