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Chapter 3
Measurement of Radioactivity

Viktar S. Averyn

3.1 Measuring Instruments

Three basic types of measuring instruments used for the purposes of radiation control and monitoring are spectrometers, radiometers and dosimeters (Gurachevsky 2010).

Spectrometers (Fig. 3.1) provide the most complete information about radiation. The most frequently used ones are spectrometers for measuring gamma-ray spectra. They are equipped with semiconductor or scintillation detectors that have high-energy resolution. The most informative part of the gamma-spectrum from the particular radionuclide is the total absorption peak. Its position is determined by the energy of gamma-radiation, and its height – by the intensity. In this manner, spectrometers are used for both qualitative and quantitative analyses of the content of the sample as they can determine not only the composition of radionuclides in the sample but also their activities. The role of processing the spectra is usually played by personal computers.

In measuring radiation from beta- and alpha-particles, because of their low penetrating power, the layer of the sample closest to the detector contributes to the detected radiation. Penetration of radiation should not be obstructed by the walls of a sample vessel placed inside the detector or because of the walls of its entrance window. This interference can be totally avoided by dissolving a sample in the liquid scintillator.

To enhance sensitivity of the measuring device, the samples are preprocessed using a thermal scavenging technique to the point of being partially ashed. Liquid samples, e.g. water or milk, are first filtered through fibrous cationites, then dried and used as samples.

V. S. Averyn (✉)
Faculty of Biology, Francisk Skorina Gomel State University , Gomel, Belarus

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Fig. 3.1 Gamma-beta spectrometer. (From: Gurachevsky 2010)

Fig. 3.2 Gammaradiometer. (From: Gurachevsky 2010)

The most complicated spectrometers are alpha-spectrometers. Since alpha- radiation has a very low penetrating ability, the measurements are typically carried out in a vacuum chamber using a semiconductor detector. Importantly, the composition of radionuclides is determined by measuring “thin” samples placed on special plates using a technique called electrode position. The total activity, on the other hand, is a much easier task, since it can be determined by measuring “thick” samples obtained through attrition and chemical or thermal concentration methods.

The main purpose of radiometers is measuring the specific activity and activity concentration (volumetric activity) of the sources of ionizing radiation. The most commonly used are radiometers for measuring gamma-emitting radionuclides.

The simplest radiometers are able to determine activity by counting all detector pulses with the deduction of the background with account for the geometry. However, the most efficient radiometers are those with discriminative characteristics which can offer selective properties to react only to radiations emitted

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from a particular radionuclide. Such partition becomes possible due to the built-in electronic circuits able of selecting detector signals of certain amplitudes and a microprocessor for data processing. Modern-day radiometers, such as RKG-AT1320 (Fig. 3.2), are just like a downsized version of spectrometers.

Fig. 3.3 X-ray and gamma- radiation dosimeter. (From: Gurachevsky 2010)

Whole-body counters (WBC), used for measuring the activity of ^{137}Cs in a human body, can also be classified as radiometers. A typical WBC has a chair equipped with several scintillation detectors intended for different parts of the body. Using the resulting readings, one can assess the internal radiation dose of a person. The WBC for measuring the content of strontium-90 is a considerably more complex device. There are only a few whole-body counters of that kind in the world.

Dosimeters (Fig. 3.3) are aimed at assessing the equivalent or effective radiation doses. The simplest devices are suited only to be able to detect photon radiations, i.e. gamma- and X-rays. A typical dosimeter is built using inexpensive Geiger-Mueller counters, the signals of which do not yield information about the photon energy. Diverse contribution into the absorbed dose made by the photons of different energy levels is taken into account by adjusting the energy response through filter compensation.

3.1.1 Personnel Dosimeters

Personnel exposed to ionizing radiation are monitored to determine their occupational exposure. Although this consists primarily of monitoring external exposure, it is also necessary to assess the need to monitor internal exposure and, if necessary, incorporate it into a worker's total monitoring system. External monitoring can be accomplished by using photographic film or thermoluminescent or pocket dosimeters (Fig. 3.4).

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3.2 Measuring Contamination Levels in Live Farm Animals

Animal products represent as a major contributor to the internal dose, and live monitoring of animals is an integral part of many remedial actions. Radiocaesium can be measured in live animals using a robust gamma-monitor applied to the muscle mass of a restrained animal. Live monitoring is a rapid, simple, inexpensive and effective

Fig. 3.4 Different types of pocket dosimeters. (From: Gurachevsky 2010)

Fig. 3.5 MKS-01 Sovetnik. (From: Gurachevsky 2010)

method of monitoring contamination for gamma-emitting radionuclides. The monitoring needs to be conducted using a robust and portable, preferably lead-shielded, NaI detector, linked to (or with integral) single or multichannel analysers (RIARAE 1993; Brynilsen and Strand 1994). In areas of elevated external dose, it may be necessary to ensure adequate shielding to attain sufficiently low minimum detachable levels in the detector. Live monitoring of livestock is largely relevant for gamma-emitters, notably radiocaesium. It can be carried out on the farm and also at slaughterhouses. These measurements are performed largely before slaughtering to confirm that intervention levels are not exceeded.

Some dosimeters, e.g. a modern device MKS-AT6130 (Fig. 3.3), can detect the flux density of beta-rays from the contaminated surface. In this mode, the filter-equipped lid, hinged on special joints, is flicked open. Since the flux density measurement is typically related to radiometry objectives, such devices are called dosimeters-radiometers.

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Another multipurpose instrument worth mentioning is the MKS-01 Sovetnik dosimeter-radiometer (Fig. 3.5). It uses a large-volume scintillation detector (196 cm^3) and original algorithms of functioning and information processing.

In its dose measuring mode, Sovetnik has a significantly higher sensitivity as compared to more simplified instruments, with only 2–3 s needed to reach 10% statistical error of the measurement. For this reason, the use of Sovetnik in its "dosimeter" function is very efficient in controlling the homogeneity of the produce batches. As a radiometer, Sovetnik is exceptionally convenient for measuring contamination levels in live farm animals, notably the cattle.

Photographic film dosimeter is sensitive to ionizing radiation, and when it is used as a monitor, the amount of film darkening is a measurement of radiation exposure. The filmstrip and holder constitute the film monitor, called a ***film badge***. This film badge has a small, open window that allows the film to be exposed with most X-ray and gamma-radiation and high-energy beta-radiation. The film badge also

contains a set of plastic and metal filters. Since different types and energies of radiation will be attenuated differently by these filters, the pattern on the processed film may be used to determine the type, approximate energy, and intensity of exposure. Since film response is energy dependent, this approximate energy determination allows the use of a film energy response calibration curve. Such monitors can be used for exposures as low as 0.01 mSv and as high as several Sv.

Target of the measurement	Tissue
Level of radioactive contamination – radiation dose rate in area	Portable instruments (survey meters)
Identity and quantity of radioactive material	Laboratory counters
Accumulated dose to individuals in area	Personnel dosimeters

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