A method of lowering the background in low-level radioactivity measurements

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Abstract. This paper discusses the main source of background in detecting radioactivity of low-level radiation and the methods to reduce the background in practical application.

1. Introduction
In radiation protection, environmental science, biomedicine, food hygiene, archaeological geology and other fields of radioactivity measurement, the sample is often encountered with very weak radioactivity[1-3]. In these measurements, the specific radioactive activity of the sample is often less than 10Bq/kg, so that the count rate of activity is equivalent to the background level or even lower. The measurement of such samples is often disturbed by non-sample count. These disturbances can be roughly divided into two categories: one is the background count caused by various factors, mainly from the radioactivity of the surrounding environment, the radioactivity of the detector itself, and the false count caused by electronic equipment[4]. The other is the interfering radioactivity in the sample, which may exist in the carrier of the sample.

Low level measurement generally consists of three steps: sampling, sample preparation and measurement. Representative samples should be collected in the area of interest; the sample area or volume suitable for measurement can be made by physical or chemical method. The measurement results should be compared with standard samples, and the measurement error and result analysis are given. In low level measurement, it is very necessary to use the detector with high detection efficiency and take effective measures to reduce the background[5].

2. The source of background
Generally speaking, a count caused by any other than the radionuclide to be measured can be regarded as a background, including both the out-of-sample (out-of-source) and in-sample (in-source) factors.

Living in a natural radiation field, human beings are always exposed to radiation from the natural environment. This radiation is called background radiation, also known as natural radiation or background radiation. It comes from cosmic rays and natural radionuclides contained in earth and living things.

2.1. Cosmic Rays
Cosmic rays, also known as cosmic radiation, are radiation composed of high-energy primary particles that reach the earth from outer space and secondary particles produced by their interaction with...
atmosphere air. The high-energy primary particles in outer space are mainly charged particles, mainly composed of protons, electrons, a small number of alpha particles and various nuclei, etc., they come from the solar system radiation, galactic radiation and the earth's magnetic field capture radiation. These primary cosmic rays interact with the nuclei of the air in the atmosphere, producing a large number of secondary particles, which form secondary cosmic rays, including neutrons, protons, electrons, muons, photons (gamma rays), and nucleons. Part of the cosmic radiation, such as muon, neutron, etc., penetration capacity is very large, can penetrate into deep water or rock, known as hard cosmic radiation; the other parts, such as charged particles and gamma rays, have less penetrating power and are called soft cosmic rays.

In addition to producing background count in the detector, cosmic ray will also produce a large number of high-energy electrons, bremsstrahlung radiation, annihilating photons, muons, neutrons and x-rays in the shielding material and surrounding objects. The relative contribution of these particles to the base count depends on the atomic number and volume of the shielding material.

2.2. Natural radionuclides in the environments

Naturally occurring radionuclides in nature are called natural radionuclides. The sources of natural radionuclides mainly include the following three aspects:

- Formed natural radionuclides. There are three decay families of these nuclides: uranium-radium, thorium and actinides, which have existed since the formation of the earth. These nuclides all have atomic Numbers above 81 and are mostly alpha radioactive and a few beta radioactive. Alpha and beta decays are almost always followed by gamma rays.

- Unformed long-lived natural radionuclides. Such nuclides, which have a lifetime greater than 108a and less than 1015a, also existed when the earth was formed, such as 40K, 50V, 87Rb, 144Nd, 199Pt, etc.

- Radionuclides produced by cosmic rays. This nuclide is generated by the interaction of neutrons and protons in cosmic rays with the atmosphere and the earth's surface biosphere and lithosphere through some nuclear reactions, mainly including 14C, 3H, 10Be, 22Na, etc.

When there is no radioactive source and radioactive sample around, the radioactive measuring device can still detect a certain counts, which is called natural radioactive background or natural radioactive background. The natural radioactive background is derived from the above-mentioned cosmic rays, natural radionuclides, trace radioactive materials that may be contained in the detection materials and shielding materials in the measuring device.

2.3. Artificial radiation in the environment

With the development and application of nuclear science and technology, man-made radiation is also produced, such as radioactive material diffusion, pollution, leakage radiation, activation induced radioactivity and so on. This artificial radiation is different from the radionuclides (artificial radionuclides) produced artificially by reactors and accelerators. Today, the world's man-made radiation sources include: nuclear weapons explosion ash, reactors and nuclear power production, accelerators, nuclear medical irradiation, scientific research and production sources, nuclear accidents and so on. In low-level radioactivity measurements, much of this man-made radiation can be isolated and avoided.

2.4. Background count of electronic equipment

Interference, breakdown of insulator high voltage, bad technology and grounding, unreasonable wiring and so on may generate additional background counts. This kind of interference can be completely avoided by using good devices, improving the technological level and taking anti-interference measures.
2.5. Internal factors of sample source
The source factor causing the background is mainly the interference count of radioactive impurities, which may be present in the sample or may be mixed with contamination during sampling and sample preparation.

3. Radionuclides in shielding materials
Laboratories for low-level radioactivity measurements often use bricks and concrete as building materials, and measuring devices are usually shielded with heavy lead and iron measuring Chambers in which detectors and samples are placed.

Building materials such as bricks and concrete often contain trace amounts of Ra, U, Th and their child products, such as $^{222}\text{Rn}$ and $^{40}\text{K}$. For large NaI (Tl) crystal scintillation detectors with size of 10cm×100, background counts of ~ 104/min can be given within the range of less than 4MeV without shielding. Concrete contains more hydrogen, which can effectively shield the nuclear (proton and neutron) components in cosmic rays.

Lead has a high density and is a good shielding material. However, Ra, Th and their daughter products are often found in lead, among which $^{210}\text{Pb}$ has a half-life of about 20 years. Gamma rays interact with lead to produce characteristic X-rays of ~ 73keV. Steel is also a widely used shielding material, and steel produced after world war ii may contain contaminated $^{60}\text{Co}$, $^{106}\text{Ru}$ and other nuclides.

The radioactive impurity contained in the detection element is also an important source of background. For scintillation detector, the specific activity of 40K in ordinary photomultiplier glass is about 10Bq/g, and the scintillation crystal of sodium iodide (thallium) also contains a small amount of 40K, Ra and Th. For the end-window type G-M counter, the mica window material also contains 40K, and the mica window with a diameter of 2.5cm and a mass thickness of 4mg/cm2 contributes about 1.7/min to the counter background.

4. Measures to reduce the background
After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

4.1. Shielding
Material shielding is usually used for the soft components and ambient background of cosmic rays.

- Concrete with less radon content is selected as the building material of laboratory wall.
- Pre-world war II steel is used as structural support material, which can be obtained by salvaging sunk warships.
- Choose over 100 years of old lead or special refined lead as the lead room, to reduce the influence of $^{210}\text{Pb}$.
- Lead interior lining. From the lead body to the inside add 1mm thick cadmium, 1mm thick electrolytic copper, 3mm thick organic glass plate. Low-energy scattered gamma rays (100 ~ 300keV) and characteristic X rays (73keV) produced in lead absorption by cadmium plate; characteristic X-ray of cadmium absorption in copper plate (23keV); characteristic X - ray absorption of copper by organic glass plate (8keV). Figure 1 is a schematic diagram of shielding structure of low-level radioactivity measuring device.
- Using appropriate shielding thickness. Shielding thickness of gamma rays will need to meet the requirements of reducing the highest energy to 1 % of the originals, increasing the thickness of the shield to shield the soft component of cosmic rays and the surrounding environment of gamma radiation effect is better, according to the optimization principle, also is not as thick as possible, too
thick will increase shielding materials in radioactive impurity interference and increase the probability of secondary radiation produced. Generally, 15cm of lead or 25cm of iron is sufficient.

Figure 1. Schematic diagram of shielding structure of lead chamber

4.2. Anticoincidence technique
The hard components of cosmic rays cannot be eliminated by material shielding. For hard components, anti-coincidence technique can be used to install a set of auxiliary detectors around and on the top of the main detector and measure the sample against the main detector. Cosmic rays must pass through an auxiliary detector before hardening into the main detector, which also has a signal output and is time-dependent. The radiation emitted by the sample has lower energy and poor penetration ability, so it is unlikely to reach the auxiliary detector, so only the main detector has an output signal. By sending both signals into the anti-coincidence circuit at the same time, the background caused by cosmic rays can be expelled by using time correlation. Only the sample count is recorded.

4.3. Energy spectrum method
General counting measurement is an integral measurement, which does not emphasize the energy relationship between pulse amplitude and radiation. A discrimination threshold is set, then any pulse over the threshold will be recorded. Under the linear condition, only a pulse of a certain amplitude can be selectively recorded by using the specific energy of the radiation to be measured, which can greatly eliminate the interference and background influence of other impurities radionuclides, which is called energy spectrum differential measurement. Figure 2 is the schematic diagram of energy spectrum measurement. Assuming that the ray amplitude to be measured is somewhere in the middle, a lower threshold V1 and upper threshold V2 are set for this, and the corresponding channel addresses are Ch1 and Ch2. Only the counting between the two addresses can be recorded.

Figure 2. Schematic diagram of energy spectrum measurement

4.4. Eliminate interference
The extra counting caused by the imperfect performance of the measuring device can be completely eliminated by taking appropriate measures. Try to choose low noise devices. Reasonable wiring, try to shorten the length of connecting cable between detector and main amplifier. Reasonably arrange the
connection point, and choose grounding at the main amplifier. Shield the interference source such as transformer, add l-c low-pass filter to the power supply entry end. The high voltage part of the detector should have sufficient insulation strength and withstand high voltage, and prevent leakage. Improve process quality, clean treatment, prevent pollution. The raw material of sodium iodide (thallium) crystal needs to be purified by potassium removal. Quartz glass is replaced by photomultiplier glass. Select low background structural materials, etc.

5. Conclusion

This paper summarizes the sources of natural background, and how to shield the radionuclides in materials in the process of radioactive practice, and expounds the methods and related technologies to reduce the natural background through practical cases.

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