Available online at www.elixirpublishers.com (Elixir International Journal)

Pollution

Elixir Pollution 45 (2012) 7771-7773

ISSN: 2229-712X

Atmospheric beta activities on a nuclear site in Ghana

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ARTICLE INFO

Article history:

Received: 13 February 2012;

Received in revised form:

17 March 2012;

Accepted: 4 April 2012;

Keywords

Filter,

Airborne,

Gross beta activities.

ABSTRACT

Airborne beta activity measurements have been carried out on the site of the Ghana Atomic Energy Commission (GAEC). The GAEC is a nuclear institution in Ghana that is involved in the application of nuclear techniques in research, radioisotope production and utilization, operation of a research reactor and processing of radioactive waste. Ludlum model 333-2 air beta monitor was used to conduct the measurements. Monthly averages of gross beta activities ranged from 1.2 to 3.0 mBq/m^3. The gross beta activities measured were found to be due mainly to decay products of natural radioisotopes. Monthly total suspended particulate mass concentrations ranged from 22 to 110 µg/m^3. Gross beta activities and particulate mass concentrations partially correlated. Based on these results, it could be stated that present ambient airborne radioactivity has minimal radiological consequences on the environment and inhabitants of the study area. Mass concentration levels would however need to be regulated.

Introduction

Ambient air quality is affected by the amount of radioactivity in the atmosphere. Airborne radioactivity is caused by the presence of natural and artificial atmospheric radioisotopes which emit alpha or beta particles or gamma photons. Natural atmospheric radioisotopes like tritium, beryllium-7, carbon-14, radon gas and potassium-40 come about as a result of interactions of cosmic rays with atmospheric elements like carbon and nitrogen and, decay of uranium-238 and thorium-232 (Reitz, 1993). Natural radioactivity is noted to contribute over 80% of total ambient radioactivity. Artificial atmospheric radionuclides such as cesium-137, strontium-90 and iodine-131 come about as result of nuclear and related activities such as operation of nuclear installations, fallout of weapon testing, nuclear accidents and discharges from radiation wastes (Sternheim and Kane, 1999; Smith et al., 2005). Accretion of radiation emitting radionuclides on dust and fog particles enables airborne radioactivity to be measured. Ambient radioactivity measured at a particular time in a particular place is dependent on factors such as: meteorological conditions and the amount of dust and fog particles present in the atmosphere during sampling (Flury and Völkle, 2007).

Atmospheric radioactivity can have radiological effects on human health depending on the amount present. These effects could be chronic or acute. Acute effects are not common but rather chronic effects resulting from low-level prolong exposures have been reported (Stochioiu et al., 2009). When radiations find their ways into the human body via inhalation or ingestion, depending on the level of exposure and the dose absorbed, normal functioning of human cells and tissues can be affected leading to cellular malfunctioning which consequently causes health disorders and cancers. Beta particles travel further in body tissues than their alpha counterparts. When a beta particle is ingested into a body tissue, it loses its energy and becomes like any loose electron. These cause biochemical bond breaks and ion formations leading to cellular damages such as mutations. Beta cellular damages are more disperse than their alpha counterparts because a beta particle carries less electrical charge compared to an alpha particle (Kitto et al., 2005; Ryan et al., 2000).

The Ghana Atomic Energy Commission (GAEC) is a nuclear establishment in Ghana that is involved in the civil application of nuclear techniques in activities that include research, radioisotope production and utilization, operation of a research reactor and processing of radioactive waste. This work was undertaken to measure atmospheric beta activities on the GAEC site for the purposes of obtaining baseline data for the site in general and specifically for the radioactive waste facility in the vicinity of which the measurement was carried out as this is the first of its kind.

Experimental

Equipment Description

Ludlum model 333-2 air beta particulate monitor was used for the survey. This is a low-volume air beta monitor which has a pump and detector system attached to it. The pump draws air through the detector compartment. The detector system utilizes a dual pancake GM radiation detector assembly to count beta radiation while allowing for gamma background subtractions. The detection chamber comprises of stainless steel surrounded by 2-inch lead shield.

The detectors are situated in the lead shield of the detection compartment where the primary detector is co-axially positioned with a circular fibre filter paper which traps airborne particulates, and the secondary detector is placed behind the primary detector for gamma subtraction. The primary detector has counting efficiency of 36% of 2π Tc-99. Particulates for detection are collected when the pump draws air continuously through the filter which is placed in a holder in the detection chamber. The pump system is attached to the main unit. Other operating features on the unit include alarm level bell, alert level strobe, calibration controls, reset pushbutton, 4-cycle logarithmic scale meter dial and meter readout (Ludlum Measurements, Inc.).

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Airborne Particulate Sampling

The sampler unit was placed 3 m high. The pump system, which draws air continuously through the circular filter paper which is in the detection chamber, was used to collect aerosol particulates. Low-volume (47 mm circular diameter) filters (made from cellulose acetate) with aerodynamic pore sizes of 0.45 µm were used (Toyo Roshi Kaisha, Ltd). A filter to be used was first desiccated, weighed and then immediately capped into the filter-holder that is inside the detection chamber. The desiccated filter is capped immediately after desiccation to avoid the filter absorbing moisture. The detector system continuously record beta activity accumulating onto the filter. Count rate readings were taken every one to two hours during sampling, and then averaged for the day for an average sampling period of 6 hours a sampling day with an approximate sampled volume of 18.0 m^3. This reading schedule was chosen as the optimum one so as to cover the measurement of activities of short lived natural radon daughters, as well as monitor medium and long lived natural and artificial radioisotopes. Each filter was changed roughly every one week. After the sampling, the sampled filter was again desiccated and weighed to determine the net weight (mass) of collected particulate matter. Filters were handled only with forceps and kept in filter cassettes to avoid damage as well as for quality assurance purposes. The volume of air sampled by the equipment for a given sample filter was calculated based on air flow rate measurements read on the device which were in well determined range of 50 to 55 L/min. Daily count rates and weekly accumulated particulate mass concentrations were averaged as representation for the sampling month. No predetermined atmospheric conditions such as temperature and pressure were adhered to during sampling.

Measured count rates were recorded in counts per second (cps) and converted to activity concentration (Bqm^{-3}) using the relation (2.1) given below. Count rate values were corrected for background.

$$A = \frac{C}{\varepsilon V \eta} \qquad 2.1$$

Where:

A is gross beta activity concentration in mBq/m^3

C is gross beta count rate in cps (counts per second)

ε is the count rate detection efficiency in %

V is volume of air sampled in m^3

η is the particulate retention yield of the filter paper in %

Total suspended particulate (TSP) mass concentrations were calculated from the relation (2.2) given below

$$M = \frac{TSP}{V \eta} \qquad 2.2$$

Where:

M is TSP mass concentration in $\mu g/m^3$

V is volume of air sampled in m^3

η is the particulate retention yield of the filter paper in %

The retention yield of the filter paper was found to be 98 %

Results and Discussions

The results of gross beta activities show comparatively low level airborne radioactivity on the GAEC site (Figure 1). The highest monthly average gross beta activity recorded was 3.0 mBq/m^3 in January 2010 and the least value recorded was 1.2 mBq/m^3 in May 2010. The trend of airborne radioactivity on the GAEC site within the measured period is attributable to factors such as emanation rate of radon gases from soils of the area, meteorological conditions, and amount of atmospheric atomic beta emitters present at sampling time. Though radon is alpha emitter and a gas which cannot be measured directly by airborne particulate filtering, some of its solid atomic daughters are beta emitters and contribute to atmospheric radioactivity. Weather conditions influence both emanation rate of radon from the soil and quantity of radioisotope present in air. More radon gas is given off in dry soil than in wet soil. Similarly, a dry sunny weather would have more suspended particular matter unto which solid beta emitting radioisotopes can attach so that more activities is recorded. This explains the comparatively higher beta activities in dry months. Ghana has two main weather seasons: the wet season starts from somewhere April to October and the dry season which starts from November to March. Kitto et al. (2005) have reported similar values of gross beta activities in the state of New York, US. Considering that beta activities measured in this work are low, it could be inferred that they are due mainly to the decay series of natural uranium and thorium particularly short lived radon daughter products such as Pb-214 and Bi-214, though some long lived natural beta emitters may have also contributed. From aforementioned, it could be inferred that the contributions of artificial radioisotopes such as Sr-90 and Cs-137 to results of this work was negligible. These beta activity values are within acceptable limits for airborne radioactivity and compare well with results of works done elsewhere (Arkian and Amidi, 2005; Hirsikko et al., 2007).

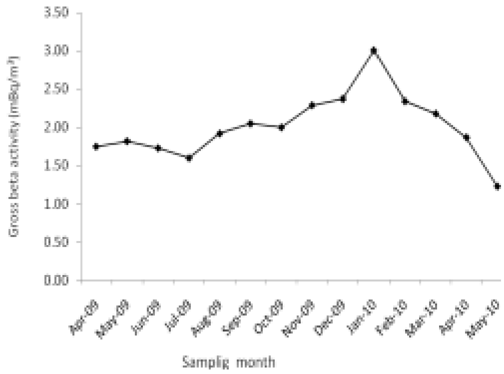

Figure 1: Monthly averages of airborne gross beta activities

Total suspended particulate (TSP) mass concentration values were between 22 and 110 $\mu g/m^3$. It is evident from the figure (Figure 2) that these values are weather dependent. The dry season recorded elevated mass concentrations compared to the wet season. This could be explained by the fact that during the dry season in Ghana, which is called the Harmattan season, the atmosphere becomes hazy and there is so much suspended dust. The dust is from the soil, but become suspended as result of the dryness of the environment. The season is also characterized by some fog at dawns. However as rain begins, the dust settle and that is why low mass concentrations were recorded during the wet season. Human activities such clearing, burning and road construction do also affect TSP mass concentration. Such effect is responsible for the slight differences in mass concentrations recorded for similar seasons of the two years; say the difference in values for April 2009 and April 2010. The TSP mass concentration values recorded are also low compared to results of research done elsewhere. For instance Tippayawong and Lee (2006) reported TSP mass concentration of between 50 and 370 $\mu g/m^3$ in Chiang Mai, Thailand. Figure 3 shows that gross beta concentrations and particulate concentrations at the site partially correlate. This affirms in part the assertion that amount of ambient airborne particulate matter determines the amount of airborne radioactivity.

Based on these results, it could be stated that present ambient airborne radioactivity on GAEC site has minimal radiological consequences on inhabitants and does not immediately pose hazard to the environmental as well. Mass concentration levels however, would need to be regulated by concerned authorities so as to deal with rising atmospheric dispersions and pollutions levels. It is planned that similar measurements would be conducted within regular periods for longer times than this in order to establish the real trend of these parameters.

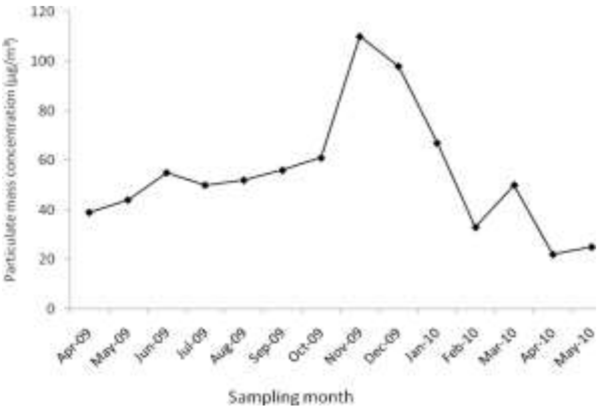

Figure 2: Monthly variations of total suspended particulate mass concentration

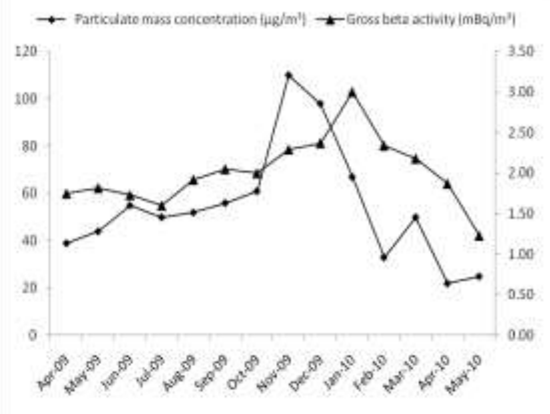

Figure 3: Plots showing monthly variations of airborne gross beta activities and suspended particulate mass concentrations

Conclusions

Average monthly gross beta activities and monthly TSP mass concentrations measured for GAEC site within the period of assessment were moderately low. The gross beta activities measured were mainly attributable to decay products of natural radionuclides. The results show partial correlation between gross beta activities and TSP mass concentrations. This confirms partly the assertion the amount of airborne radioactivity measured at a particular time is influenced by the amount of atmospheric particulate matter present at that particular time. These results would serve as baseline data for the GAEC site and also provide a basis by which decisions can be made especially in the event of an emission or accident since this project is the first of its kind to be carried out on the site.

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