F-PRAKTIKUM:
Natural and Man-Made Radioactivity in Soil

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1 Introduction

Radioactivity can be found in almost every environmental medium, when sensitive detection methods are used. The origin can be natural or artificial. Measurement of environmental radioactivity is necessary for radiation protection purposes, but can also be useful to reveal transport processes in the environment.
In this practical, you will perform gamma-spectroscopy of calibration sources and of a soil sample which you will collect. You will learn how to identify different radionuclides in the spectra and to quantify the obtained results. You will see that natural radioactivity can produce a strong background and you will learn how to deal with it. The special aim is to look for residues of the 1986 Chernobyl reactor accident in locally obtained soil samples.
All radioactivity levels you will work with are at, or only slightly above, natural background level. So, there is no health risk. The impressive lead shieldings are there to protect the detectors from external (mostly natural) radiation in order to make them more sensitive.

2 Required knowledge

2.1 Topics/keywords for literature search

Radioactive decay - natural decay chains - environmental radioactivity - gamma spectroscopy - semiconductor detector - multi channel analyzer (MCA) - Chernobyl nuclear reactor accident - counting statistics - Marinelli beaker.

2.2 Suggested readings

- script "Radioisotopes in Soil": `http://www.msc-ep.uni-bremen.de/services/lectures/practicals/meas_tech_radioactivity_hf_rev3.pdf`;
- radioactive decay, from a physics textbook;
- natural decay chains and environmental radioactivity, from the University library;

- fundamentals of gamma spectroscopy, e.g. from the website of a detector manufacturer (`http://www.canberra.com/literature` or `http://www.ortec-online.com/application-notes/application-notes.htm`);
- counting statistics, from a statistics or nuclear physics textbook or the Canberra and Ortec websites.

3 Preparation

Please make an appointment with the tutor about one week before the practical. On this occasion, you will have a first look at the lab and pick up a "Marinelli Beaker". Determine the tara weight of the beaker.

4 Taking the soil sample

Find a suitable place for taking a sample: the surface should be undisturbed (i.e. not cultivated recently), preferrably old lawn or meadow. Fill the beaker with soil from the upper 5 cm. Cut plants off, but leave the plant roots in the soil. Determine the weight of the sample. Label the filled beaker with date, place, net weight and your name. Clean the outside surface of the beaker to prevent contamination of the detector.

5 Experiments

5.1 Test source with one gamma line

Make yourself familiar with the use of the multichannel analyzer. Place the ^{137}Cs test source on top of the detector and record a spectrum. Identify its principal components. Then, do some experiments with position of the test source on the detector (center of the detector, rim, corner of the detector chamber), absorbers of different thicknesses and materials between source and detector and with open and closed shielding door. Discuss the changes in the spectrum with your tutor.

5.2 Test source with multiple lines - energy calibration

Place the ^{60}Co and ^{137}Cs test sources on the detector and record a spectrum. Try to find the lines given in the table handed out to you and check the energy calibration of the spectrum display. If the peak energies do not match the table values, perform a new energy calibration following the instructions given in the MCA manual.

5.3 Efficiency calibration

Place the ^{137}Cs sample on the detector and record a spectrum for 5 min, using the first half of the MCA memory. Using peak and background integrals from the spectrum, measurement time, activity and calibration date printed on the source, and literature values for the decay characteristics, calculate the peak efficiency of the detector for ^{137}Cs in point source geometry. Calculate the statistical error of the efficiency. Discuss your results with the tutor.

5.4 Soil sample measurement

You can start collecting this spectrum whilst you are doing your calculations for experiment 5.3. Place the Marinelli beaker with the soil sample on top of the detector. Record a spectrum for 60 minutes using the second half of the MCA memory.

5.5 Data analysis

Identify the major natural lines in the spectrum and the corresponding radionuclides, using the gamma energy table and the schemes of the natural decay chains provided by the tutor.
Try to find the peak of ^{137}Cs, the only long-lived gamma emitter left over from the Chernobyl accident and from atmospheric nuclear bomb test fallout.
Calculate the specific activity of your sample for two of the prominent natural lines and for the ^{137}Cs line using the net peak integral, detector efficiency (values for Marinelli beaker geometry provided by the tutor) and measurement time. Include an error calculation.

6 Questions and discussion topics

- Which kinds of radiation can you expect from environmental samples?
- What are the principal features of a semiconductor gamma detector?
- What is the advantage of a Marinelli beaker?
- Discuss the keyword "standard deviation".
- Why does natural radioactivity in the sample degrade the sensitivity for ^{137}Cs? Which possibilities do you have to improve your measurement?