Peculiarities of Environment Pollution as a Special Type of Radioactive Waste: Field Means for Comprehensive Characterization of Soil and Bottom Sediments and their Application in the Survey at the Floodplain of Techa River – 13172

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ABSTRACT

Contamination of natural objects - zone alarm fallout, zones and floodplains near production sites (the result of technological accidents and resource extraction) occupy large areas. Large area and volume of contaminated matter, moderate specific activity (as low - medium-level wastes) make such objects specific types of radioactive waste. These objects exist for a long time, now they are characterized by a bound state of nuclides with the matrix. There is no cost-effective ways to remove these waste, the only solution for the rehabilitation of such areas is their isolation and regular monitoring through direct and indirect measurements.

The complex of instruments was developed to field mapping of contamination. It consists of a portable spectrometric collimated detector, collimated spectrometric borehole detector, underwater spectrometer detector, spectrometer for field measurements of the specific activity of Sr-90, connected to a portable MCA "Colibry (Hummingbird)". The complex was used in settlements of Bryansk region, rivers Techa and Yenisei. The effectiveness of the developed complex considered by the example of characterization of the reservoir 10 (artificial lake) in Techinsky cascade containing a huge amount of radioactive waste.

The developed field means for comprehensive characterization of soil and bottom sediments contamination are very effective for mapping and monitoring of environment contamination after accidents. Especially in case of high non-uniformity of fallout and may be very actual in Fukushima area.

INTRODUCTION

Contamination of natural objects - zone alarm fallout zones and floodplains near production sites (the result of technological accidents and resource extraction) occupy large areas. Large area and volume of pollution, moderate activity facilities (at low - medium-level radwastes) to make such objects specific types of radioactive waste. These objects exist for a long time, now they are characterized by a bound state of nuclides with the matrix. There is no cost-effective ways to

remove these radwastes, the only solution for the rehabilitation of such areas is their isolation and regular monitoring through direct and indirect measurements.

The task of mapping and subsequent monitoring of pollution is very complex. Most of the complexity of the laboratory measurement techniques, as well as high levels of contamination (to 10^9Bk/m2) for radionuclides ^{137}Cs and ^{90}Sr require for mapping pollution field physical methods of measurement of the specific activity of radionuclides directly on the ground. Designed to map the complex, consisting of a portable spectrometer collimated detector collimated downhole spectrometer detector - underwater spectrometer detector spectrometer for field measurements of the specific activity of ^{90}Sr, connected to a portable MCA "Kolibry(Hummingbird)". The complex was used in N / Bryansk region on the Techa river and Yenisei. The effectiveness of the developed complex is considered as an example of the reservoir # 10 Techinsky cascade containing a huge amount of radioactive waste. Measurements are performed in the framework of international expeditions in 2008 and 2011.

MAIN FEATURES AND SPECIFICATIONS OF PORTABLE DEVICES

Penetrating radiometer (measurements in wells)

• No sampling

• High spatial resolution and sensitivity

• Designed to measure in the field of distribution of radionuclides in soil depth

Operation parameters:

Parameter	Value
The energy resolution (at 662 keV)	<8%
The spatial resolution	5 cm
Sensitivity (Cs-137)	50 Bq / kg
Operating temperature	5 - 35 ° C

Underwater Radiometer

• Rapid screening contamination of bottom sediments of rivers without sampling

• Measurement of the surface activity of Cs-137 and other radionuclides

• Method has no analogues

Operation parameters:

Parameter	Value
Measured surface activity	^{137}Cs: (0.5-400) uCi/m2
Measurement error	<30%
Depth	15 m

Radiometer CORAD

The device allows:

• To measure the total surface activity of Cs-137 and the thickness of the soil contaminated with a spatial resolution of 2 m;

• Measurement of activity of K-40, Ra-226, estimation of Eu-152,4, Co-60

The device includes:

• - collimated detector NaI (Tl) 50 x 50 mm + PMT;

• - control panel with spectroscopic electronics, processor, memory, and processing software for measurement data

• - data exchange with a PC via RS 232

Operation parameters:

Parameter	Value
Measurement range	
Surface activity Cs-137	(0.05 - 1000) uCi/m^2
Thickness of contaminated layer	<40 cm

Instrument for field measurements of Sr-90 specific activity

• No sampling

• High spatial resolution and sensitivity

• Measurements in the field condition with presence of Cs-137, Co-60 radionuclides in soil

Operation parameters:

Parameter	Value
Measurement range	
specific activity	(60 - 3.0x10^6) Bq / kg;
counting sample	(0.5 - 2.0x10^4) Bq
Sensitivity	
soil samples with ERN	60 Bq / kg
counting sample	0.5 Bq

Other applications possible with described field instruments:

Environmental monitoring and analytical equipment and applied in relation to the management of radioactive waste and spent nuclear fuel (dosimetry, radiation systems and portals, sampling and analysis of substances, etc.)

UNIQUE "MAN-MADE" OBJECT: PONDS B10 AND B11 OF TECHA CASCADE RESERVOIRS

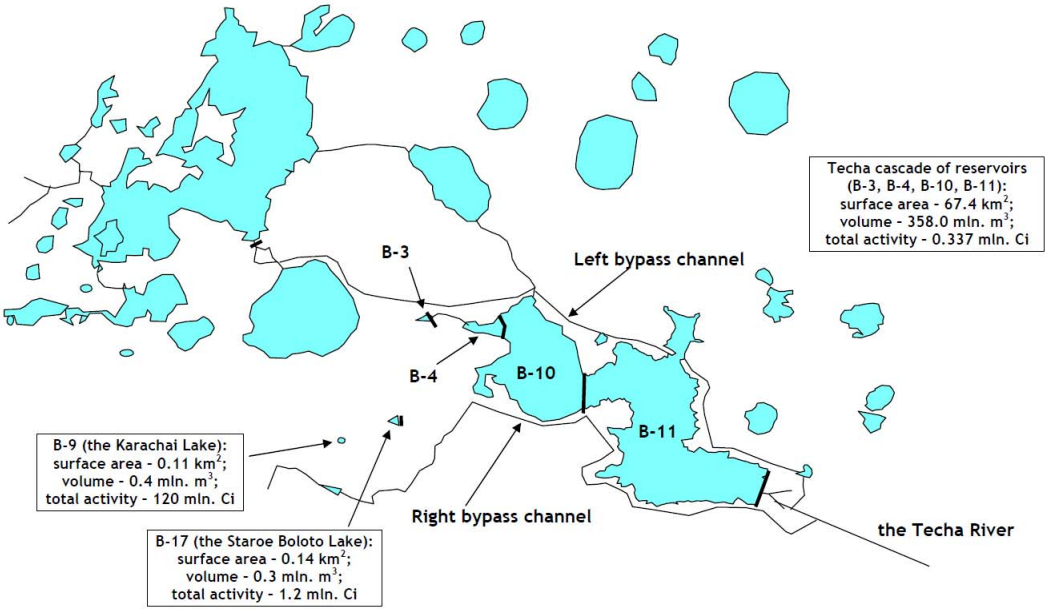

Fig.1. General arrangement of water reservoirs of Techa cascade.

The bottom of water reservoirs B10 and B11 (or bottom sediment) are a waste with the level of specific activity at the boundary between the low and intermediate waste. The position of objects is shown in Fig.1 and Fig.2.

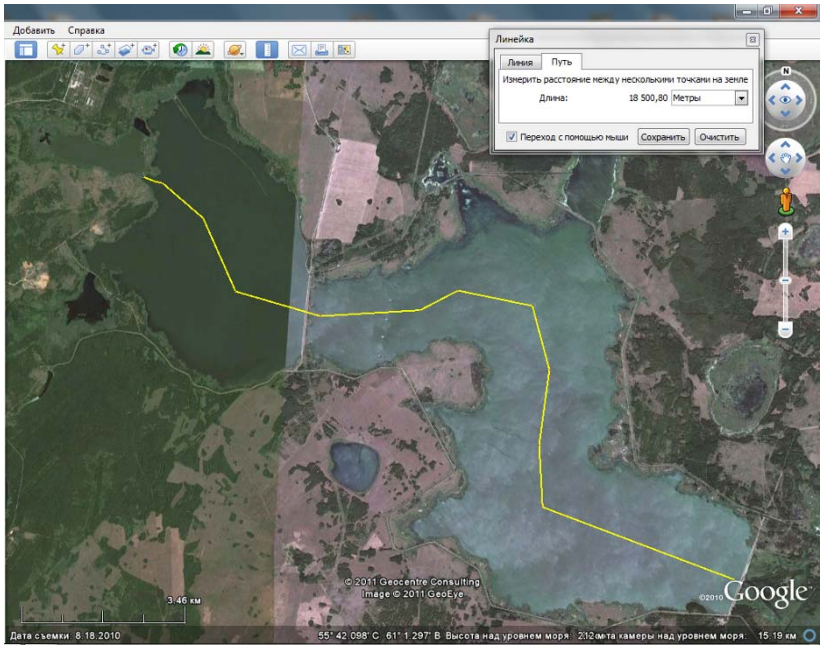

Fig.2. Ponds # B10 and B11. They have a length along the former bed of the Techa River more than 18 km.

Fig.3. Measurements on the pond B10 in the expedition SOLO (2011, 2012) were carried out near the mill dam

RESULT OF MEASUREMENTS WITH SET OF DETECTORS

The structure of bottom contamination and the scheme of measurements of ^{137}Cs in bottom sediments is shown in fig 4. Results of measurements are present in Tables 1-4.

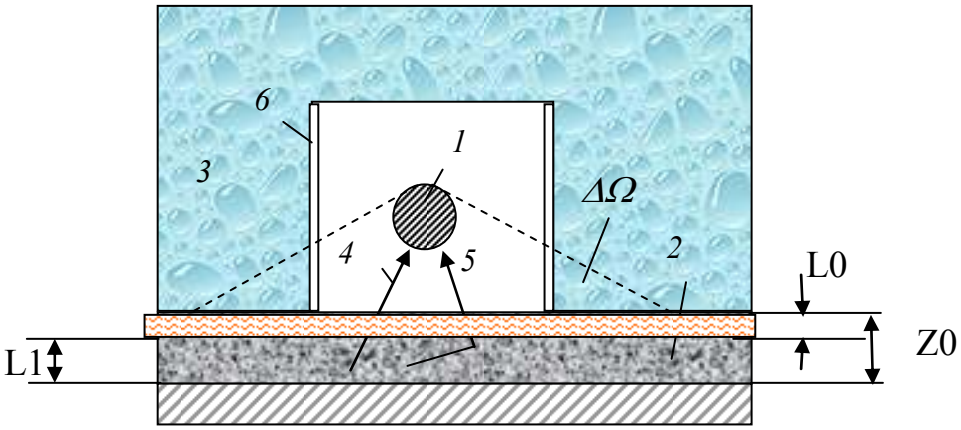

Fig. 4. Model of the structure of contamination on the bottom and the scheme of measurements of ^{137}Cs in bottom sediments: 1 - scintillation detector, 2 - layer sediment thickness L1, containing radionuclides ^{137}Cs; 3 - water, 4, 5 - unscattered and scattered radiation is detected, 6 - a support for fixing the position of the detector. ΔΩ- effective solid angle of radiation. L1 - conditionally blank layer above the layer containing radionuclides, Z0 = L0 + L1.

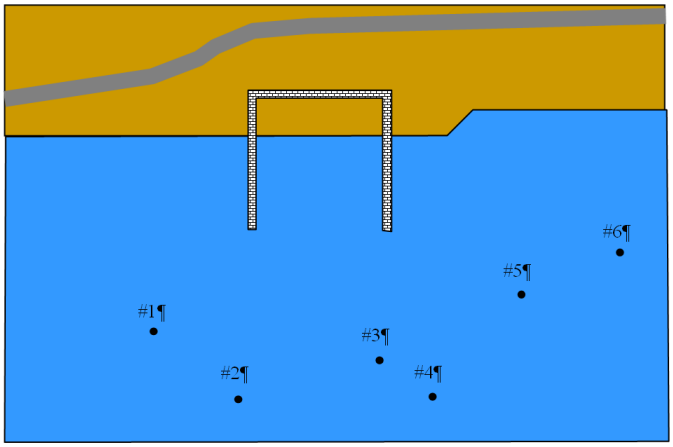

Fig.5. Scheme of measurements with underwater detector on 12/09/2011.

Table 1. Results of measurements with underwater detector 12/09/2011

No	depth, м	A_{Cs}, GBq/m^2	L0, см	L1, см	Z0, см
1	3.2	1.680	14.8	>25	39.8
2	3.2	1.210	12.8	>25	37.8
3	3.5	1.410	14.0	>25	39.0
4	3.5	1.520	14.8	>25	39.8
5	2.2	1.350	18.2	>25	43.2
6	2.2	0.826	14.3	>25	39.3

Table 2. Results of measurements with underwater detector 15/09/2011

No	depth, м	A_{Cs}, GBq/m^2	L0, см	L1, см	Z0, см
1	2.0	1.910	17.3	>25	42.3
2	2.2	1.580	16.7	>25	41.7
3	2.6	1.430	20.1	>25	45.1
4	4.0	0.967	15.8	>25	40.8
5	3.0	1.820	15.5	>25	40.5
6	2.4	1.560	17.3	>25	42.3
7	1.9	1.560	17.9	>25	42.9
8	1.6	0.877	16.4	>25	41.4
9	2.8	0.961	13.6	>25	38.6

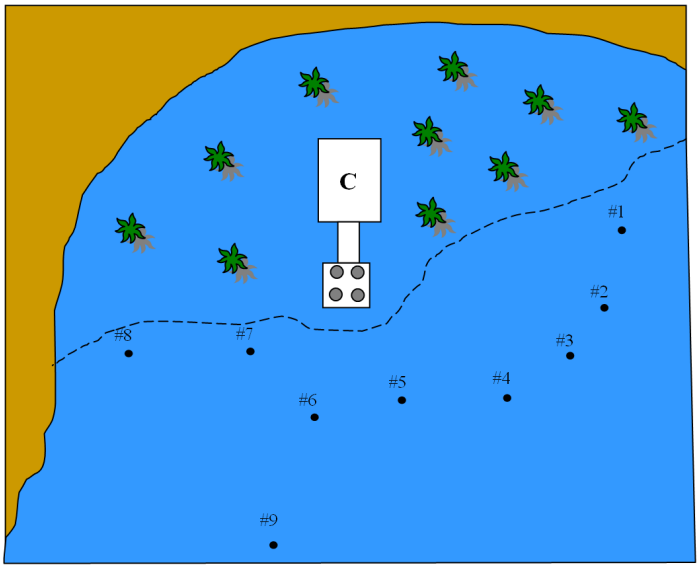

Fig.6. Scheme of measurements with underwater detector on 15/09/2011.

Table 3. Measurements of Sr-90 activity in bottom sediments

Sample №	Specific activity ^{90}Sr, Bq/kg
Near point 4	46880. +/- 7597.
Near point 9	62700. +/- 10151

Table 4. Cs-137 activity near banks of lake measured with device CORAD

No point	A_{Cs}, kBq/m^2	A_{Cs}, μCi/m^2	Depth, cm	Dose rates, μGy h^{-1}
1	218000±1500	5890±40	11	56
2	121000±4000	3280±100	26	26

These data make it possible to make an estimate of the total content of Cs-137 in water B10 and B11:

Area - 18 x (2 - 2.5) ≅ 40 km2

Total activity - 4 10^7 1.5 10^9 m2 Bq/m2 ≅ 6 10^{16} Bq = 2 10^6 (2000000) Ci (But may be 10 to 20 times less) This value is within the range of estimates for the pollution of water bodies being given based on historical or archival sources in the works [1-5].

Conducted test measurements show that the developed complex of devices can be used in a program to monitor water bodies as to obtain accurate data on the local dynamics of pollution bottom water and to determine the integral quantities of contamination throughout the area of lakes.

CONCLUSIONS AND SUGGESTIONS

To develop plans and programs for the rehabilitation of non-standard large-size objects containing radioactive waste precise and detailed measurement data are necessary and very often there is not enough of such data.

Measurements of contaminated soil and bottom sediments in area of water reservoirs of Techa cascade have shown that unique system of detectors and methods for field environmental applications allows the necessary measurements.

A comprehensive program to study the spatial and temporal dynamics of processes in reservoirs B10 and B11 is necessary for the selection of effective measures and methods of handling them [6].

The devices are developed and designed, if to make the necessary accessories it is possible to start small scale production of such instruments. The developed field means for comprehensive characterization of soil and bottom sediments contamination are very effective for mapping and monitoring of environment contamination after accidents. Especially in case of high non-uniformity of fallout and may be very actual in Fukushima contamination area.

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LITERATURE

1. Slyunchev OM, PV Kozlov, exactly S., Soldatov BV Kichik VA, AV Manakov, Parilova O.F rationale advanced technical solutions for water treatment Techa reservoirs "VRB, № 2, 2007, p. 14-26

2. Bazylev VV Fevraleva LT, Martyushov VV Rubchenkov MM Martyushov VZ "On the question of the potential danger stripped coastal waters-10 and B-11" VRB, № 2, 2001, p. 74-77.

3. Droshky EG, Smooth SI, Romanov GN, et al, "Environmental Passport reservoir V-10" / Report: "Mayak". - Ozersk. - 1997.

4. Droshky EG, Smooth SI, Romanov GN, et al, "Environmental Passport reservoir V-11" / Report: "Mayak". - Ozersk. - 1997.

5. Smagin A. "Radiological features of the waste storage pond radiochemical plants and the state population living in it pike (Esox Lucius L.)" VRB, № 2, 1996

6. Sergey Kazakov, Sergey Utkin, Legal and ecological aspects of decommissioning of nuclear heritage objects (by the example of Techa cascade of reservois of the «Mayak» plant), DEM08, Avinion. France 2008.