NONGOVERNMENTAL MONITORING AND TECHNICAL ASSESSMENT OF PAST, PRESENT, AND FUTURE TECHA RIVER RADIATION

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Part 1:

ANALYSIS OF RADIONUCLEAR CONTAMINANTS IN TECHA RIVER WATERSHED BIOTA AND ENVIRONMENTAL MATERIALS DOWNSTREAM OF THE MAYAK CHEMICAL COMBINE IN CHELYABINSK OBLAST IN SOUTH CENTRAL RUSSIA

Part 2:

NONGOVERNMENTAL MONITORING – PAST, PRESENT, AND FUTURE OF TECHA RIVER RADIATION: WHAT IS THE KEY CHALLENGE OF THE TECHA RIVER TODAY? HOW DO WE ASSESS THE CONDITION OF THE TECHA RIVER?

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Introductory Letter – *Government Accountability Project, Tom Carpenter*

In 2005 scientists Marco Kaltofen, PE and Dr. Sergey Pashenko collected environmental samples in and around the Russian village of Muslyumovo and the Techa River in Chelyabinsk Oblast to document contamination levels. The following report summarizes their joint findings.

Background

The normal operation of Soviet nuclear weapons facilities routinely released radioactive solids, liquids, and gases directly into the environment, contaminating air, soil, and ground and surface waters. In general, the environmental damage in the former Soviet Union is far greater than that in the US, largely due to the greater quantity of radioactive wastes discharged directly into the environment.

The plutonium factory at Mayak, located in the southern Ural Mountains, poured radioactive wastes to the river Techa. The Techa had been used in 1950's and 60's for watering private and collective gardens. Radioactive contaminants migrated through the water to the collective gardens and also drained to the lower river systems.

Mayak dumped an estimated 125 million curies of strontium-90 and cesium-137 into the Techa River in the 1950's. To put this figure into perspective, the U.S. limits the amount of strontium-90 contamination in a liter of drinking water to 8 *trillionths* of a curie (picocurie). Both strontium-90 and cesium-137 have a half-life of roughly 30 years. Contaminants from the Techa, a tributary of the Ob River, eventually drain to the Arctic Ocean. But before it gets there, the Techa flows through the middle of a town of about 4,000, called Muslyumovo.

Muslyumovo is a village highly polluted by radioactive discharges from Mayak. In addition to dumping millions of curies of cesium and strontium into the Techa River in the past, Mayak was the site of a severe nuclear disaster in 1957 when a waste tank exploded, dispersing 25 tons of high-level radioactive material into the surrounding environment. Muslyumovo is one of only four villages still inhabited in this nuclear waste zone; all the others have been evacuated. The disease rate of Muslyumovo's citizens is alarmingly high and numerous locals have died with symptoms of cancer.

Because of the alarmingly high levels of radiation in the Techa River, Russian physicist Sergey Paschenko has spent years studying the Techa as a citizen researcher. He invited GAP and GAP consultant Marco Kaltofen of Boston Chemical Data Corporation to spot-check the town of Muslyumovo and the Techa, and in October 2005 a joint sampling mission was undertaken.

This report documents the findings from this and other visits over the years to the Techa River and Muslyumovo.

Findings

Significant findings include documentation of soil, sediment, groundwater, and airborne radioactive contamination within the village itself. The residents of Muslyumovo are being exposed to a multivector assault of radionuclides which arrive via Techa River sediments. These sediment-borne radionuclides then collect and re-disburse via the village's soil, vegetation, and dusts. They fluctuate with seasonal river flow variations.

The data suggests some of the radiation in the area is short-lived and non-legacy waste (not merely remaining from past decades). Both Pashenko and Kaltofen agree that radioactive Cobalt-60 is present in their environmental samples. Cobalt-60 is a short-lived and dangerous radionuclide in the human environment. Cobalt-60 has a half life of 5.24 years. It is a beta emitter as are Cesium-137 and Strontium-90. Cobalt-60 beta emissions may be masked by Cs-137 and Sr-90 beta emissions, which may explain why Co-60 is unfamiliar to Muslyumovo residents. This suggests that the radiation threat has been underestimated and that it may include both past and recently produced radioactive products.

According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), on average, the yearly radiation dose for a human being, from background sources, is 2.4 mSv. UNSCEAR also says that average yearly exposure to radiation via medical tests is between 0.04 and 1.00 mSv. The US public dosage limit for radiation is 1 mSv per year. (Reference: 10 CFR 20.1301) Based on testing by Kaltofen and Pashenko, a Muslyumovo resident standing on the bank of the Techa River in the center of the village would receive the equivalent to this annual dose every four days.

Residents exposed to groundwater would get this dose every two days. Muslyumovo residents we interviewed got their water from wells. They were fully aware of the potential for contamination from the groundwater, but had no alternative source.

Muslyumovo's inhabitants experience continuous radiation exposure. Unlike a medical test which briefly exposes a person, the radiation around Muslyumovo's residents is chronic. The US Environmental Protection Agency warns that chronic exposure to radiation leads to cancer and DNA mutations with inheritable consequences at much lower levels than will acute, short term, exposures.

Kaltofen and Pashenko's results are especially grave in light of a new plan announced by the Russian nuclear ministry (Rosatom) to replace Dam 11 on the Techa River, which is holding back millions of curies of radioactively-contaminated silt. This threatens a new release of contaminants, prompting more risks to human health and an even greater need for evacuations of villages. According to Gosman Kabirov, a Muslyumovo resident, Rosatom Director Kirienko promised to relocate the three closest streets to the Techa River in Muslyumovo. The relocation will cost one million rubles (37,000 dollars) per family, and will relocate about 600 people. This relocation is essential as the replacement of Dam 11 will contaminate the village further. This will not protect the remaining residents from airborne and ground water contaminants, nor will it erase decades of preventable radiation exposure to the evacuees. It should also be noted that past promises by the Russian government to evacuate Muslyumovo have been broken.

Recently, U.S. President George Bush announced that he would approve a plan to ship hundreds of tons of new nuclear waste from U.S.-owned foreign reactors for disposal at Mayak. Both Russia and the U.S. have also announced plans to build hundreds of new nuclear reactors and to engage in reprocessing spent fuel. Meanwhile Muslyumovo's radioactive plight, and the Russian government's refusal to protect its people, should serve as a warning to the rest of the world about the wisdom of expanding this technology without taking into account the long-term human and environmental costs.

Part One

ANALYSIS OF RADIONUCLEAR CONTAMINANTS IN TECHA RIVER WATERSHED BIOTA AND ENVIRONMENTAL MATERIALS DOWNSTREAM OF THE MAYAK CHEMICAL COMBINE IN CHELYABINSK OBLAST IN SOUTH CENTRAL RUSSIA

Summary

Muslyumovo lies 78 Kilometers downstream of the Mayak Chemical Nuclear Works on the Techa River in Chelyabinsk Oblast in Southern Central Russia. This village lies on an escarpment above the Techa River. The Techa River has drains from the Chemical Nuclear Works and is the receiving water for a large burden of radionuclide waste, particularly Strontium- 90 and Cesium-137 among other radionuclides.

Much of the radioactivity is transported as bedload, meaning that the river carries its radioactivity primarily as contaminated sediments. Particularly during high river flow periods, these sediments have been transported more than 200 kilometers downstream.

While the total quantity of new releases to the Techa has declined significantly since 1950, large amounts of contaminated sediment are still being transported. Contaminated material remains in the Techa River floodplain, and this material is presumably replenished during flood events.

A series of environmental samples were collected in October 2005 in Muslyumovo and surrounding areas by civil engineer Marco Kaltofen, PE of Natick, Massachusetts and physicist Dr. Sergey Pashenko of Novosibirsk, Russia. Samples were selected so as to be representative of bioaccumulation processes. Specific sample media included wood, bark, grasses, manure, bones and teeth, and crops. In addition air and sediment samples were also collected.

Conclusions

The testing found that airborne transport of beta and gamma emitters was significant in Muslyumovo. Previous dose calculations which do not provide for this vector of contamination are likely to underestimate total radiation dosages to local residents. This conclusion is based in part on elevated radiation levels found on wood surfaces, in indoor dust accumulations, lichens (which do not have root systems subject to contaminated groundwater), and in air and other samples.

Residents are exposed to airborne radioactive particles. This is evidenced by air samples tested via filter media and by examination of surfaces vs. bulk samples.

Radiation exposures result in a multimedia dosage, encompassing air, food, surface water, ambient gamma radiation, dermal contact with soils and sediments, and possibly from groundwater as well.

The airborne radiation dose consists primarily of beta emitters, most likely Strontium 90. This intake of Strontium 90 is consistent with the detection of pure beta emitters in hair samples from residents.

Children are at the highest risk. Children's exposure is higher than adults' based on higher food, air and water intake per kilogram of body weight, and from soil ingestion from outdoor activities and pica. One hand to mouth soil ingestion (defined by USEPA as 50 mg) yields a dose of 195 pCi for children using public swimming locations.

Equipment

Laboratory analyses were performed with a Ludlum Measurements, Inc Model 3030 two channel alpha, beta counter. Laboratory gamma counting was done with a Victoreen Thyac V Survey Meter Model 190.

Field analyses in Muslyumovo and laboratory total counts surveys were measured with the same RadAlert Inspector Nuclear Radiation Monitor.

Additional samples were analyzed by gamma spectroscopy, Cesium and Uranium isotopic analyses, and method RA-320 for Strontium-90, at PACE Analytical Services in Madison, Pennsylvania.

Sample Descriptions

Wood samples – Wood samples were collected from a pre-war era banja, which is a rustic outbuilding used as a sauna. Since this material was harvested prior to the start radionuclide contamination in the Techa River, the samples could be expected to have limited radionuclide contamination. Live breast height samples of birch were collected as cross sections, with a BH diameter averaging 3 inches. The birch samples are potentially exposed to radionuclide inputs from root uptake, transaxial migration (particularly for cesium), and adsorption by bark and leaves.

Grasses were collected from areas with shallow groundwater actively recharged by river waters.

Manure samples were air dried unashed samples.

Air samples were 200 L samples collected by hand pump using micropore filter membranes to collect airborne radionuclides. Samples were shielded to monitor beta and gamma radiation. Alpha radiation was treated as radon-related.

Ambient / Air Samples

Location	CPM For 10 min. averging time
Chelyabinsk Ambient Background Hotel room ambient air on passive charcoal absorber	53.1
Chelyabinsk Hydrometeorology Ambient air - particulate trap	11.88 to 12.45 uR/Hr
Breathing zone ambient air Muslumovo resident's auto	47.7
Breathing zone ambient air "skyshine" On Techa Riverbank, aiming detector downward	360 uR/hr.
Muslumovo - Lenin Street, Indoor air, 200 L sample, House A	209.3
Muslumovo - Lenin Street, Indoor air, 200 L sample, House B	214.2
Muslumovo - Lenin Street, Outdoor air, 200 L sample	99.3
Muslumovo - Karl Marx Street, adjacent to Techa River	
Indoor air, 200 L, 5 minutes post sampling	545.5
Indoor air, 200 L, 100 minutes post sampling	135.6
Indoor air, 200 L, 100 min., alpha shielded	95.0
Muslumovo - Karl Marx Street, further from Techa River	
Indoor air, 200 L, 5 minutes post sampling	231.2
Indoor air, 200 L, 11 min., alpha shielded	100.0
Indoor air, 200 L, 5 minutes, crawlspace	852.6
Indoor air, 200 L, 11 minutes, crawlspace	300.0
Blank sample - air	45.2

The alpha radiation component of air data which shows rapid decay is likely due to the emissions from Radon and its decay products. The outdoor and long-lived nonalpha radiation ranges from 50 to 55 blank-corrected cpm and is more indicative of particulate radionuclides and nonradon emitters.

Material / Surface samples

Location	CPM For 10 min. averaging time
Nonmuslyumovo Samples	
Crossroads - Muslumovo Road Ditch sediment	66.9
Cow manure (at cross roads)	56.4
Cat tails - undried, unashed	60.6
Muslyumovo Abiotic Samples	
Flooring material Resident's auto	77.9
Flooring material Home - Lenin Street	45.0
Indoor dust accumulation Home - Lenin Street	45.0
Indoor dust accumulation Home - Karl Marx Street, adj. to Techa River	78.0
Techa Riverbank sediment	2,200 uR/hr
Techa Riverbank sediment - 15 ft. inshore	1,059 uR/hr
Background site	12 uR/hr.
Muslyumovo Biological Samples	
Muslumovo - Lenin Street, goat teeth (young, extracted)	96.6
Muslumovo - Lenin Street, goat teeth (mature, extracted)	145.5
Banja lumber, bark	72.8

Material / Surface samples

Location	CPM	For 10 min. averaging time
Banja lumber, heartwood	45.4	
Banja lumber, sapwood	44.5	
Ashed Banja lumber, blank corrected - heartwood		0 cpm / 1.31 g
Ashed Banja lumber, blank corrected - barkwood		11 cpm / 4.90 g
Birch tree - breast height cross section, sapwood	109.4	(field measured)
Birch tree - ashed and blank corrected, heartwood		23.6 cpm / 2.40 g
Birch tree - ashed and blank corrected, sapwood		19.6 cpm / 2.01 g
Birch tree - ashed and blank corrected, barkwood		68 cpm / 2.10 g
Lichens, unashed	64.2	
Lichens, ashed	150.	
Garden potato, as cooked	60.4	
Cow manure (Lenin Street, dry, sample A)	62.4	
Cow manure (Lenin Street, wet, sample B)	69.2	
Cow manure (Karl Marx Street, dry)	55.8	
Techa Riverbank reeds, ashed	155.2	
Techa Riverbank bark, ashed	2,360.	
Techa Riverbank bark, ashed, alpha shielded	1,314.	
Human hair sample, Muslyumovo resident	149 beta DPM / gram no alpha detections	
Human hair sample, Muslyumovo resident	150 cpm / gram (blank corrected) no alpha detections	

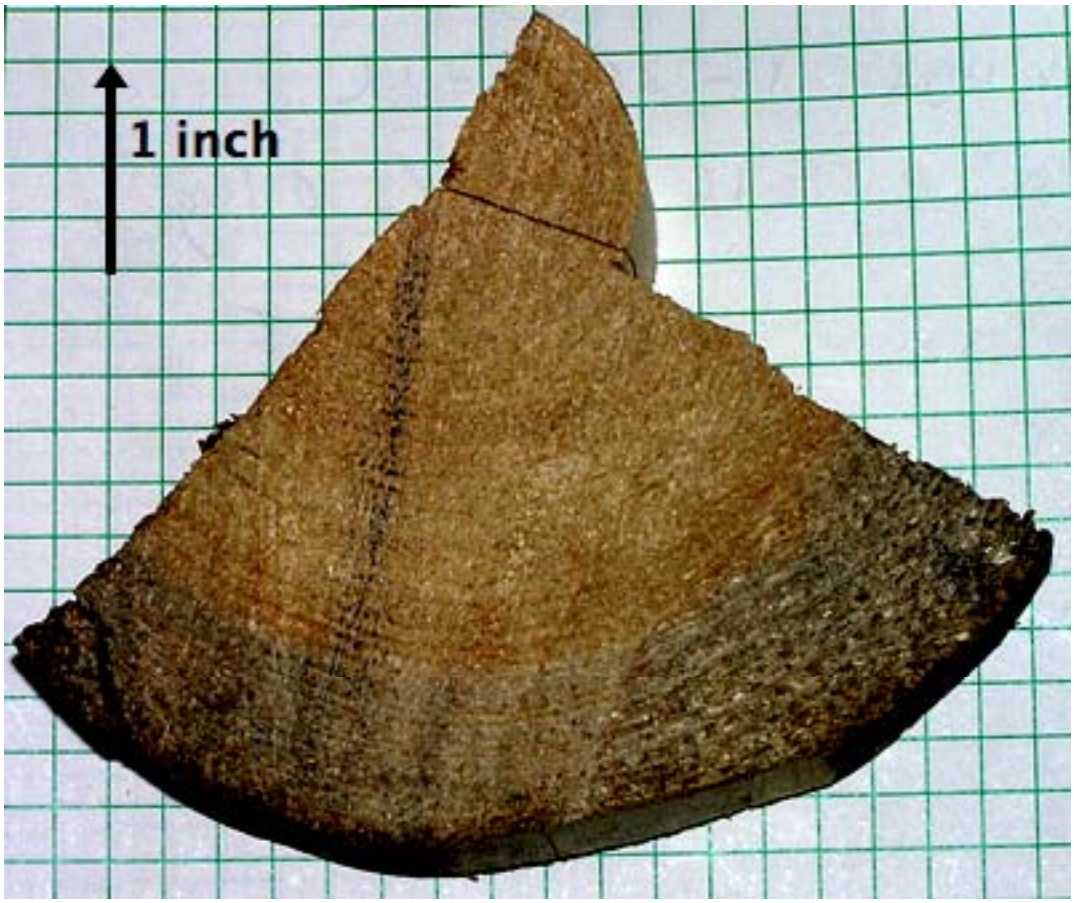
Tree Ring Data

Tree rings provide a useful source of information about Cesium 137 and Strontium 90 in the environment. Strontium is the better indicator of radionuclide exposure over time because Cesium 137 can move across tree rings after initial exposure or uptake by the wood. Strontium also is readily taken up by the soil so that trees have an extended period in which to absorb Strontium 90. Soil retention adds to uptake via groundwater and trans-bark absorption. Correction of Strontium 90 concentrations in older tree rings is required because this radionuclide has a half-life of 28.8 years, which is quite significant compared to the age of the wood specimens. (ref. 1 - Kagawa et al, 2001)

This sample showed a maximum of 32.4 cpm per blank-corrected ashed gram.

Pictured below - Wood sample "1A" from a floodplain of the Techa River in Muslumovo.

Pictured below - Wood sample "1B" from a Banja (sauna) in Muslumovo. The construction of this banja predates widespread radionuclide contamination.



This sample represents wood which is unlikely to have absorbed strontium 90 and cesium 137 from soil or groundwater because of its reported pre-1945 origin. Upon initial sampling a surface radioactivity of 72.8 cpm was recorded, possibly from airborne contaminants which may have been incorporated into the wood surface. After 40 days the surface radioactivity was recorded with the same instrument and yielded 52.6 cpm. Blank levels were 45.4 and 46.0 cpm respectively for 0 and 40 days. These blank levels are essentially identical to the heartwood and sapwood levels, which were 45.4 and 44.5 cpm respectively.

Upon laboratory ashing and analyses none of the tree ring groups from this sample showed greater than 2.2 cpm/ashed gram. Based on these data this sample met the criteria for a wood reference sample.

Results

The wood samples showed significant uptake of beta emitters however this uptake took two very different forms. Significant airborne radionuclides were detected and not attributable to radon. Air measurements will be a future priority for additional sampling.

The riverbank reed sample was analyzed for the following radionuclides:

K-40	Co-60	Cs-137
Eu-154	Tl-208	Bi-212
Pb-212	Bi-214	Pb-214
Ac-228	Th-234 (GS)	U-235 (GS)
Am-241 (GS)	Sr-90	U-234 (GS)
U-235 (AS)	U-238 (AS)	

Of these the following radionuclides were detected. These are reported as pCi/g original field wet weight of 1.00 grams. Percent moisture was minimal. Ashed weight was equal to 0.30 grams. The survey of this sample detected only beta emissions. Alpha and gamma emissions were not detectable by survey instruments.

Co-60	4.55	+/-	1.12	MDC = 1.67
Cs-137	4,160	+/-	438.	MDC = 3.05
Sr-90	8.90	+/-	1.00	MDC = 0.10
U-234	2.24	+/-	0.56	MDC = 0.10
U-235	0.28	+/-	0.13	MDC = 0.09
U-238	2.04	+/-	0.52	MDC = 0.10

The Muslyomovo goat's teeth samples were analyzed for the following radionuclides:

K-40	Co-60	Cs-137
Eu-154	Tl-208	Bi-212
Pb-212	Bi-214	Pb-214
Ac-228	Th-234 (GS)	U-235 (GS)
Am-241 (GS)	Sr-90	U-234 (GS)
U-235 (AS)	U-238 (AS)	

Both tooth samples displayed significant beta activity, but the laboratory testing did not identify which radionuclide was responsible for this result. Cesium-137 was nondetect at less than 0.27 pCi/g and Strontium-90 was nondetect at less than 2.5 pCi/g. Trace levels of U-234 were detected at 0.11 +/- 0.09 pCi/g. Although U-234 is a product of the beta decay of other radionuclides, there is not enough U-234 to explain the beta activity.

Goat teeth - mature, fresh 96.6 cpm

total alpha counts	0	as disintegration per minute
total beta counts	62	as disintegration per minute
total gamma	< 0.25	uR/Hr*grams

Goat teeth - juvenile, aged

total alpha counts	0	as disintegration per minute
total beta counts	211	as disintegration per minute
total gamma	< 0.50	uR/Hr*grams

Techa Riverbank sediment samples

Filled riverbank area

A series of measurements were taken in a disturbed area of the Techa Riverbank just upstream of Muslyumovo where an NGO (the Blacksmith Institute of New York, NY) sponsored a pilot project to cover a portion of the riverbank soils and biota with fill. Surface measurements for total radiation exposure varied from 0.210 to 0.396 mR/Hr.

Riverbank area near abandoned public school

A series of measurements were taken in a riverbank area which was most easily accessible to the public and has been historically used as a swimming area.

Surface soil radiation measurements average	1.06 mR/Hr.
Subsurface soil at groundwater table (0.5 ft. bgs)	2.20 mR/Hr.
Ambient measure for same site, 5 ft. above surface	0.36 mR/Hr.

Wood samples from riverbank area

Correcting for both methods and field blanks, the birch sample showed a maximum 30.2 cpm per gram after ashing. The birch's central heartwood showed 7.6 cpm per gram by similar calculations. Both samples showed evidence of absorption of radionuclides from airborne deposition. The reference sample which had been harvested prior to the start up of radionuclide waste discharges did not show significant infiltration of Cesium-137, which has been detected in other studies. (ref. 1)

The birch sample result may be indicative of absorption from both contaminated groundwater and airborne deposition. Cesium-137 gamma-emissions were responsible for 24 % of the total radioactivity in the birch heartwood. This is more indicative of Cesium-137 transport from airborne deposition than of groundwater absorption.

References

1) *Tree-Ring Strontium-90 and Cesium-137 as Potential Indicators of Radioactive Pollution*, Akira Kagawa, Toru Aokib, Naoki Okadac and Yukio Katayamad; Kyoto University, Japan 2001

2) Steven M Carr; Genetics, Evolution, and Molecular Systematics Laboratory, Department of Biology, Memorial University of Newfoundland
St. John's NF A1B 3X9, Canada

A millisievert is defined as "the average accumulated background radiation dose to an individual for 1 year, exclusive of radon, in the United States." 1 mSv is the dose produced by exposure to 1 mGy (milligray) of radiation. In terms of historical measures of radiation dose, exposure to 1 roentgen (R) of X-rays results in absorption of 1 rad , which had the effect of 1 rem: this is equivalent to exposure to 0.1 mGy producing a dose of 0.1 mSv. The threshold for acute hematopoietic syndrome or "radiation sickness" is 500 mGy. A dose of 5,000 mGy is considered the LD 50 / 30, that is, the lethal dose for 50% of the population in 30 days. © 2005 by Steven M Carr

3) An Evaluation of Radiation Exposure Guidance for Military Operations: Interim Report (1997). Committee on Battlefield Radiation Exposure Criteria, Fred A. Mettler, Jr., Chairman, J. Christopher Johnson and Susan Thaul, Editors, Medical Follow-up Agency, INSTITUTE OF MEDICINE , National Academy of Sciences. ISBN 0-309-05895-3;

"Radiation doses that exceed a minimum (threshold) level can cause undesirable effects such as depression of the blood cell-forming process (threshold dose = 500 mSv, 50 rem) or cataracts (threshold dose = 5,000 mSv, 500 rem). The scope and severity of these effects increases as the dose increases above the corresponding threshold. Radiation also can cause an increase in the incidence, but not the severity, of malignant disease (e.g., cancer). For this type of effect, it is the probability of occurrence that increases with dose rather than the severity. For radiation protection purposes it is assumed that any dose above zero can increase the risk of radiation-induced cancer (i.e., that there is no threshold). Epidemiologic studies have found that the estimated lifetime risk of dying from cancer is greater by about 0.004% per mSv (0.04% per rem) of radiation dose to the whole body (NRC, 1990)."

End of Part One

PART TWO

NONGOVERNMENTAL MONITORING – PAST, PRESENT, AND FUTURE OF TECHA RIVER RADIATION: WHAT IS THE KEY CHALLENGE OF THE TECHA RIVER TODAY? HOW DO WE ASSESS THE CONDITION OF THE TECHA RIVER?

Current Challenges for the Techa River

The central purpose of the research on the Techa River is to discover why radiation is so unevenly spread along the river and why the general level of radioactivity in the river has recently stopped decreasing.

The Techa River is recognized by researchers as one of the most contaminated rivers in the world. The second purpose of our research is to understand the environmental fate of the river and the transport mechanisms related to its primary radioactive hotspots.

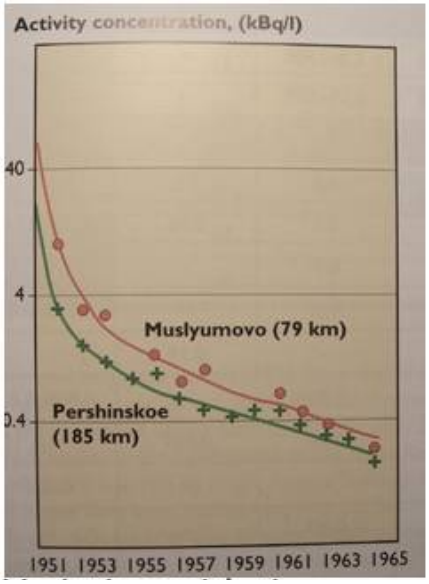


Figure 1: The left graph shows the activity concentration of beta-emitters over time.

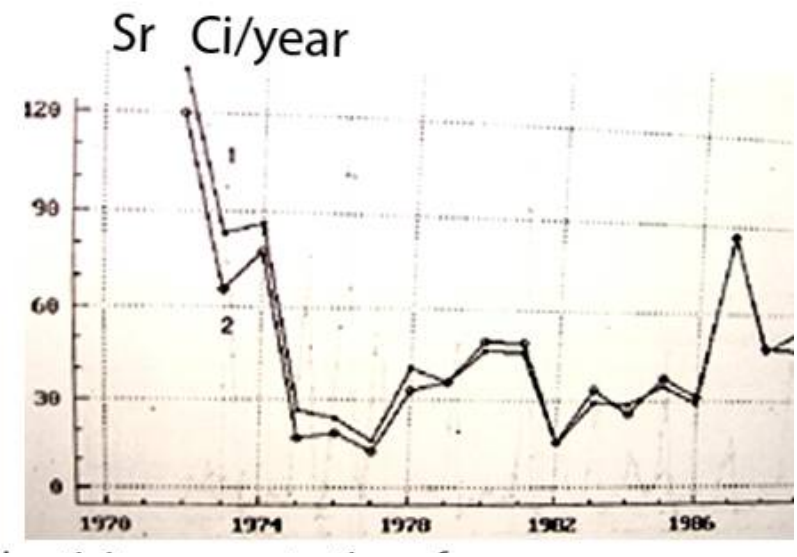


Figure 2: The right graph shows the activity concentration of Sr-90 over time.

The data available makes it difficult to understand what is happening with the radiation level of the Techa River. Official researchers usually give average figures (Figure 1), whereas the Techa River mainly has a stain-like structure of heterogeneous residual radiation. This is most obvious downstream of the Techa Bridge where there is a strip of soil with a radiation level equal to 10,000 cpm (multi-channel x-ray spectrometer units per minute) or greater for measurements taken right on the soil. Meanwhile, surrounding levels are of approximately 30-50 cpm and are almost equal to background radiation for measurements taken with the help of an INSPECTOR-type device.

Among the many research papers written on Techa River contamination, [3-11] for instance, there is only one paper clearly stating the fact that the Sr-90 radiation, in 90% of cases, is spread

by snowmelt floods [2].

It is very difficult to understand why the Techa River radiation level is so high 100 km downstream from the last 11 dams (Figure 3), since 50 years have passed since the large radiation emission into the Techa River.

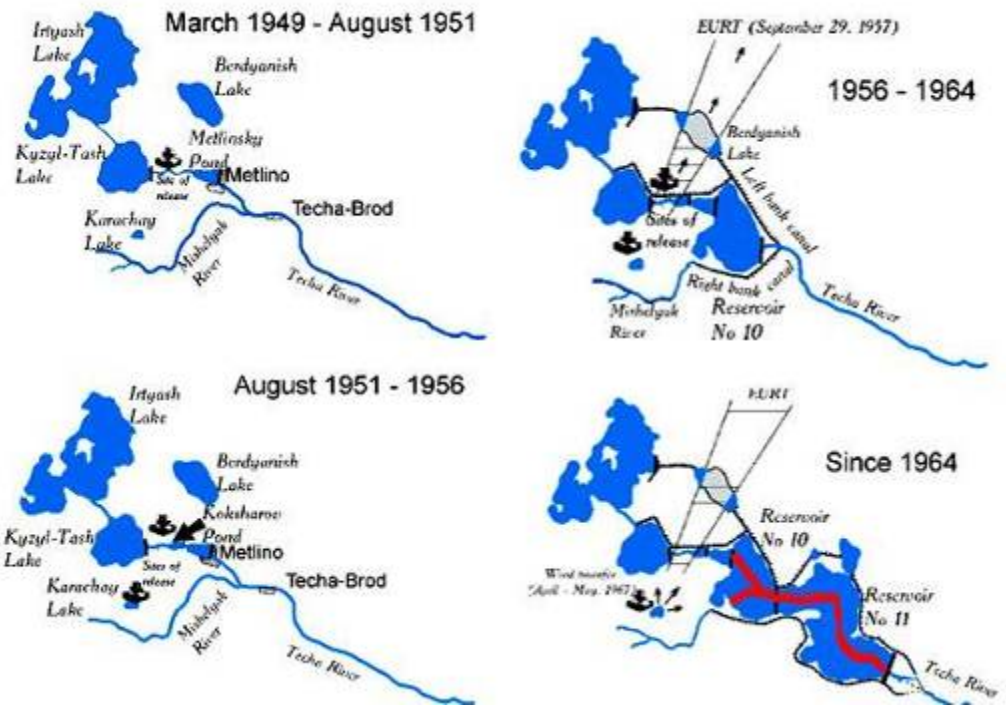


Figure 3: A history of protective dams built on the Techa River. We hypothesize that large radiation channels, signified by red lines, lie at the bottom of the lakes.

The history of protective dams on the Techa River

It seems likely that large radiation channels have accumulated on the bottoms of the lakes. These are shown by red lines in Figure 3. This is very dangerous because of the large radiation gradients between the mixture of moving water and radionuclide deposits. The main problems occur in winter and spring, in Russia's cold climate.

In the U.S. a very similar heterogeneity problem occurred at Hanford, though that case dealt with soil rather than sediments.

Recently one official article [2] was found showing data on the seasonal variation of new radiation levels (Sr-90) in the Techa River water (Figure 4).

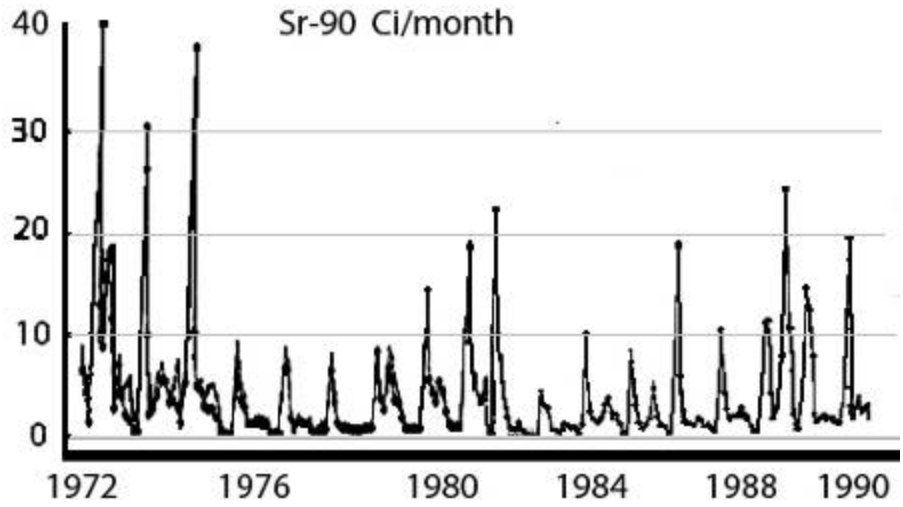


Figure 4: Shown is the activity concentration of Sr-90 over time. The graph indicates a yearly fluctuation according to seasonal changes.

Assessing the condition of the Techa River

The use of modern sensitive devices for last few years in cooperation with the Government Accountability Project (GAP) and new methods for applying these devices developed by SSGR for quantitative field research allow us to carry out independent research on a new technical level.

The Mayak Chemical Nuclear Complex (Mayak) has disposed of large quantities of radioactive elements into the system of Asanovo Bogs and the Techa River, thus the source of extra radioactivity begins in these Asanovo bogs.

Our research was carried out at different times of the year and on various sites of the Techa River and Asanovo bogs, (Figure 5), to account for this heterogeneity.

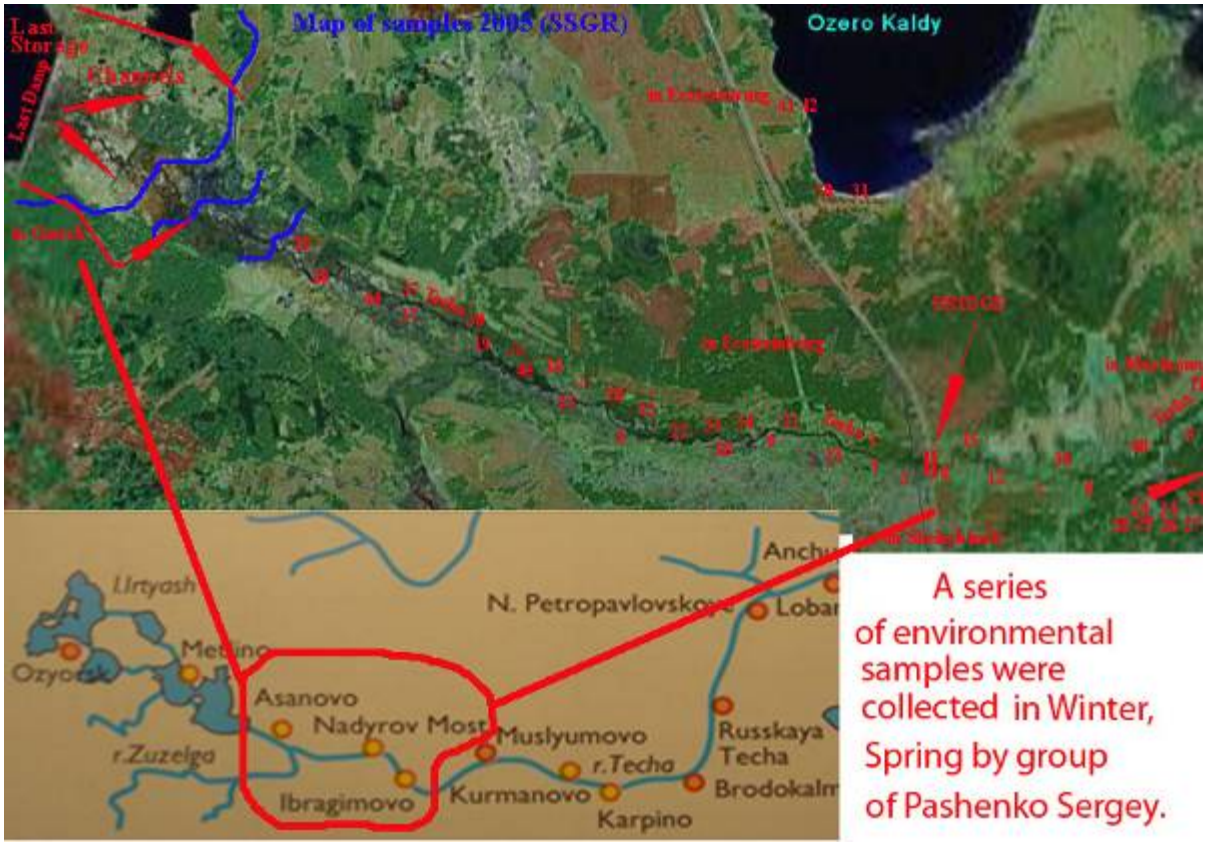


Figure 5: The sites of environmental sampling done by Sergey Pashenko's research group in the winter and spring.

A series of environmental samples were collected in winter and spring by Sergey Pashenko's research group. The descriptions of all the samples below the bridge in the winter to summer seasons and in autumn seasons near Muslyumovo are contained in Appendix 1 and 2.

Physical and Hydrological Characteristics of the Techa River

The climate of the region is continental, with cold winter during 5.5 to 6 months. The average annual precipitation is 375 mm with 15% fall during the winter. Annual runoff is 25 mm and evaporation 250 mm.

The controlled discharge from Kasli-Irtyash lake system into the Techa River via the Left Big Channel (LBC) is shown in Figure 3. Average annual water discharge at the mouth is 6.9 m^3/sec. The catchment area is 7700 km^2, of which forest area is 31% and boggy area is 11%. The river is fed mainly by melted snow and has distinct spring floods contributing to 50-60% of the annual runoff. The Techa River can experience summer flooding when there is a large discharge of water from the Kasli-Irtyash lake system via the LBC after heavy precipitation. During the summer and winter low-water period, a substantial proportion of the water in the river is attributable to groundwater and underground water runoff.

The Techa valley may be divided into two parts. The first is a boggy flood plain between 200 and 1000 m wide – from Dam 11 to the village of Muslyumovo, 40 km in length. Because of the high groundwater level, most of the flood plain is bog. We collected samples only from part of

the river. The mean inorganic chemical composition (mg/L) of the Techa River in summer and winter low water, and in spring floods respectively is: Calcium (II) 62 and 39, Magnesium (II) 30 and 15, Sodium (I) plus Potassium (I) 30 and 23, HCO3(-1) 225 and 166, Sulfate 58 and 50, Chloride 31 and 18, hardness 438 and 310.

At the beginning of the 1990s the discharge of water into the upper reaches of the Techa River via the Left Big Channel had, on average, risen 5 times. Monitoring data from Muslumovo is not available – Mayak's monitoring works in Muslyumovo were closed.

Today in all official Russian government-authored articles we find only one mention of these discharges: "It should be stressed that the major source of Sr-90 is remobilization from the previously contaminated reservoir sediment".

The U.S. Department of Energy (DOE) and Minatom now jointly perform major works on the Techa River (see appendix 3-4). Unlike Russian NGO's, a U.S. nongovernmental organization can acquire the reports from DOE under the U.S. Freedom of Information Act. (SEE: DOE/EM 1000 Independence Avenue, SW, Washington D.C. USA tel. 202-586-6382 The Contract was signed by Dr. E. Drozhko, Principal Investigator PA Mayak L. Samsonova Principal Investigator Close Joint-Stock «Company Geospetzecologiya» Dr. M. Glinsky Contract Manager FSUGE «Hydrospetzgeologiya» Dr. L. Chertkov Director General Close Joint-Stock «Company Geospetzecologiya» Dr. A. Hutter Technical Program Manager DOE/EM)

The Climate is an important part of the Radiation Problem around Mayak. Temperate data shows that the cold period begins in October and ends in May. The soil temperature in 0.5 m soil generally follows the air temperature, the greatest depth of soil freezing is 1.8-2 m, and is recorded in May.

In official reports we cannot find direct discussion about the role of freezing and ice-cover on the Techa River for processes that diffuse radiation, but all our field radiation data and mathematical analysis of official Sr-90 data and meteorological data [12] confirm the important role of ice-cover on Techa River.

Normalized data on maximum of Spring Sr-90 flood near Muslyumovo is shown in figure 6. Two years – 1978 and 1988 the Spring Sr-90 floods were anomalies biggest and are signified in red.

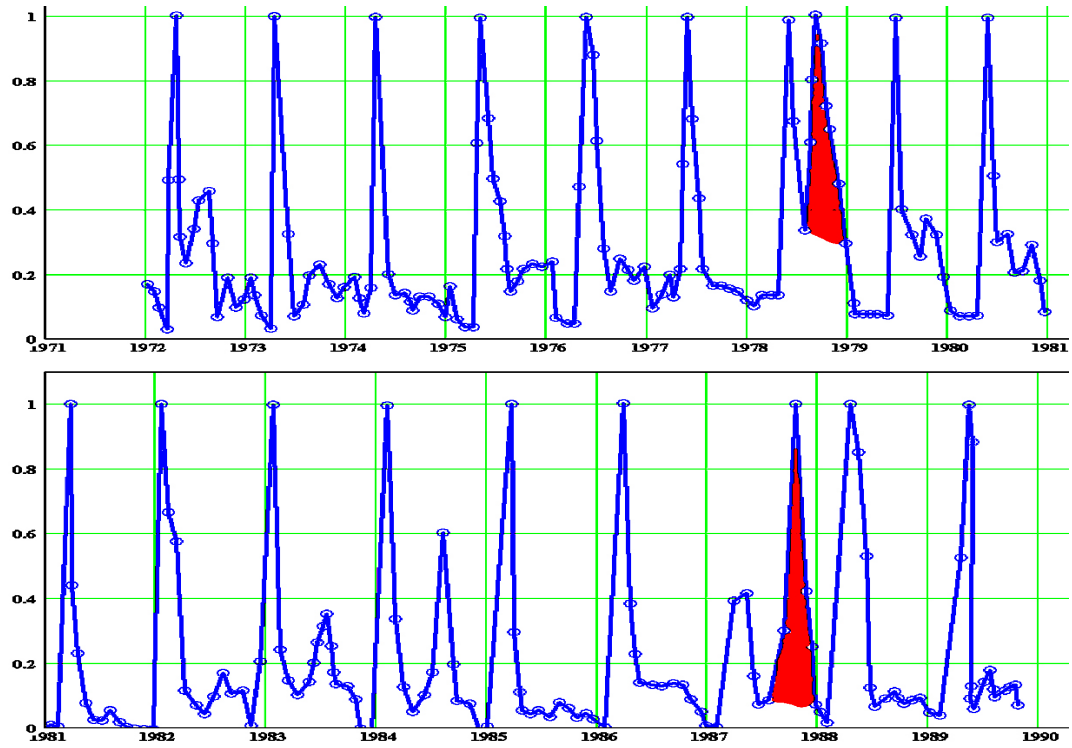


Figure 6: Normalized data on maximum of Spring Sr-90 flood near Muslyumovo from 1972 to1989.

Radionuclides that must be measured in Techa Investigations

Movements of key radionuclides in the Techa vary by isotope. [1-11, 13-16]. Different radionuclides historically give different distributions. According to the very preliminary estimation, the fractions give an equivalent inventory in 1956 of, for Sr-90 – Dam 4 to Muslyumovo, 2.5 PBq (68 KCi), for Cs-137 1.3 PBq (3,468 KCi).

The official perspective is that present day activities at Mayak do not represent a significant source of radionuclides to the aquatic environment. Officials think that the contamination of river water around Mayak area is largely due to remobilization from previously contaminated soil and sediments.

Primary sources of radionuclides to the Techa are surface run-off through the channels, exfiltration of reservoir water through the dams and channel dykes, and remobilization from Asanovo Swamp. We know that a number of potential sources of contamination exist [1].

Important conclusion for the investigators – today we can (must) only measure Sr-90 and Cs-137 conditions on the Techa River. The radiation characteristics of these elements differ greatly, which allows for easy measurement in the field and simple laboratory conditions that don't require expensive and difficult interpretation. This is illustrated in the next thesis.

Winter analysis is very important – we can easily move in the Asanovo swamp without official observers and can take measurements and samples under the ice and water at all sites on the Techa River. We now understand what happens when the warm water from Mayak accumulates on the surface of old ice and can now determine the warm radiation pulse from the structure of

the ice and its radiation directly in the field.

Figure 7: Sampling on the Techa River in winter months.

Theses 1

The main radiation contamination is only long-lived. We investigated in a very sensitive long time regime the decay analysis of about 20 samples taken above the Bridge (in Asanovo Swamp) in winter, spring, and summer. In figures below we can see details and results.

Over a period of 18 months a series of Techa River sediment samples were collected and analyzed. Field analyses were carried out with a portable GM radiation detector with a 4.7 cm port. (Radalert Inspector NRM)

In the results we can see mainly long half-life radionuclides (Figure 8).

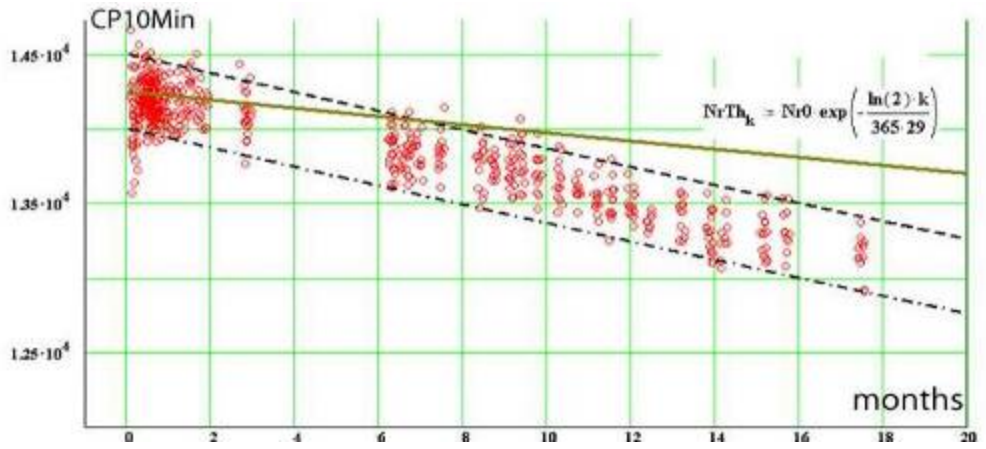


Figure 8: The continuous measurement sample of the bottom the Techa River in a big spring flood. The brown line shows decay with a half-life of 29.5 years (Sr-90 and Cs-137). The error (dispersion) = 0.64%.

Figure 9: Sampling during summer months.

Theses 2

Based on newly collected data, the decay of Cs-137 and Sr-90 cannot account for the currently observed activity and a non Cs-137/Sr-90 radionuclide must be present. From [1] we know that in the radiation composition of the discharge from Mayak were middle half-life radionuclides: Ru-106 and Rh-106 (1.02 years half-life), Ce-144 and P-144 (284.9 days half-life), Pm-147 (2.63 years half-life), and others.

Table 1: Radionuclide Composition in Techa River Sediments from 1953 and 1963-1964 Results are stated as percentage of total beta-activity.

Location 1953	**Sr-90**	**Ru-103, Ru-106**	**Cs-137**	**Other**
Reservoir 3	37-40	5-22	10-18	18-37
Reservoir 4	15-63	7-27	15-51	14-41
Techa 18 km	6	7-27	46-50	37
Techa 34 km	5	6	24-45	44
Techa 49 km	60	7	19-24	9
Location 1963-1964	**Sr-90+Y-90**	**Ru-103, Ru-106**	**Cs-137**	**Other**
Techa 49 km	6	1.7	92	0.2
Techa 55 km	12	1.3	86	0.6
Techa 132 km	60	2.8	36	1.0
Techa 185 km	95	1.6	2.0	1.2

Calculation of non Cs-137/Sr-90 radionuclides in sediment samples showed that it is likely that 8% of the total beta activity is due to Ru-106 and Rh-106 (Figure 10).

$$Ntot = N(CsSr2003)\exp(-\frac{\ln(2)}{TCsSr}t) + N(Ru106)\exp(-\frac{\ln(2)}{TRu106}t) \qquad (1)$$

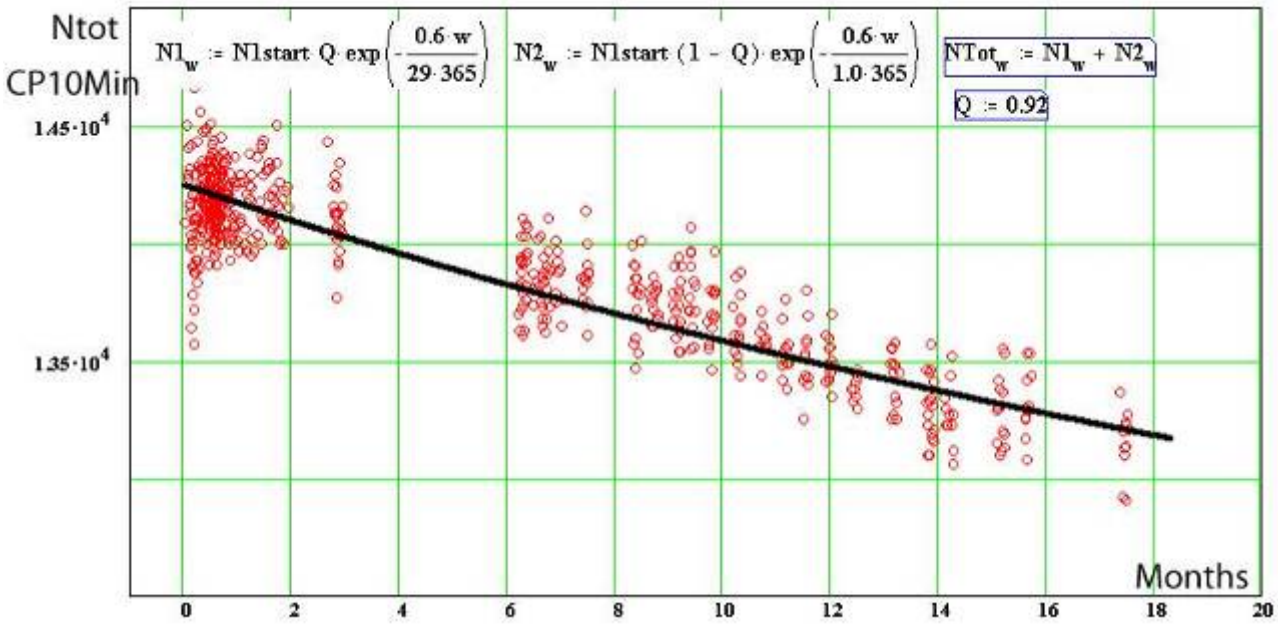


Figure 10: Long-months measurement of bottom and modeling it with 8% of Ru-106 and Rh-106 (1.02 year half-life).

Result: The ratio of decay activity in bottom sediments, (Act106Ru+106Rh)/ (ActCs137+Cs90), was equal to 8/92, for the period from in 1963 to 1964, when the last protection dam N11, was created. Assuming that the ratio remains the same for 2003 to 2005 then the activity ratios would be described by equation (2) 3.3*10(**11).

$$\frac{Act1963(Ru+Rh)}{Act1963(Cs+Sr)} = \frac{8}{92} \times \frac{\exp(-\frac{\ln(2)}{TCsSr}50)}{\exp(-\frac{\ln(2)}{TRu106}50)} \qquad (2)$$

Actual Mayak data gives a true ratio close to 1/10. Given this ratio our new data shows that the Mayak sediment bed load discharged at spring high water is “fresh” radiation.

Theses 3

Principal Techa contaminants are Sr-90 and Cs-137 and other contaminants include some sediment (5-10%) Ru-106 and Rh-106. Below figures show the main characteristics of beta and gamma emission of these elements for discussion what and their respective field measurements [17, 18].

Applications and possibilities of the fine-screen method in analyzing beta radiation

Each β-radioactive element is characterized by a maximum energy E_{max} or a set of maximum energies in the case of a complex spectrum. We take the magnitude of the maximum energy and the form of the spectrum from a set of special electron tables (Figures 11-13).

The loss of energy by electrons in passing through a substance requires two methods of analysis—one for a thin sample, the other for a thick sample.

It is convenient to express the thickness of the absorbing layer by the magnitude of its mass m with regard to unit area S.

$$d(\text{г} / \text{см}^2) = \frac{m}{S} = \rho l$$

A certain minimum thickness of the absorbing layer traps all electrons with a given energy. This important radiometric value is called the range (R) of electrons of a given energy in a medium.

E_{max} can be determined from R_{max} by empirical tables or (recommended here) the Flammersfeld formula defined within a broad interval of energies (0.05-3 MeV):

$$E_{\max} = 1{,}92\sqrt{R_{\max}^2} + 0{,}22R_{\max}$$

Field Application Notes

Rate of error - SSGR quantitatively modeled the effects of boundary conditions (detector position, distance, humidity, and beta source) to validate the ability to reliably employ field test gear for non Cs-137/Sr-90 radionuclide detection. The level of error ranged from 5 to 8 percent based on the Monte Carlo method.

Screen fineness - In accurately calculating the thickness of the absorbing layer, the absorption of radiation in the window of the detector and in the layer between the specimen and the detector is taken into account. The thickness of the mica window is taken from the instrument specifications, while a layer of air with a thickness of 1 cm under a pressure of 760 mm of mercury at 25° C is equivalent to 1.18 mg\cm^2 of aluminum. Aluminum screens matching the dimensions of the Inspector are used under field conditions.

Gamma interferences - The field instrument's gamma-sensitivity allows separate field measurement of beta and gamma activity, but interferes positively with the fine-screen calculations for quantitative beta source measurement.

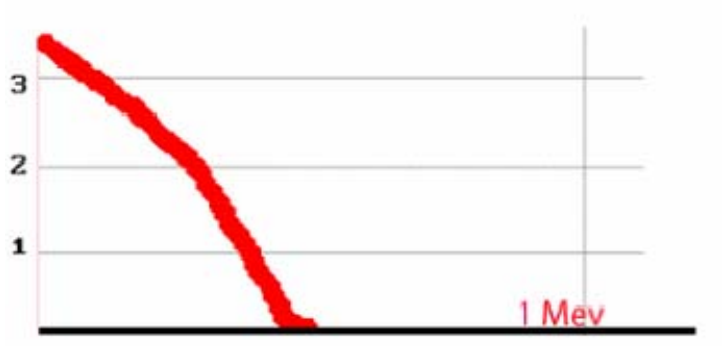


Figure 11: Decay Series for Cesium 137
Cs-137 → 30 years → Ba-137 (stable)
Gamma – 661 Kev 85.1%

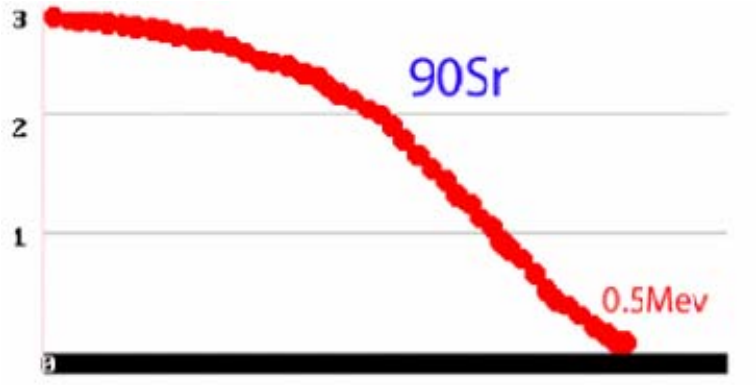


Figure 12: Decay Series for Strontium 90
Sr-90 → 29.1 years → Y-90 → 2.67 days → Zr-90 (stable)

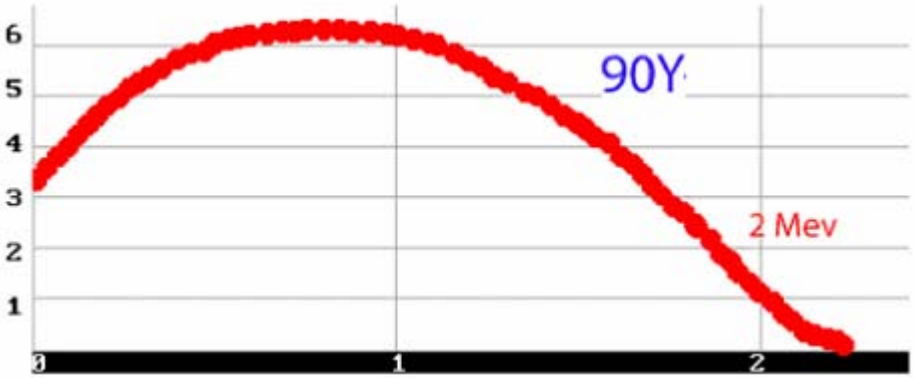


Figure 13: Decay Series for Yttrium

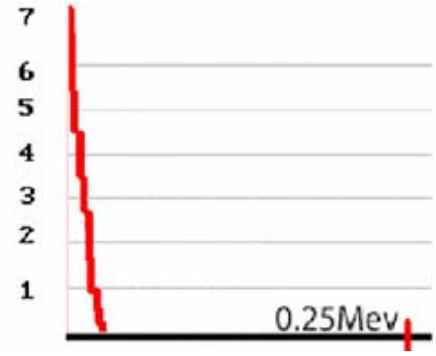


Figure 14: Gamma (-), beta spectrum of Ru. Ru-106 (1.02 yr), Rh-106 (29.8 s), Pd-106 (stable).

Figure 15: Gamma and beta spectrum of Rh-106

Theses 4

Spring flooding on the Techa re-suspends previously settled sediment-associated radionuclides from the river bottom. This bed load of sediment increases faster than the rate of increase of water flows, due to the slow settling velocities of fine particles.

The nonlinear increase in sediment bed loads with higher Techa River flows remobilizes non Cs-137/Sr-90 radionuclides detectable to field gear when as Ru-106 and Rh-106 after mathematical interpretation. In the laboratory additional information on sediment-related beta emissions can be collected measuring beta activity over time related to the differential settling velocities of increasingly fine sediment particulates. Differential settling velocity is responsible for the nonlinear increases in high water radionuclide remobilization and is quantified in this laboratory procedure. The laboratory procedure is illustrated below (Figures 16 and 17).

Figure 16 shows three graphics on the right, the top and bottom show beta activity due to coarse particles, and the central graphic shows beta activity due to fine particles, such as those detected during spring high waters on the Techa. These finer particles will travel much greater distances than the coarse particles.

Figure 16: The method for determining the beta activity of suspended small particles.

Figure 17: The examination of samples on gamma-spectrometers. Note that the sample and detector are separated by a thin membrane.

In the four theses above we tried to outline the strategy of the Techa River radiation contamination research that we followed. The key postulates would be the following:

1. Sr-90и Cs-137 are the main pollutants;
2. Sr-90и Cs-137 screen method fission in soil and water is only possible with the INSPEKTOR device;
3. Concentration levels of these elements undergo manifold changes in soil, water, and plants depending on the season, snowfalls and rainfalls (especially storm precipitation), water regime and characteristic features of the Techa River flow (fenlands, narrow channel, weedy soil).
4. Complex research of numerous samples is required in large floodplain areas at different times of year in order to create a complex model of pollutants transfer in the river.

Remarks: GAP presented SSGR with a very useful new radiation testing instrument called FieldSpec. It can measure spectrums of series elements, including Cs-137 (as difference of count calibration Cs-137 in FieldSpec and count with sample), but Sr-90 is only a beta-radiation source; therefore our screen method is faster and more sensitive for the Techa River radiation research.

FieldSpec allows a user to distinguish man-made and natural isotopes. It combines high sensitivity with a wide dose rate range. FieldSpec performs gamma spectrometry and nuclide identification. FieldSpec is a complete digital gamma spectroscopy and dose rate system. It integrates a multi-channel analyzer, amplifier, high voltage power supply, and memory with an integral scintillation detector. FieldSpec is suited for remote applications, advanced warning systems, hazardous environments and nuclear inventory monitoring. It has a standard Ø 1_ x 2_NaI (Tl) detector.

Using FieldSpec expedition samples analysis with long periods of signal accumulation and background

The optimal method of testing our samples, taking into account FieldSpec specific features, comprises the following operations:

1. Obtaining the background gamma spectrum at the measurement point over an extended period of time - up to 100,000 seconds.
2. Obtaining the gamma spectrum from samples over the same period, determining the 24-hour drift of the spectrum in the range of up to 300 keV.
3. Smoothing the spectrum according to special algorithms using MCAD software.
4. Subtracting the background spectra from the spectrum of the samples.

In addition, a technique was employed using lead screens for the spectrometer, in order to decrease background signals.

Results from our Techa River Expeditions

All the official papers normally look at the part of the riverbed between the last dam #11 and Muslyumovo village as the river headstream. Asanovo Bogs are mentioned less frequently. Therefore it is difficult to imagine what physical and chemical processes are exactly going on in that part of the Techa River. More or less systematic measurements of Sr-90 flows in the river were taken around the 11^{th} dam (floodways) and Muslyumovo village only. On the other hand, the Techa estuary was officially tested mainly for gamma radiation only, i.e. using the testing devices that are not sensitive to Sr-90 beta-radiation (with Y-90).

However, it is Sr-90 that is considered the most dangerous pollutant, since it is easily transferred with water flows, soaked into plants and can therefore expose the population to radiation via food chains [1].

Cs-137 has a moderate migration capacity and a reduction factor of 10. Sr-90 has the greatest migration capacity. In [1] the official estimates were based on the spatial distribution of Sr-90 and Cs-137 content in the floodplain soil from dam #11 to Muslyumovo. The research included the main measurements of the gamma-radiation dose rates from surface layers of contamination soil (Figure 19). Other data from Gosman Kabirov included measurements of gamma-radiation in Muslyumovo and the Techa headstream (Figure 20). We took heavily irradiated samples from this area in October 2005.

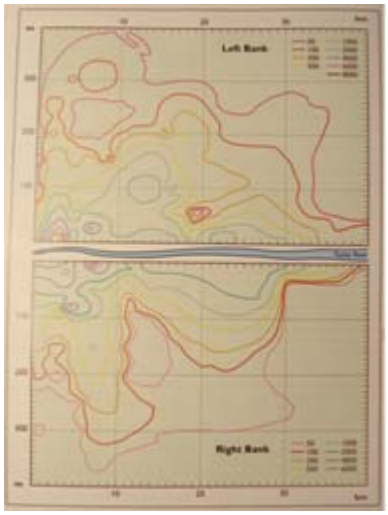


Figure 19: Special distribution of radioactive contamination of the upper reaches of the Techa River, estimated in 1991-1992 from measurement of the gamma-radiation dose rate.

Figure 20: Where high radiation samples were taken in October 2005.

Table 2: Results of the research around Muslyumovo
Radioactivity in samples taken near Muslyumovo in October 2005
Working data for samples from Muslyumovo in October 2005

No.	**Samples**	**Date and Time of collection**	**Type of measurement**	**Result and remarks**
No.A 1	A tree cut by beavers for a lasher	October 2005	Surface activity of Sr-90 and Cs-137 (cpm) around the stem	Sr-90+ Cs-137 < 30Bq/(cm^2*min) Leff=0.22 cm. N0=250cpm
No.A 2	A birch near the Techa waters, 1 meter away	October 2005	Surface activity of Sr-90 (cpm) around the stem	Sr-90=180Bq/(cm^2*min) Cs-137< 5% Sr-90 All activity is registered on the surface only Leff = 0.22cm. N1=190 cpm, N2=150cpm (point 1 and 2).
№2	Soil around a cow stock watering area	October 2005	Surface activity of air-dry samples	Leff = 0.21cm. N1=700cpm
№3	Water (0.5L) around a cow stock watering area where cows move and drink	October 2005	Activity of evaporated water and colloid particles without the hard sediment only	Leff beta = 0.11cm. Sr-90 =220cpm Cs =10cpm (see graph) or 22 Bq/L of Sr-90 and 1. Bq/L of Cs-137(see formula below). **Russian standard for drinking water is 1.0 Bq/L.**

№4	Sediment (from 0.5L) around a cow stock watering area where cows move and drink	October 2005	Activity of the air-dry sediment without water and hard colloid particles (weight equal to 52g)	Leff = 0.21cm. N1=770cpm Or 11680 Bq/kg Sr-90 in sediment We cannot find Cs-137, which means that all Cs-137 was collected in hydro-practical about 1 mkm in diameter (special experiment described in the next part of the report)
№5	Bark of a large tree in water and soil opposite of the old mill in Muslyumovo	October 2005	Air-dry =159g, ash =24.5g	Leff = 0.216cm, N1(Sr-90) = 4400 cpm, Cs-137 = 0 (<1%) Or 10300 Bq/kg of Sr-90 in air-dry bark
№7	Soil near the big tree (see #5)	#7a Standard beta field SSGR method	Air-dry 30grams	Leff = 0.22cm N1(Sr-90) = 2050 cpm or 4800 Bq/kg of Sr-90 in soil-dry
		#7b Standard gamma field SSGR method	Air-dry 820 grams	Leff (Cs-137) 25cm N1(Cs-137) = 205 cpm or 200-250 Bq/kg of Cs-137 in soil-dry

Working data for samples from Muslyumovo in October 2005

No.A1 and No.A1 (Table 2) In the tree test figures we see that beta radioactivity of the birch at the waterside is 220-40 cpm/cm^2 = 180Bq/cm^2*min. This is equal to the Russian standard for surface contamination for nuclear transport containers [19-20]. In the waterside birch (1 meter away from water) the radiation reaches its maximum. We discussed this wind-water process after the last expeditions with GAP near Seversk (Tomsk-7) in 2000, and mentioned this in other radiation research papers [21-23]. For beta-screens spectrums approximation we use the following formula:

$$Act(Nsc) = Act(0) * EXP(-\frac{Nsc \bullet (1/\rho) \bullet 0.02g/cm2}{Leff}) \quad (A1),$$

where Act stands for the experimental data in cpm, Nsc is the number of screens, ρ is the screen density (g/cm3), and Leff is equal to the length of beta-electron ray in the screen material.
For samples from graphs NoA1 and No.A1 Leff = 0.22cm.

If we want to estimate water activity (Bq/L) from the dry deposit activity of evaporated water, we can use the following clear formula where ActCPM will be taken adapted from experimental results in MCAD using formula (A1):

$$Act(Water) = \frac{ActCPM(All\_dry\_deposit, the\_\text{thickness} < 0.5\text{mm})}{60} * \frac{Eff\_Inspector * 2}{Vwater(L)} \quad (A2),$$

Next step: for a good estimate of activity (Bq/kg) for the cpm activity sediment calculations we will use the following formula where R is the radius of INSPEKTOR Geiger wicket. The diameter of samples MUST be equal to the sample tube diameter (Figure 21):

$$Act(Bq/kg) = \frac{ActCPM(dry\_\text{thickness} > Leff\_or\_3mm)}{60} * \frac{1000g}{\rho \cdot \pi R^2 \cdot Leff} * Eff\_Inspector * 2,$$

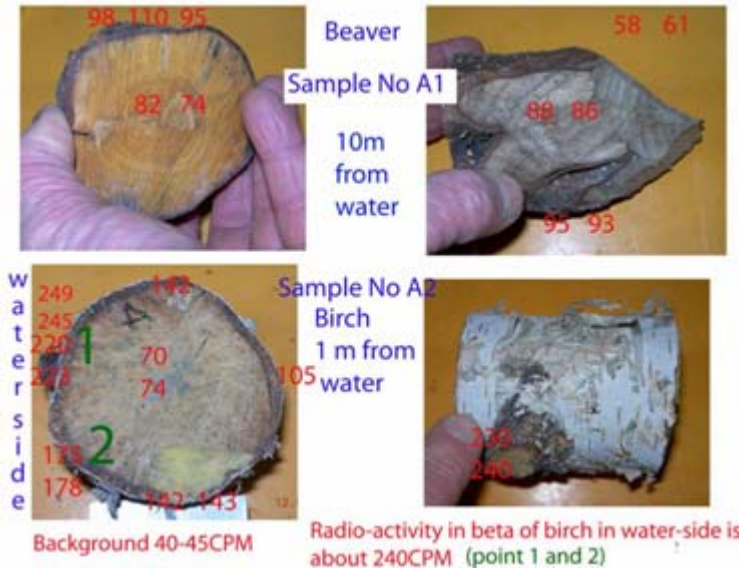


Figure 21: Profiles of trees, samples No.A1 and No.A2.

Figure 22: Beta screen data for two spots from the surface of the birch.

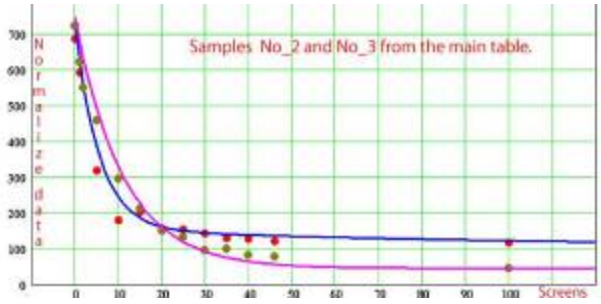


Figure 23: Sample No.2 and No.3 from Table 2. Compare the beta-screen normalize data of soil (sediment – brown dots) and water (water) near watering-place of caw.

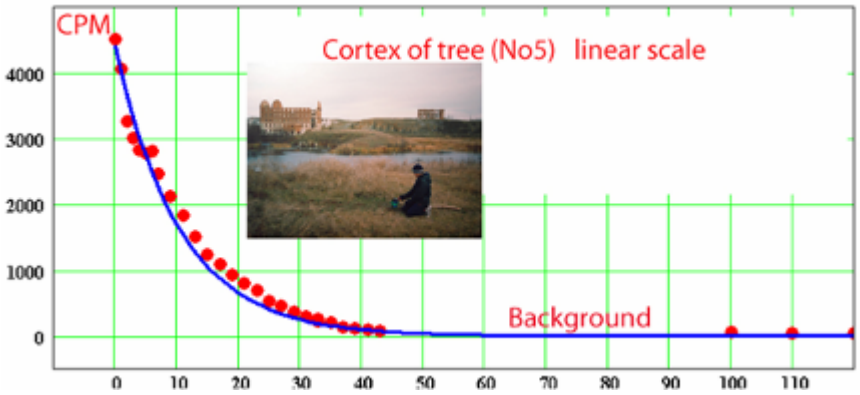


Figure 24: Profile for sample No.5.

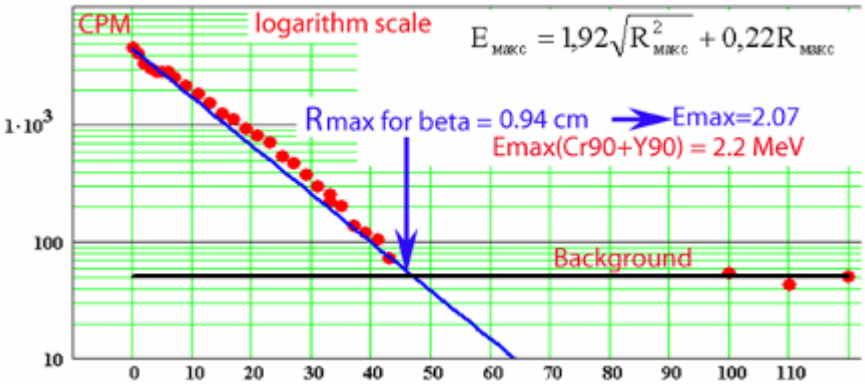


Figure 25: Logarithmic view of data in Figure 24 for No.5.

No.7, #7a and #7b (Table 2). Standard beta field SSGR method and standard gamma field SSGR method. Many officials discussing the radiation situation in Muslyumovo speak of gamma radiation only, often not understanding what type of radiation will be more dangerous for the population of Muslyumovo. Using the test samples taken in the center of Muslyumovo we will have a closer look at the problem.

As mentioned above, Cs-137 has a gamma line and a little beta spectrum, and Sr-90 and Y-90 have only the beta spectrum. Gamma Cs-136 (661.7MeV) moves in the air about 100 meters high, and in soil about 20-30cm deep. Y beta radiation (2.2MeV max.) can rise 1-2 meters high in air and plumb ONLY 1-2 mm into water and soil. Therefore, in Muslyumovo we must use contact radiation methods only to days. This is because the fraction of Sr-90 is increasing every year. The reason for it will be discussed below. In Table 2 one can see that Sr-90 is the largest. But simultaneous determination of Cs-137 quantity in Sr-90 field is a very important research aspect that allows one to understand the radiation diffuse process in the Techa River and its floodplain. We use the character of Sr-90 and Cs-137 rad-emission and the screen method for the large INSPEKTOR Geiger wicket.

Description

Step1: The big sample (820 grams) of radiation soil taken opposite the old mill in Muslyumovo in a good geometrical cup (for easy computer calculation of the calibration data) was measured with INSPEKTOR with a special beta screen at the bottom of the device.
Step 2: We measure radiation using the screens from the little cup with soil (30 grams of soil).

Step 3: Two different spectrums were found and computer calibration gave us Sr-90 and Cs-137 with good resolution (10-15%) for field condition and for the laboratory special experiments.

Figure 26: Images of the steps for measuring radiation in soil samples. Step 1 (Upper left) measures the large sample for radiation, Step 2 (Upper right) measures the radiation of smaller samples.

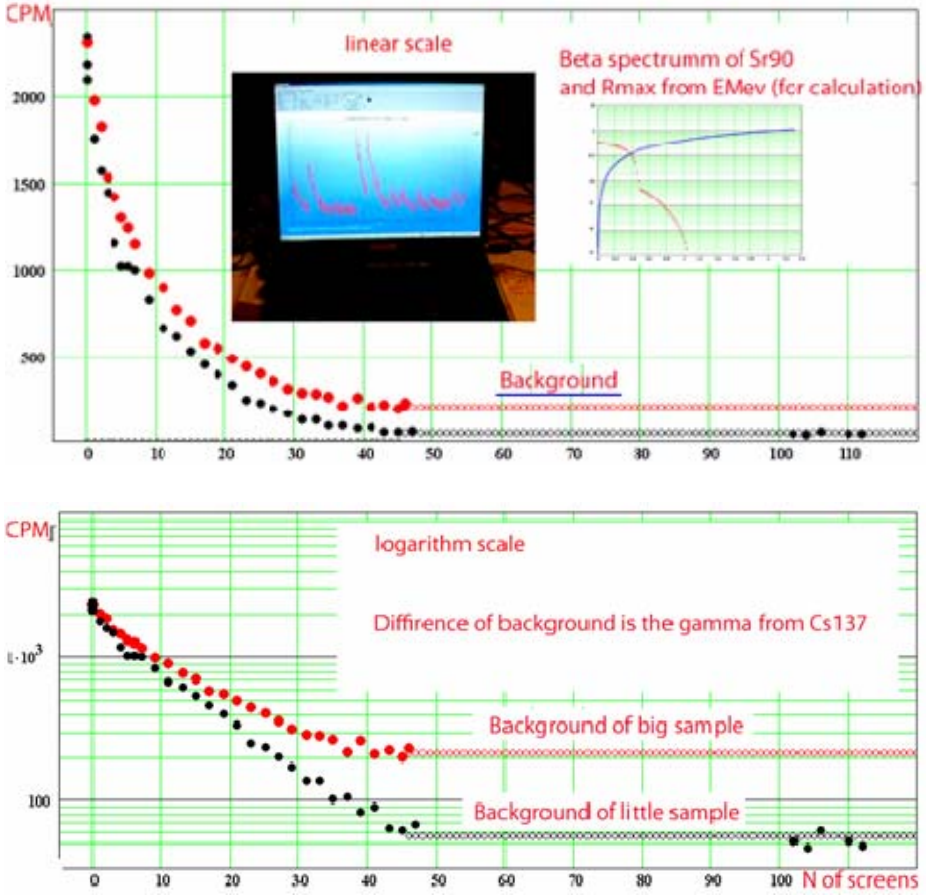


Figure 27 and 28: Non-beta radiation is still getting through the screens for these samples.

Appendices and References:

Available upon request, contact Tom Carpenter of the Government Accountability Project for more information.

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