Review of modern application of gamma-beta spectrometer - radiometer MKGB-01 “RADEK”

Finkel Felix[1]
[1] Scientific and Technical Center “Radek” ltd., RUSSIAN FEDERATION

Review of a modern application of spectrometer- radiometer of gamma-beta-radiation MKGB-01 “RADEK”

In the year 2001 STC “RADEK” Ltd. company produced spectrometer-radiometer of gamma-beta-radiation MKGB-01 “RADEK”. Since then the device is widely used by various scientific and educational institutions, certification authority, research laboratories and organizations of nuclear fuel cycles. Apart its common use as a measuring instrument of activities of γ-radiating radionuclides in samples of ground, vegetation, water, foodstuff, materials of construction and other substances, it was also applied as a basis for the construction of unique spectrometric units.

Thus, the Railway Service Institute uses MKGB-01 as a measurement instrument of radionuclide contamination of railway acres and roads. On basis of MKGB-01 the underwater gamma-radiation spectrometer was developed for Geologic Institute, allowing the radioactivity measurement of bottom silt with the moving of detector along the bottom. The same spectrometer was also produced for the Federal Security Guard Service of Russian Federation for installation on boats patrolling water area.

The special place in radioactivity measurement of radionuclides belongs to spectrometry of body radiation. So the SEG-10P was developed as a modification of MKGB-01. It is completely implemented in the form of armchair and allows to measure the activity of incorporate γ- emitting radionuclides. The apparatus is used by nuclear power plants and medical centres.

In 2006 in the Russian Centre of Emergency and Radiation Medicine the expert spectrometric unit for human radiation measurement was constructed and put into operation. It is completely composed of analyzers of MKGB-01 spectrometer (14 pieces) and different types of detectors (scintillation and semiconductor detector). The unit is presented by steel chamber with 4x2x2 meters dimensions edged by lead, cadmium and copper. The chamber is provided by scanning operation.

Due to STUK Finland has about 50 devices of such kind.

Introduction

Nuclear-physical analysis methods of samples are widely used in various fields of science and technology. It provides an opportunity to resolve the tasks in such spheres as medicine, ecology, geologic intelligence, atomic industry, etc. To study the radionuclide composition of samples, among others, gamma- and beta spectrometric methods of analysis are used.

In the beginning of 2001 the company STC "RADEK" manufactured a spectrometer-radiometer of gamma and beta radiation MKGB-01 "RADEK". Since that moment this device is widely used in different scientific, educational organizations, centers of certification, research laboratories and enterprises of NFC (Nuclear Fuel Cycle). Besides the standard use of this device by way of mean of measuring of γ and β radiating radionuclides activities in samples of ground, vegetation, water, foodstuffs, constructing materials and other substances, a unique spectrometric complexes are also constructed on its base.

Review

Thus, the institute of railway transport (VNIIZhT, Russia, Moscow), uses MKGB-01 by way of mean of measuring of radionuclide contamination of railroad track right of way and of automobile roads[1]. This complex is called "Main gamma-spectrometer of high sensivity (MGSHS)" and is placed in laboratory rail car of VNIIZhT. High sensitivity of gamma-spectrometer is determinated by a large volume of scintillator.

Constructively the spectrometer MGSHS consists of two DSU (detection and selection unit with 2 detectors each); unit for summing signals; four analog-digital converters (ADC) MD-129; three high-voltage power supplies; low-voltage power supply and PC. Functionally and programly the complex allows to use a signal from GPS - receiver, to turn on the alarm signal (bleeper, light, etc.), means of objective control, etc. Each DSU has 2 detectors in it on the base of crystals NaI(Tl) with size 100x200 and a PMT-49 (Photomultiplier Tubes) for registration of external gamma-radiation, and a stabilization unit based on beta-gamma coincidence (detector on the basis of scintillating plastic and PMT-85 for stabilization, source of ionizing radiation on the base of ^{60}Co with activity less than the minimum significant).

Conducted in 2007 the induction and performance tests on the known contaminated territories showed, that during the correlation of graphs of ^{137}Cs density contamination measurements, performed with an interval of 17 years, paying respect to the decay and migration of radionuclide correction, the discrepancy doesn't exceed 20%. At this moment the spectrometer is used in laboratory rail car, belonging to VNIIZhT [1].

Also an underwater gamma spectrometer on the basis of MKGB-01 is developed for geological institute, which allows to measure the radioactivity level of bottomset beds through the aid of the detector moving along the bottom. The

spectrometer consists of a detector towed on bottom and of an onboard analytical complex. The full consist of the complex includes: a sealed shock-proof sleeve with an obstacles bypass system "Eel", containing a scintillation gamma-radiation detector with crystal CsJ(Tl) with size 80×80 mm; an analytical unit, containing an analog-digital converter board (ADC); power supplies and amplifiers (Fig.1); control PC with appropriate software; armored towing - connecting cable [2].

To stabilize and to control the amplification, a reference source of ^{113}Sn mounted in the detector sleeve was used, which allowed to change operatively the amplifying coefficient depending on the involving facts. The spectrometer is calibrated in the measurement units of specific activities on the volumetric, saturated for gamma-radiation state standard norms. Estimated minimum detected activity with the exposure time of 30 seconds is as follows for ^{137}Cs - 4 Bq/kg, ^{226}Ra - 10 Bq/kg, ^{232}Th - 7 Bq/kg, ^{40}K - 90 Bq/kg. The working depth of spectrometer sleeve immersion - 500 meters, and by towing with speed 3–4 knots, using 600 meters of a tow cable-hemp – to 200 meters. By towing the underwater gamma-spectrometer the exposition set of each spectrum was about 30 seconds. The towing speed – 3 knots. Thus, in average each single spectrum corresponds to 50 meters of profile.

Fig.1

An example of underwater use of spectrometer MKGB-01 in geological purposes is the charting of ferromanganese nodules fields (FMK) in the gulf of Finland of Baltic sea. It's well known that FMK of marginal and inland seas sorb intensively the ^{226}Ra and are largely enriched with it. At the same time the accumulation of ^{137}Cs by nodules is insignificantly to the aleuropelite precipitations, which are intensively accumulating ^{137}Cs in zones, related to the impact of the Chernobyl disaster. These provisions give a theoretical basis of FMK fields charting by means of underwater gamma-spectrometry. Conducted in the gulf of Finland the experimental-methodological works have confirmed the assumptions made above. It can be stated a fairly reliable charting method of FMK fields on the ratio ^{226}Ra/^{137}Cs. Besides it the underwater gamma-spectrometry directly on the activity of ^{137}Cs, and also on the ratio ^{137}Cs/^{40}K and ^{226}Ra, ^{232}Th/^{40}K in many cases allows to separate and to chart the fields of aleuropelite sediments, of sands and boulder-pebble material.

Another successful example of underwater gamma-spectrometer use in geoenvironmental purposes was its application for radiogeochemical situation study in

bottom sediments on the mass burial areas of PDUO (potentially dangerous underwater objects), representing the container landfills, containing radioactive waste, or single large objects, containing large quantities of radioactive substances. The researches of four burial plots showed, that by one of the profiles, passing close to two sunken ships with radioactive substances and containers landfill, an extended anomalous zone with ^{137}Cs activity up 1500 Bq/kg was detected. In a container burial area with radioactive waste, a local anomaly with length about 100 meters with ^{137}Cs activity in the maximum of 80 Bq/kg was also detected by another profile. Besides, in different sectors, the ^{137}Cs anomaly with activity from 40 to 60 Bq/kg were allocated by several profiles. It should be noted, that all the identified anomalies are located in the distribution area of aleuropelite precipitations, which, as known, sorb intensively ^{137}Cs. Cesium background activity for the entire area was vastly negligible and ranged from values below the MDA (minimum detectable activity) to 7 Bq/kg.

Thus, the towed underwater spectrometric complex MKGB-01 proved to be quite suitable for solving problems of ^{137}Cs areal distribution study in bottom sediments and of local pollution identification in bottom sediments, associated with specific objects [2].

The same spectrometer was created by order of Federal Security Guard Service of the Russian Federation (FSGS RF) for installation on boats, patrolling the water areas.

A special place in the measurement of radionuclide activity is occupied by spectrometry of human radiation. In this field a spectrometer of human radiation SEG-10P is developped, it's a modification of MKGB-01. It is designed as a chair with console module on the anvil, aimed at the geometric center of the chair (Fig.2).

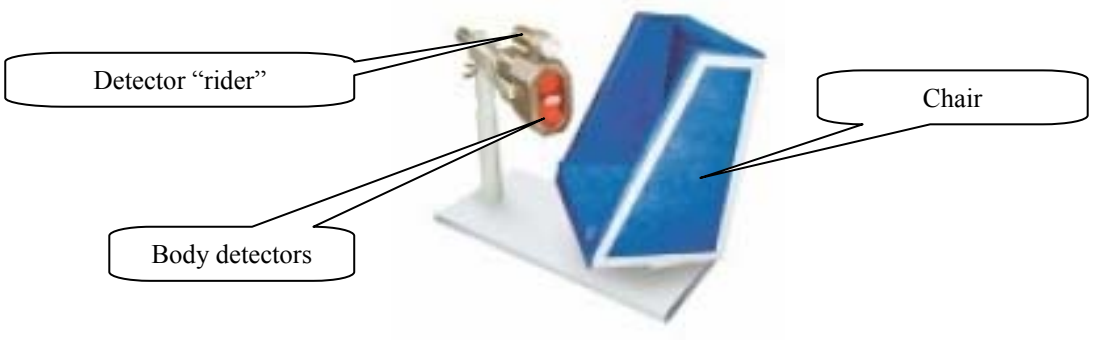

Fig.2

The module consists of two body detectors and so-called detector "rider", and allows to evaluate the activity of incorporated γ- radiating radionuclides in human body, lungs and thyroid. The spectrometer calibration is made by means of unified phantoms UF-02T (body) and FSZ-04T (thyroid). The phantoms are made of rectangular polyethylene blocks with bulk 1 kg with openings for placing the rod sources of radioactive material. The spectrometer is widely used on nuclear power plants and in medical centers.

In 2006 in the center of emergency and radiation medicine in Saint-Petersburg an expert low-background spectrometric complex of high sensitivity "SICh-E" for measuring human radiation was manufactured and was put into operation. In fact it's a totality of low-background spectrometers of human radiation and consists of 28

different spectrometric tracts (scintillation and semiconducting), based on electronic modules of spectrometer-radiometer MKGB-01 (14 two-channel analyzers MD-198, Fig.6). The low background of spectrometer is provided by its construction, which represents a steel chamber with size 4x2x2 meters, plated from the inside by lead, cadmium and copper (Fig.3,4,5).

Fig.3

Fig.4

Fig.5

Fig.3 – Chamber of spectrometer of human radiation inside view. Fig.4 – Detectors view inside the chamber without couch. Fig.5 – Detectors view inside the chamber with couch and with phantom.

Fig.6. View of 14 analyzers MD-198 from the front side in the control cabinet.

The complex is intended for expert surveys of the content of incorporated radionuclides of persons, exposed to the radiation in various accidents and incidents, of nuclear technology cycle factory staff during the current and periodic monitoring of internal irradiation, and also of people, living in the radioactively contaminated areas [3]. The works performed on the spectrometer:

- identification of radionuclide composition and measurement in the linear longitudinal scanning mode of low activity levels of gamma - radiating radionuclides throughout the human body in minimum dependence from the character of their distribution in organism and from variations of examined body anthropometric parameters (the contingent of examined people – adults and children from 5 y.o.);

- identification of radionuclide composition and gamma – radiating radionuclides activity measurement in particular human organs: lungs, thyroid, liver, reins, etc.;

- measurement of ^{90}Sr radionuclide content in bones by the bremsstrahlung spectrum as in skeleton entirely, and in separate skeleton parts (in frontal bone, shin bone, etc.);

- measurement of content in the lightweight transuranic radionuclides with low photon radiation energy: plutonium, americium, etc., and also of gamma-radiating radionuclides content with energy less than 300 keV;

- research of radionuclides metabolism in human body in the estimation of parameters;

- research of homeostasis (on potassium metabolism by measuring the ^{40}K radionuclide activity in human body).

The widespread use of MKGB-01 is not limited only by RF. Thanks to STUK (Radiation and Nuclear Safety Authority) Finland has about 50 such devices. Since the mid 1980's in local laboratories of Finland from 6 to 20 counters Mini-Assay were used for evaluation the specific and radioactive substances volumetric activity in foodstuffs and of radon in potable water. The counters showed the total intensity of gamma radiation in samples, and when they began to fail, STUK started to develop a modernization plan of radiometric control equipment. Thus, a new equipment was

purchased – gamma-spectrometer MKGB-01, which is used for radionuclide evaluation in samples. The spectrometer consists of a detector NaI(Tl) with size 63×63, located in a lead protection with thickness 60 mm, computational electronics and of a gamma radiation spectrums processing program. Two measurement geometries are used – Marinelly container with volume 1l for liquids and cylindrical cuvette with volume 320 ml for solid foodstuffs. The minimum detectable specific activities of ^{137}Cs with measuring time - 1000 sec. in laboratory - 50 and 30 Bq/kg for cuvette with volume 320 ml and Marinelly container, respectively. The spectrometer is calibrated for samples density from 0,2 to 2,0 g/cm³ [4].

Referring to the scientific-research sphere of application of spectrometer MKGB-01, it's necessary to mention its use in the maquette of device, which realizes the method of KX-gamma coincidences, created in the ionizing radiation measurements department of D.I. Mendeleev Institute for Metrology (VNIIM). The activity evaluation results, obtained on this maquette, enable to recommend it for inclusion in the primary standard of RF [5].

Another example of MKGB-01 use in the research activity can be the Nephrology Department of Saint-Petersburg Medical University, where spectrometer MKGB-01 is used as an equipment for reins function study. For this, a so-called parameter GFV (glomerular filtration velocity) is evaluated. A patient is injected by a certain amount of radioactive medication (DTPA ^{99m}Tc) with known (measured in syringe on the spectrometer) activity, then after some time the blood of the patient is sampled, centrifuged and the activity in blood plasma is measured, some time later the blood is sampled, centrifuged again and the activity is measured again too. Then, according to the given algorithm, a so-called clearance is evaluated, with the help of which the reins function is studied.

Thereby, the gamma-beta spectrometer MKGB-01 have found a wide application in various applied and scientific problems, and, therefore, the realization of this project can be considered as successful.

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