Measurements of Ambient Gamma Radiation Levels as Practical Teaching for Physics Students

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INTRODUCTION

Nuclear energy has the potential to meet the ever increasing electrical energy demands in the world, particularly in the developing countries. Use of nuclear energy has become more important due to the fact that conventional energy resources such as coal and hydrocarbon produce greenhouse gases. However, due to the Chernobyl and recent Fukushima nuclear accidents, the subject of using the nuclear energy for power generation and the release of radioactivity into air as a result of such accidents are very hot issues of discussion for the public as well as students. Generally, they believe that all levels of radiation are dangerous and artificially created, i.e. the natural environment is free of radiation. Consequently the terms “radiation” and “radioactivity” elicit fear and phobia in people. Therefore, it is necessary to create awareness among the public, especially the students so as to educate them that some sources of radiation are natural and unavoidable in the environment. This highlights the need for educating the students, particularly those at higher secondary and college levels, about the natural sources of radiation and radioactivity around us. This would help the students to appreciate the fact that natural sources of radiation are the major contributors to the radiation dose received by the population, whereas the contribution of man-made sources of radiation is relatively small.

RADIATION DETECTION DEVICES USED FOR EDUCATION

Two common and easy-to-use radiation measuring devices were used for this work:
(1) GM dosimeter that provides the values of ambient dose rate with data logging, and (2) NaI(Tl) spectrometer connected to a laptop computer via a USB connection.

Test measurements with the dosimeter

Portable gamma dosimeters are mainly used to measure the gamma dose rates prevailing in a region. For the representative value of a region, a number of measurements are taken within a small area and the mean value is considered. The time intervals for each measurement may be fixed deepening upon the user requirement. Figure 1 shows the histograms for 50 readings for the dose rate as recorded by the GM-dosimeter in a fixed indoor position for three different sampling intervals of 1, 10 and 60 minutes, to demonstrate how the range of data becomes more confined when longer sampling intervals is used for the measurement. This is done to emphasize the stochastic nature of radioactivity and why students should not consider a single instantaneous or short time duration measurement as a true (or representative) value of the radiation dose. Instead, the scientific approach is to carry out the measurements repeatedly and find the mean, which is often more representative of the true value.

The results clearly suggest that longer time intervals should be considered for obtaining a better estimate of the gamma dose in a region. However, in a classroom/laboratory experimental session students spend only 2-3 h and therefore the 60 minutes measuring interval would not be feasible. In such situations sampling with shorter times such as of 10 minutes would be sufficient enough to provide an acceptable accuracy with reduced fluctuations compared to the fast and too short measurements that are considered for 1 minute sampling only.

Understanding the role of shielding against radiation

The students may be asked to collect the background gamma energy spectrum using the NaI(Tl) gamma spectrometer placing it inside and then outside a typical 10-cm thick lead shield. Inside such a lead shield, the energy spectrum would show no gamma peaks and the counts obtained in the spectrum is essentially due to the cosmic-ray component prevailing in the laboratory environment. Then, the NaI(Tl) detector is placed outside the shielding and the experiment is repeated to obtain an idea about the background terrestrial radiation due to primordial radionuclides in the environment, Figure 2. Also shown in Figure 3 is the dose rate as measured inside the lead shield (left) and outside the shield (right) in an indoor location.

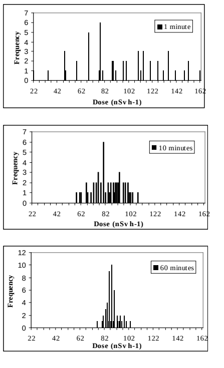

Figure 1
Histograms: The dose rate distribution for three different sampling intervals of 1, 10 and 60 mints.

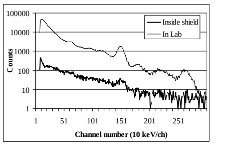

Figure 2
The background energy spectra.

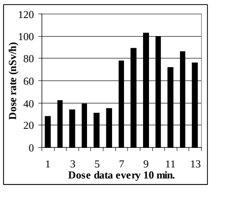

Figure 3
The dose rate as measured inside the lead shield (left) and outside the shield (right) in an indoor location.

Summery

The paper describes a classroom experimental method using basic radiation measuring devices, available in many teaching laboratories, to demonstrate the occurrence of natural background radiation for high schools and undergraduate students. The experiments, if introduced in the laboratory curriculum, would help the students to appreciate the existence of natural radioactivity around us and help in educating the students. It is important to highlight the fact that we should NOT consider instantaneous sudden changes in the dosimeter readings as representative dose rate values. Instead, we must use accumulated readings over sampling time of typically 10 minutes (depending on the type of instruments used/available) as a more realistic approach. The students will be convinced by some demonstration, e.g. as shown in this work.