RADIOMETRIC DETERMINATION OF THE PRESENCE OF CESIUM-137 AND STRONTIUM-90 RADIONUCLIDES IN FOOD

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Abstract: The article studies the determination of the presence of Cs-137 and Sr-90 radionuclides in food with a radiometric method based on beta radiation. The presence of cesium-137 and strontium-90 radionuclides in food was experimentally determined. The objects of research were milk, meat, fish, potatoes, carrots, radishes, cabbage, radishes, onions, eggplant, watermelon, and pumpkin. An increased amount of Cs-137 was revealed in fish, cabbage, and watermelon.

Keywords: radionuclide, radiometer, becquerel, Marinelli vessel.

INTRODUCTION

Today radionuclides are the main pollutants of the environment (air, soil, drinking water, and food). Therefore, food safety is the main focus of the healthcare system. According to reports from the Ministry of Health of the Republic of Uzbekistan, over the past 30 years, the number of cancer patients in the Republic has increased up to 5 times, and in the Surkhandarya region up to 7 times. Drinking water and food play a major role in this growth.

We know from the literature that contaminated soil and water will lead to contamination of food and agricultural products. In the Republic, vegetables are the main food elements. The daily diet of a person has 500 grams of vegetable products. For this reason, the determination of the presence of radionuclides in vegetable products is relevant and of particular scientific importance [1, 8].

The main food contaminants-radionuclides are cesium-137 and strontium-90. These radionuclides get into vegetable products through the soil, and then into the human body and cause oncological diseases in the digestive system [2].

In SI, the unit for determining the activity of radionuclides in the becquerel (Bq) - this is the activity of any nuclide in which 1 nucleus decays in 1 second. The unit is named after the French physicist, Nobel laureate Antoine Henri Becquerel. Very often, in practice, a non-systemic unit of activity is used - Curie (Ki) - $3.7x10^{10}$ Bq (deg/sec). This unit arose historically: 1 gram of radium-226 in equilibrium with daughter decay products possesses this activity. It was with radium-226 that the Nobel Prize laureates' French scientists, spouses Pierre Curie and Marie Sklodowska-Curie, worked for many years. Dose rate, i.e. irradiation per unit of time, in radiometry, is expressed in amperes per kilogram (A/kg), micro roentgen per hour (μR / h).

The radioactivity of mountain ores is the higher, the higher the concentration of natural radioactive elements in them. We divide the rock-forming minerals into four groups (Fig. 1):

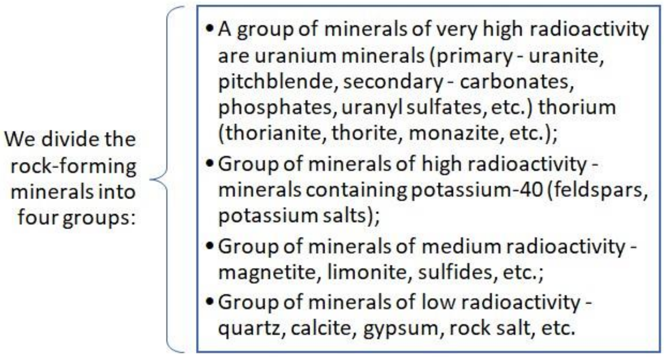

Figure 1 We divide the rock-forming minerals

The radioactivity of mountain ores is determined by the radioactivity of rock-forming minerals and varies over a very wide range depending on the qualitative and quantitative composition of minerals, conditions of formation, age, and degree of metamorphism. The concentration of radioactive elements in igneous rocks increases from basic to acidic rocks [3].

Cesium-137, a radionuclide with a half-life of 30 years, is a source of β-radiation. Beta radiation is a flow of electrons (β-radiation) or positrons (β + -radiation) arising from radioactive decay (Fig. 2). Currently, about 900 beta - radioactive isotopes are known. The mass of β-particles is several tens of thousands of times less than the mass of alpha particles. Depending on the nature of the source of β-radiation, the speed of these particles can be in the range of 0.3-0.99 speed of light. The maximum value for β-radiation is 4 million electron volts (MeV). β-particles mainly cause ionization of the environment.

Figure 2 β-decay of the radioactive isotope potassium-40 with its transformation into a stable isotope of calcium-40.

The physiological law of Ardna-Schultz applies to radiation: "Weak stimulation has an activating effect, medium stimulation has a normalizing effect, strong stimulation inhibits, over-strong stimulates suppressive and damaging". We all know from which ailments aspirin helps. But you can't swallow the whole pack at once. So, it is with iodine preparations, the thoughtless use of which can lead to unpleasant consequences. So, it is radiation, which can both heal and cripple. Constant studies are showing that small doses of radiation are not only not harmful, but rather, on the contrary, increase the protective and adaptive forces of the body [3].

It has been established that the main background radiation on our planet is created by natural sources of radiation. According to scientists, the share of natural sources of radiation in the total dose accumulated by an average person throughout his life is 87%. The remaining 13% comes from man-made sources. Of these, 11.5% (or almost 88.5% of the "artificial" component of the radiation dose) is formed through the use of radioisotopes in medical practice. And only the remaining 1.5% is the result of the consequences of nuclear explosions, emissions from nuclear power plants, leaks from nuclear waste storage facilities, etc. [4, 7].

The main source of external and internal human exposure is radioactive cesium (Fig. 3).

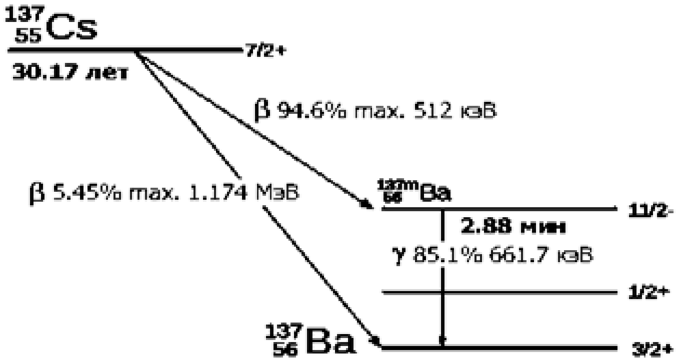

Figure 3 Simplified scheme for the decay of cesium-137.

Of the radioisotopes of cesium, ^{137}Cs is of the greatest importance, characterized by a high yield in fission reactions and lifetimes ($T_{1/2}$ = 30.2 years) and toxicity. It is considered to be one of the most significant radionuclides of nuclear fission products. Cesium-137 is a beta emitter with an average beta energy of 170.8 keV. Its daughter radionuclide 137Ba has a half-life of 2.55 min and emits gamma quanta with an energy of 661.6 keV during decay.

Natural strontium belongs to trace elements and consists of a mixture of four stable isotopes ^{84}Sr (0.56%), ^{86}Sr (9.96%), ^{87}Sr (7.02%), ^{88}Sr (82.0%). In terms of physical and chemical properties, it is analogous to calcium. Strontium is found in all plant and animal organisms. The body of an adult contains about 0.3 g of strontium, and almost all of it is in the skeleton.

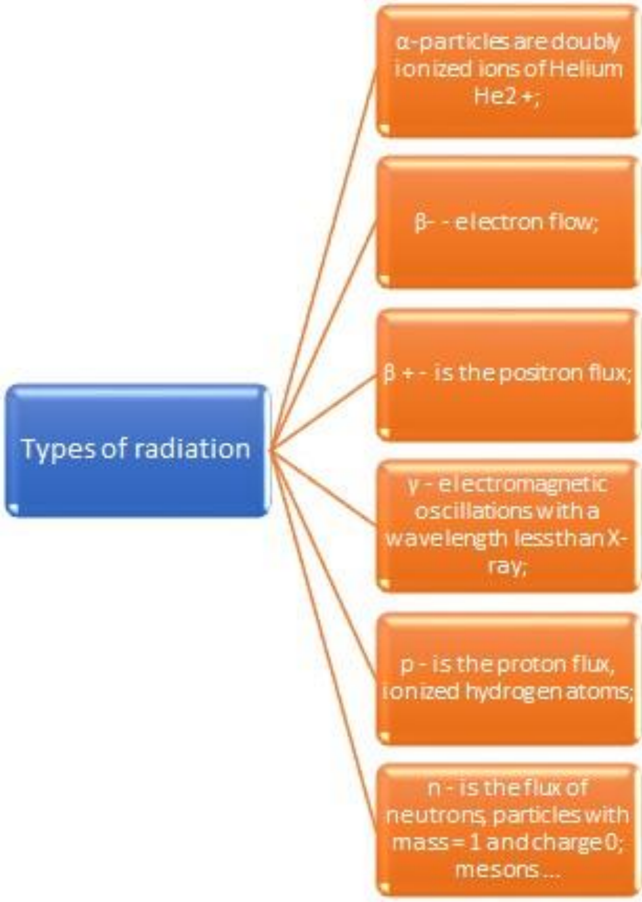

Figure 4 Types of radiation

Radiation can be characterized by its energy in electron volts (eV) (Fig. 4).

eV - is the energy possessed by a particle that has an elementary charge in a field of 1V / cm2. The greater the energy of the particle, the greater its penetrating ability into the material.

The half-life - characterizes the life of a radioactive isotope.

This is the time during which half of the radioactive isotopes decay.

- Isotopes - are nuclides with the same charge but different masses, Isobars are nuclides with the same mass number.
- Isotonic - are nuclides with the same number of neutrons.

The radiation intensity - is the number of radioactive decays per unit of time. 1 curie is taken as a unit of intensity - this is 3.7 · 1010 decays per second. This radioactivity has 1 g of radium. In analytical practice, they use objects whose radiation does not exceed hundreds of microcuries [5, 6]. Geiger-Muller counters are usually used as instruments for measuring radioactivity. The counter is a tube made of aluminum foil filled with molecules of gaseous organic matter. The housing is connected to the negative pole of the electric current source. In the center of the tube is a metal thread connected to the positive pole of a high voltage electric current source. But this method has low sensitivity and high measurement error. Therefore, to determine radioactivity, it is better to use radiometric methods of analysis.

MATERIALS AND METHODS

Radiometric analysis methods

The methods are based on measuring the radiation spectrum of the sample under study both by the nature of the radiation and by its intensity. The method allows you to determine the nature of radiation, energy, and intensity of radiation. There are 2 methods in radiometry: direct and activation.

Direct method.

If the sample contains an impurity of a radioactive substance, then the concentration of this impurity is determined by directly measuring the intensity of radioactive radiation. Among ordinary natural substances, such objects are extremely rare, because most of the elements of the periodic table are mixtures of stable isotopes. To investigate a system, which is a mixture of stable isotopes in natural conditions, one resorts to its radiochemical activation, i.e. cause reactions of radioactive decay in it.

The activation method

Consists of irradiating a substance that, under normal conditions, does not have radioactive radiation, by exposing the sample to a powerful source of radioactive radiation. For this, the test sample is placed in a reactor, which is a lead container with an ampoule filled with a radioactive substance, for example, Sr90 (a source of γ-radiation). In some cases, the hydrogen isotope, tritium, is used as a low-energy β-radiation source. The radiochemical reaction caused by irradiation in the test sample is investigated, i.e. the nature of the radiation and its intensity is measured.

In radiometric measurements, portable, portable, and stationary radiometers are used. The first two types are mainly used for operational (inspection) control. Stationary radiometers are used to monitor individual points (including for emergency monitoring) or with detection units with a standard interface as part of radiation monitoring systems.

A general block diagram showing most of the possible types of radiometers is shown in Fig. 5.

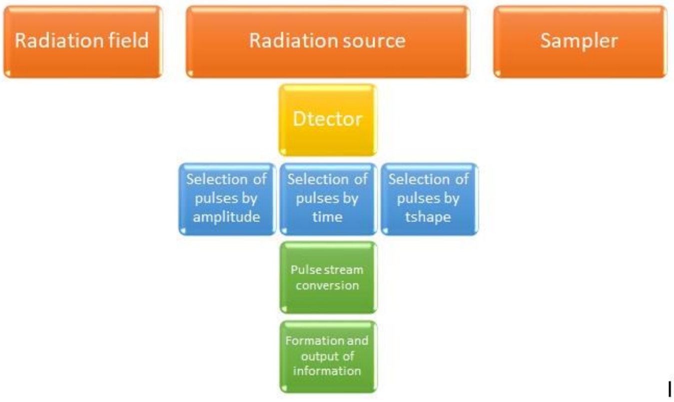

Figure 5 Block diagram of the radiometer

The main tasks that are solved in radiometric measurements are to determine the parameters of the radiation field and the characteristics of the radiation source.

EXPERIMENTAL PART

An MKGB-01 radiometer (Russia) was used to determine the presence of radionuclides in food (Fig. 6). The radiometer works with the ASW program and provides a measurement of the energy distribution of gamma radiation in the energy range from 40 to 3000 keV and beta radiation in the energy range from 65 to 4000 keV. The study was carried out under static conditions from food samples (milk, meat, beef, potatoes, cabbage, carrots, rare, radishes, onions, and pumpkin), which were selected from the “Yashil Bozor” market in the city of Termez, Surkhandarya region of the Republic of Uzbekistan. Product samples were taken and cleaned with cold water according to the O'zDSt ISO / IEC 17025: 2017 standard. Pure products were ground in a food processor with a diameter of 5-10 mm and passed through a sieve with a diameter of 5 mm.

The crushed samples were dried for 1 hour in a SNOL-80-01 drying cabinet at a temperature of 1100C. 5 containers were prepared, after cooling, the sample was placed in containers, filling the containers with the sample up to the mark on the container body.

Figure 6 Radiometer MKGB-01 "RADEK" assembled.

The containers were weighed and the weight (1-5) of the container with the sample was determined in grams and the weight of the sample was determined by the formula:

$$m_{so} = m_{knr} - mx \text{ g.} \quad (1)$$

Then the bulk density of the counting sample was determined by the formula:

$$P_{so} = m_{so} / 1000 \text{ g / cm3.} \quad (2.)$$

The bulk density of each sample did not exceed 2 g / cm3. A label was filled on each counting sample, which indicated the sample number, sample weight. The label was attached to the sample body with adhesive tape.

The prepared containers were placed in a radiometer and the beta-radiation activity of cesium-137 and strontium-90 of each sample was measured for 40 minutes.

RESULTS

The determination results are shown in tables 1 and 2.

№	Name of food	The value of the β-radiation activity of Cs-137, Bq / kg * (HC = 0.5)
1	Milk (cow)	0,35
2	Meat (beef)	0,28
3	Carp fish	0,81
4	Potatoes	0,32
5	White cabbage, Dutch	0,75
6	Rare common	0,28
7	Red radish	0,33
8	Red onion	0,36

9	Common garlic	0,06
10	Yellow carrots	0,08
11	Pumpkin gray, common	0,42
12	Local watermelon	0,66

Table-1. Results of determining the presence of Caaesium-137 radionuclide in food
(t_{meas} = 40 min, E_{max} = 624 keV, CW = 0.64 imp / s * Bq, BDEG-80, Marinelli vessel)
* (HC = 0.5) - the level of interference of cesium-137 in food

No	Name of food	Sr-90 β-radiation activity value, Bq / kg * (HC = 2.5)
1	Milk (cow)	1,53
2	Meat (beef)	1,86
3	Carp fish	0,41
4	Potatoes	0,05
5	White cabbage, Dutch	0,08
6	Rare common	0,06
7	Red radish	0,03
8	Red onion	0,06
9	Common garlic	0,06
10	Yellow carrots	0,08
11	Pumpkin gray, common	0,02
12	Local watermelon	0,01

2-table. Results of determining the presence of a radionuclide Strontium-90 in food
(t_{meas} = 40 min, E_{max} = 624 keV, CW = 0.64 imp / s * Bq, BDEG-80, Marinelli vessel)
* (HC = 2.5) - the level of strontium-90 interference in food.

Table 2 shows that in all foods the amount of strontium-90 is lower above the intervention level. Because strontium accumulates mainly in the bones.

CONCLUSIONS

Thus, we researched different food products and came to this conclusion:

- In goats and sheep, the content of radioactive cesium in milk is several times higher than that of cows;
- Cesium accumulates in significant quantities in the eggs of birds;
- 137Cs in fish muscles can reach up to 1000 Bq / kg;
- The body receives radioactive strontium mainly with food and, to a lesser extent, with water (about 2%). The highest concentration of strontium is found in the skeleton, liver, and kidneys, the lowest concentration in muscles and especially in fat;
- Radioactive strontium belongs to biologically hazardous radionuclides. As a beta emitter, it poses the main danger when it enters the body. This nuclide enters the body with contaminated foods and accumulates in bones, especially in children, exposing bones to constant radiation.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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