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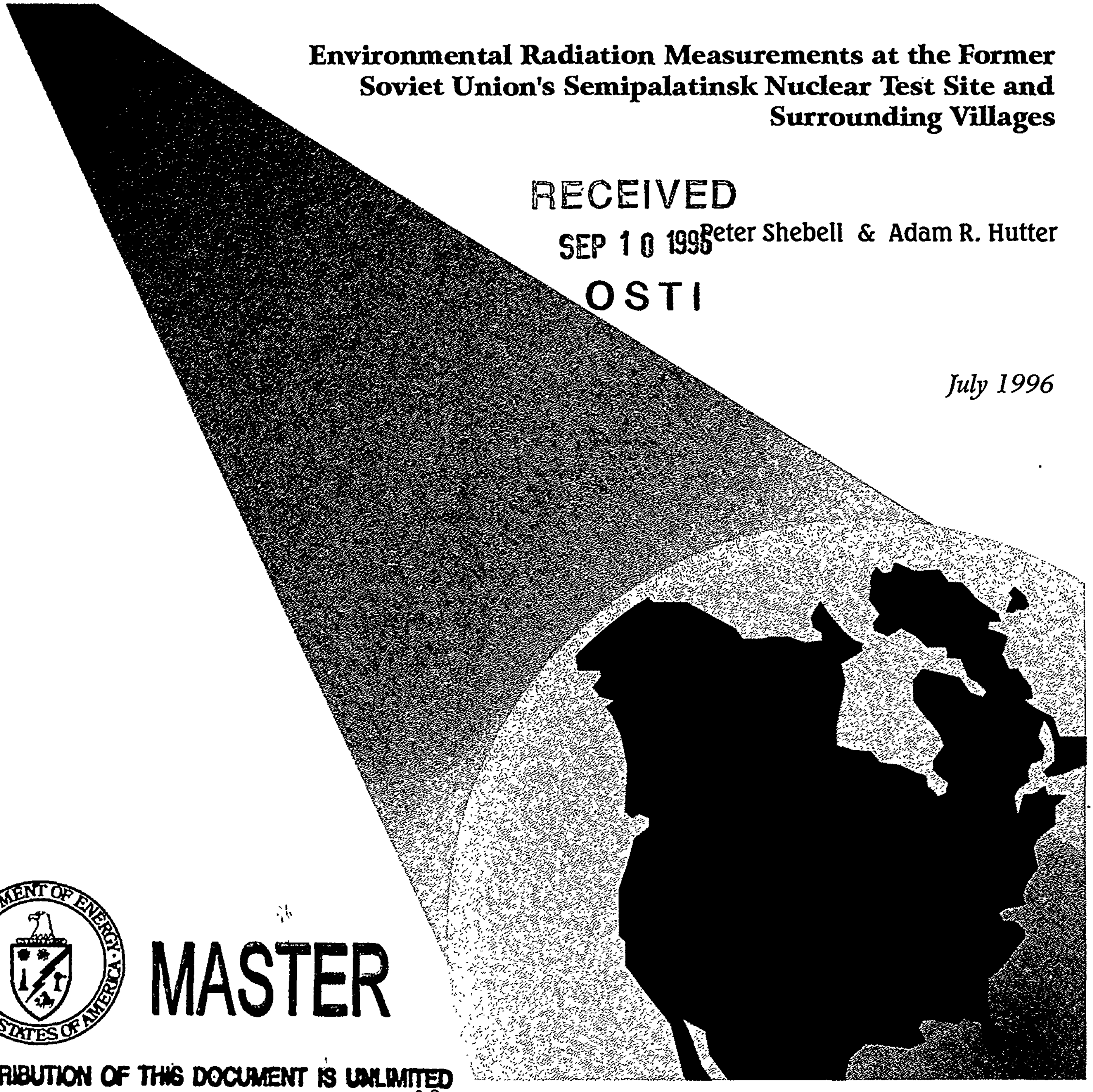

Environmental Radiation Measurements at the Former Soviet Union's Semipalatinsk Nuclear Test Site and Surrounding Villages

Peter Shebell & Adam R. Hutter

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ABSTRACT

Two scientists from the U.S. Department of Energy's Environmental Measurements Laboratory served as scientific experts to the International Atomic Energy Agency's (IAEA) Mission to Kazakhstan: Strengthening Radiation and Nuclear Safety Infrastructures in Countries of the former USSR, Special Task - Preassessment of the radiological situation in the Semipalatinsk and western areas of Kazakhstan. The former Soviet Union's largest nuclear test site was located near Semipalatinsk, Kazakhstan, and following Kazakhstan's independence, the IAEA committed to studying the environmental contamination and the resulting radiation exposure risk to the population due to 346 underground, 87 atmospheric and 26 surface nuclear detonations performed at the site between 1949 and 1989. As part of an 11-member team, environmental radiation measurements were performed during 2 weeks in July 1994. Approximately 30 sites were visited both within the boundaries of the Semipalatinsk nuclear test site as well as in and around surrounding villages. Specifically, the objectives of the EML team were to apply independent methods and equipment to assess potential current radiation exposures to the population. Towards this end, the EML scientists collected *in-situ* gamma-ray spectra, performed external gamma dose rate measurements using pressurized ionization chambers, and collected soil samples in order to estimate the inventory and to determine the depth distribution of radionuclides of interest. With the exception of an area near an "atomic lake" and a 1 km^2 area encompassing ground zero, all the areas visited by the team had external dose rates that were within typical environmental levels. The measurements taken within a 15 km radius of ground zero had elevated levels of ^{137}Cs as well as the activation products ^{152}Eu and ^{60}Co. The dose rate within a 1 km radius of ground zero ranged from 500 to 30000 nGy h^{-1}.

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INTRODUCTION

Two scientists from the U. S. Department of Energy's Environmental Measurements Laboratory served as scientific experts to the International Atomic Energy Agency's (IAEA) Mission to Kazakhstan, "Strengthening Radiation and Nuclear Safety Infrastructures in Countries of the former USSR, Special Task - Preassessment of the radiological situation in the Semipalatinsk and western areas of Kazakhstan". The former Soviet Union's largest nuclear test site was located near Semipalatinsk, Kazakhstan, and following Kazakhstan's independence, the IAEA committed to studying the environmental contamination and the resulting radiation exposure risk to the population due to 346 underground, 87 atmospheric and 26 surface nuclear detonations performed at the site between 1949 and 1989. As part of an 11-member team (see the Appendix for team member list), with participants from the United Kingdom, France, Austria and Russia, environmental radiation measurements were performed during 2 weeks in July 1994. Approximately 30 sites were visited both within the boundaries of the Semipalatinsk nuclear test site, as well as in and around surrounding villages. Specifically, the objectives of the EML team were to apply independent methods and equipment to assess potential current radiation exposures to the population. The test site is an uncontrolled area, and since nomadic peoples and herds are prevalent, the preassessment effort needed to address any location where the population could be exposed, as well as different exposure pathways. Therefore, significant time and effort was spent in the villages closest to the test site as well as within the borders of the test site. Towards this end, the EML scientists collected *in situ* gamma-ray spectra, performed external gamma dose rate measurements using pressurized ionization chambers (PICs), and collected soil samples in order to estimate the inventory and to determine the depth distribution of radionuclides of interest.

While at the test site, EML was guided by personnel who had been involved with the testing of nuclear devices at the site. This report details the EML measurements and samples collected from locations where it was escorted, including excavation lakes and the ground zero for surficial tests. There were other possible contaminated areas where the team did not survey, including "technical areas" and near the reactors.

SOIL SAMPLING

METHODS

Soil samples were collected to estimate the inventory and to determine the depth distribution of ^{137}Cs, ^{152}Eu, ^{155}Eu, ^{60}Co, ^{241}Am and ^{154}Eu. Soil samples were collected at locations where gamma-ray exposure data indicated reasonable local uniformity (see Table 1 for description and identification of sample locations, and Figure 1 for a map of sample locations). Almost all soil samples were collected in flat, undisturbed areas used for grazing cattle, sheep and/or horses, thus having short-cropped vegetation. Samples were collected using 8.9-cm diameter soil cutters. A 5-cm deep cut was removed, followed by a 10-cm corer inserted into the same hole to obtain a 5 to 10-cm cut, and finally, a 15-cm corer was used to obtain a 10 to 15-cm cut. In some instances, a core down to 30 cm was obtained using an auger. This sampling procedure is described in the EML Procedures Manual, Section 2.4.3.1 (Chieco et al., 1992).

Due to time, weight and other logistical considerations, all sites were sampled using three cores. The samples were collected at approximately equidistant locations and 3 m from the gamma spectrometer. The surface area collected using this technique (186 cm^2) does not represent the site as precisely as the normal 10-core sample as per ASTM procedures (ASTM 1983). However, our experience in soil analyses indicates that the total error in the sampling, preparation and the gamma analysis will be about 15% for the three-core samples as opposed to an estimated 8% error when using the 10-core method. The respective cuts of the soil from the three cores were composited, broken up by hand, and homogenized as well as possible. The sample was then spread out on a plastic tarp and quartered, with stones and vegetation evenly distributed. Two of the quarters were kept, resulting in an approximate split of the sample so as to reduce the sample size.

In the laboratory, the soil samples were air dried for 3-10 days in plastic trays. The samples were not sieved but large stones were removed before the samples were sealed in 90-mL aluminum cans. The samples were then allowed to stand for several weeks so that the radon progeny could build into equilibrium. A HPGe spectrometer system comprised of a reversed bias 35% efficiency (relative to a 7.62 x 7.62 cm NaI crystal at 1332 keV) was used to analyze the samples. The energy region examined was 20 to 3000 keV, and counting times ranged from one to several days depending on the activity of the sample and desired accuracy of the results.

One set of duplicate samples was obtained which translates into a frequency of about 10% (1 in 9 samples).

INSTRUMENT CALIBRATION

The HPGe detector used for the analysis of the samples was calibrated using 70-mL NIST traceable standards containing the radionuclides ^{137}Cs, ^{60}Co and ^{241}Am housed in aluminium cans. The calibration procedures are detailed in the EML Procedures Manual, Section 4.5.2.3 (Chieco et al., 1992). Deionized water samples were counted on a weekly basis to check for possible contamination and fluctuations in background. A periodic check of the efficiency with a ^{137}Cs reference material also sealed in 90-mL aluminum can was performed. The total systematic error for all concentrations, with the exception of ^{152}Eu, are <5%. Effects of cascade coincident summing raised the total systematic error for ^{152}Eu to about 10%.

RESULTS

A summary of absorbed dose rate in air calculated from the soil samples is shown in Table 2. For comparison and quality assurance (QA) purposes, this table includes estimates of the dose rates using field spectrometric methods (see following sections), as well as estimates using the results of soil sampling. Soil data and concentration values for natural and anthropogenic radionuclides are summarized in Table 3. The principal gamma emitters detected again varied with location. At all locations ^{137}Cs was detected along with other peaks connected with naturally occurring radionuclides. The ground zero samples (Location IDs 725.1 - 726.GZ), consisting of cores taken at distances ranging from 1 to ~ 10 km from ground zero were found to contain ^{152}Eu, ^{155}Eu, ^{60}Co and ^{241}Am. A sample taken about 200 m from historical ground zero (Location ID 726.GZ) was found to contain ^{154}Eu as well. A sample of loose gravel was taken from the edge of an excavation lake ~ 15 km outside of Sarzhal (Location ID 720.3) with the suspicion that a sufficient amount of plutonium might be present to assay by gamma analysis.

The concentration of ^{239}Pu was determined by analyzing the 393 keV doublet. Although weak, with an emission rate of 5.53E-6 γ/disintegration, this line was chosen because corrections for coincident summing are not necessary (Debertin & Helmer, 1988). Concentrations of ^{241}Am and ^{239}Pu are reported in Table 3, but we must emphasize that this was not the result of our standard soil sampling techniques.

The gamma analysis of the samples from ground zero, Lake Tchagan, and the excavation lake (location IDs 726.GZ, 719.1, and 720.3, respectively) were problematic. Peak interference and cascade coincident summing effects puts the total systematic error on these sample at about 15%. Just as with the *in situ* spectra, the resulting concentrations for each of the natural emitters, and inventories for the various gamma emitters, ^{137}Cs, ^{152}Eu, etc., can be converted to dose rate in air. Each contribution can then be added to an appropriate value for the cosmic-ray contribution. The resulting dose rate can than be compared to PIC measurements (see subsequent sections). Agreement to within 15% is an indication of good sample preparation and detector calibration.

Inventory estimates for these nuclides in kBq m^{-2} can be found in Table 4. Included in this table is the relaxation mass per unit area that was used to determine absorbed dose rates in air from the given inventories.

Dose rate estimates for these nuclides as well as ^{226}Ra, ^{228}Ra, and ^{40}K can be found in Table 5. A cosmic component of 34.2 nGy h^{-1} was included to produce a dose rate which could be compared to measurements taken with a PIC.

FIELD SPECTROMETRY

METHODS

A tripod mounted HPGe detector (45% efficiency relative to a 7.62 x 7.62 cm NaI crystal at 1332 keV) was used in conjunction with a battery powered EG&G Ortec "Nomad" multichannel analyzer (MCA) to collect the gamma-ray spectra at the selected sites. The standard reference height of 1 m above the ground was used in all cases. The energy region examined was 50 - 4000 keV, with a collection time of 10 min. Selection of the specific measurement location was based on the terrain. The best sites are those that approximate a 2π geometry with little or no surface features and modest vegetation. As previously mentioned, a rem meter was used to check the uniformity of the radiation field associated with the measurement site.

The conversion of the full absorption peak count rate to dose rate in air or activity per unit area on the ground depends upon the depth profile of the gamma emitter. For this reason, soil sample cores were collected from different depths. Subsequent laboratory analyses of the samples yields an inventory as well as relaxation mass per unit area. A more complete description of this technique can be found in the EML Procedures Manual, Section 3.3 (Chieco et al., 1992) and ICRU Report 53 (ICRU, 1994).

INSTRUMENT CALIBRATION

The detector was calibrated for field operation using a collection of point sources obtained from the IAEA and the National Institute of Standards and Technology (NIST). The calibration procedures are detailed in the EML Procedures Manual, Section 3.3 (Chieco et al., 1992). As pointed out in the previous section, every effort was made to select sites which had a favorable source geometry. A counting time of 10 min usually gave a statistical uncertainty of no more than 10% for the peak count rate associated with ^{137}Cs. The resulting concentrations for each of the natural emitters, and inventories for each of the various gamma emitters, ^{137}Cs, ^{152}Eu, etc., can be converted to dose rate in air using the appropriate conversion factors (Beck, 1980; Beck et al., 1972). The individual dose rates can be added together with an appropriate value for the cosmic-ray contribution. The resulting dose rate can then be compared to PIC measurements. Total systematic errors related to detector calibration, soil parameters, and source geometry has been estimated to be no > 5%. Agreement to within 5% indicates a good detector calibration, a suitable source geometry, and favorable soil conditions.

RESULTS

A summary of the absorbed dose rate in air calculated from the *in situ* analyses is shown in Table 2. Table 6 contains the inventory values for selected radionuclides obtained from the analyses of *in situ* gamma-ray spectra. Spectra from several locations were not analyzed either because dead-time losses and peak distortion from pulse pile-up could not be adequately compensated, or the source geometry was not appropriate to yield accurate inventory values. The principal gamma emitters detected varied with location. However, at all locations ^{137}Cs was detected along with peaks connected with the naturally occurring gamma emitters. Within a radius of about 13 km from historical ground zero (50 26.53 N, 77 48.877 E) the gamma emitters associated with ^{152}Eu and ^{60}Co were detected. Excessive dead-time losses and peak distortion from pulse pile-up, typically associated with high-radiation fields, were encountered within a 1 km radius around ground zero.

Table 7 summarizes the dose rate contribution from all gamma emitters to the total terrestrial dose rate. A cosmic component of 34.2 nGy h^{-1} was included to produce a dose rate that could be compared to measurements taken with a PIC. The value of the cosmic-ray component is based on geomagnetic latitude and altitude.

EXTERNAL GAMMA DOSE RATE MEASUREMENTS

METHODS

The measurement of the external dose rate in air was conducted with an 18-cm diameter PIC which incorporates signal integration and digital readout display. A complete description of the instrument can be found in Latner et al. (1983). Measurements were conducted at ~ 1 m above the ground. A series of at least five measurements, each consisting of a 40 s integration time, were obtained at each site, providing a standard error of 3% or less at the dose rate levels encountered. A more complete description of the PIC system can be found in the EML Procedures Manual, Section 3.2 (Chieco et al., 1992).

Additionally, a Bicron Micro Rem Meter was used as a survey instrument to check for homogeneity in determining site selection. The detector, based on an internally mounted tissue-equivalent organic scintillator, provides the photon response from 0 - 200 mrem h^{-1} full scale with five linear ranges, and has a response time of < 15 s. The energies of the gammas detected ranges from ~ 40 keV to 3 MeV.

INSTRUMENT CALIBRATION

Calibration of the PIC is performed with a sealed ^{226}Ra source certified by NIST in a shadow shield geometry. Conversion of exposure rate (mR h^{-1}) to absorbed dose rate in air (nGy h^{-1}) was made by multiplying by a factor of 8.76. Although the PIC has a reasonably flat energy response, small corrections are applied to account for the different energy spectra of the primary beam calibration source and that of an environmental gamma-ray field. The total systematic error due to such factors as calibration and energy response is estimated to be < 5%.

The Bicron Micro Rem Meter is calibrated with a NIST traceable 1 Ci ^{137}Cs source, and is generally assumed to be accurate to within 20%.

RESULTS

Table 2 summarizes the results of external dose rate determinations for the locations indicated. It should be pointed out that all things being equal, a determination of external dose rate is best accomplished with a PIC. Of the three methods used on this mission, a dose rate inferred from a soil sample is the least accurate and subject to the greatest uncertainties. Rem meters or survey instruments give an order of magnitude value for the dose rate, which, in several instances, was sufficient. While agreement among the various methods is generally good, there are some notable exceptions. At locations 725.2, 725.3, and 725.6 agreement between estimated dose rates from soil sampling and field spectrometric methods is excellent, but rather poor when compared to PIC measurements. We believe that the poor agreement is probably due to a malfunctioning of the PIC.

DISCUSSION

With the exception of the Lake Tchagan area and a 1 km^2 area encompassing ground zero, all the areas visited by the team had external dose rates that were within typical environmental levels. However, both field spectrometry and soil samples have shown that the dose rate on a small farm ~ 13 km from ground zero has been significantly enhanced by the presence of ^{137}Cs, ^{152}Eu, and ^{60}Co in the surface soil. In this case, the contribution from these nuclides contribute about one-third of the terrestrial dose rate. Table 8 summarizes the primary contributors to the terrestrial dose rate from all anthropogenic sources for the typically inhabited areas visited on this mission. A typical range of the dose rate value currently used for global fallout is about 1-3 nGy h^{-1}, this translates to about 1 to 5% of the total terrestrial dose rate. The results presented in Table 8 indicate that many of the towns visited are within the range of values that are typical of present global fallout.

The measurements taken within a 15 km radius of historical ground zero had elevated levels of ^{137}Cs, as well as the activation products ^{152}Eu, and ^{60}Co. The dose rate within a 1 km radius of ground zero ranged from 500 to 30000 nGy h^{-1}. The dose rate and the inventory of fission activation products decreased as we moved away from ground zero. At a distance of 20 to 25 km from ground zero, the enhancement of the ambient dose rate by ^{137}Cs is < 10% and contributions from ^{152}Eu and ^{60}Co were negligible. A location identified as a "hot spot" (50° 17.730'N, 77° 57.989'E) from a previously performed aerial gamma survey was ~ 20 km from ground zero. Soil cores, a field spectra, and a PIC measurement were taken and the results show that only ^{137}Cs could be detected and its contribution to the terrestrial dose is estimated at 1 to 2%. It is interesting to note that near ground zero the radionuclide that dominates the dose rate is the activation product ^{152}Eu. A soil sample taken approximately half a kilometer from ground zero indicated that ^{152}Eu contributes an estimated 76% of the total dose. Approximately 10 km from the location of that sample the contribution was down to just a few percent.

It should be carefully noted that the locations where our team performed measurements were supervised by officials. We observed several "technical areas," locations of which are shown in Figure 1, where the team did not perform measurements or take samples. It is quite possible that these areas may be radiologically stressed. Therefore, our samples and measurements can not be taken to be without bias, nor representative of the environmental contamination present at the Semipalatinsk nuclear test site. Additionally, with over 300 underground tests performed within the test site, the potential for ground-water contamination is a major concern. However, an assessment of the groundwater radioactivity was beyond the scope of the current team. Thus, assurances that the groundwater in the vicinity of the Semipalatinsk nuclear test site has not been radiologically contaminated have not been confirmed.

ACKNOWLEDGMENTS

This report reflects an intensive effort, not only by the scientists who served on the mission, but also other EML staff members who contributed to different aspects of this project, to carry out rigorous field work and report such unique environmental data. The authors of this report are indebted to many EML staff members for their assistance in fulfilling this mission. We are especially grateful to Kevin Miller for guidance he provided over the course of the entire project. Mr. Kevin Clancy is thanked for administrative support. We are also grateful to Catherine Klusek and Richard Godwin for the preparation of the soil samples.

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TABLE 1

SITE IDENTIFICATION GEOGRAPHICAL POSITION (GPS), DESCRIPTION OF SITES, AND MEASUREMENTS OBTAINED USING PORTABLE IONIZATION CHAMBER (PIC), HIGH PURITY *IN SITU* GAMMA SPECTROMETRY (HPGe), AND SOIL SAMPLES COLLECTED (SOIL)

Site ID	GPS	Description	PIC	HPGe	Soil
718.1	50°38.469'N 79°19.094'E	Dolok, near ferry. Bare dirt, vegetation cover ~ 0%	*		
718.2	50°39.865'N 79°18.355'E	Dolon, on side of main street. Bare dirt, vegetation cover ~ 0%	*		
718.3	50°40.034'N 79°18.542'E	Dolon, across street from administrative building, over grass, vegetation cover ~ 70%	*		
719.1	49°56.326'N 79°00.498'E	On lip of Balapan Lake ("Atomic Lake"). Zero vegetation cover. HPGe taken, but not useful.		*	*
719.2	49°56.577'N 79°06.078'E	1st State Farm Beriozka. In pasture, vegetation cover ~ 50%.	*	*	*
719.3	49°36.155'N 78°44.488'E	Sarzhal, center of town over dirt road. Vegetation cover ~ 0%.	*	*	
720.1	49°36.059'N 78°44.981'E	Sarzhal, edge of town in pasture. Vegetation cover ~ 50%.	*	*	*
720.2	49°36.330'N 78°45.549'E	Sarzhal, 1 km outside town in pasture. Vegetation cover ~ 50%.	*	*	*
720.3	49°42.781'N 78°27.817'E	~ 15 km from Sarzhal at Project Plowshare "Excavation Lake"			*
721.1	49°12.638'N 77°24.146'E	Kainar, edge of town in pasture. Vegetation cover ~ 100%.	*	*	*
721.2	49°12.651'N 77°24.218'E	Kainar, near 721.1, drainage area for 721.1. Vegetation cover ~ 100%	*	*	*
721.3	49°11.631'N 77°23.891'E	Kainar, opposite end of town in pasture. Vegetation cover ~ 100%.	*	*	
721.4	49°29.707'N 77°35.983'E	Near Polygon border, on ride back to Kurchatov. Vegetation cover ~ 100%.	*	*	
722.1	50°48.007'N 78°28.089'E	Akzhar, in the middle of town over dirt road. Vegetation cover ~ 0%.	*		
722.2	50°47.678'N 78°26.886'E	Akzhar, edge of town in pasture. Vegetation cover ~ 50%.	*		*
725.1	50°26.110'N 77°48.966'E	~ 0.5 km from GZ. In field, vegetation cover ~ 50%.		*	
725.2	50°25.810'N 77°49.502'E	1.1 km south of GZ. Field, ~ 50% vegetation cover.	*	*	*

TABLE 1 (Cont'd)

Site ID	GPS	Description	PIC	HPGe	Soil
725.3	50°26.766'N 77°48.359'E	1.1 km north of GZ. Field ~50% vegetation cover.	*	*	*
725.4	50°25.129'N 77°50.675'E	~ 3 km from GZ, surveyed with PIC and Bicron. Vegetation cover ~ 50%.		*	
725.5	50°24.799'N 77°51.188'E	~ 4 km from GZ, at site sampled by American team. Vegetation cover ~ 50%.	*	*	
725.6	50°21.898'N 77°50.660'E	Near plume, vegetation cover ~ 70%.	*	*	*
726.GZ	50°26.230'N 77°48.986'E	~ 200 m from Ground Zero			*
726.1	50°17.730'N 77°57.989'E	"Hot spot" as indicated by maps provided. Vegetation cover ~ 50%.	*	*	*
726.2	50°19.433'N 77°49.457'E	At farm near another indicated "hot spot." ~ 13 km from GZ. Vegetation cover ~ 20%.	*	*	
727.1	50°39.976'N 79°17.833'E	Outside Dolon, in pasture. Vegetation cover ~ 50%.	*	*	*
727.2	50°40.034'N 79°18.542'E	In Dolon, in middle of dirt street. Vegetation cover ~ 0%.	*	*	

TABLE 2

ABSORBED DOSE RATES IN AIR (nGy h^{-1})

Site ID	PIC	*In-situ* Spectra	Soil Sample	Other
718.1	72(1)	-	-	
718.2	69(10)	-	-	
718.3	59(4)	-	-	
719.1	-	-	-	13100 (survey meter)
719.2	77(3)	92(1)	84(1)	
719.3	82(2)	-	-	
720.1	90(5)	96(1)	96(1)	
720.2	87(2)	96(1)	95(1)	
721.1	112(4)	111(1)	120(1)	
721.2	81(4)	73(1)	71(1)	
721.3	107(5)	114(1)	-	
721.4	89(3)	96(01)	-	
722.1	77(6)	-	-	
722.2	81(2)	-	92(1)	
725.1	-	-	-	32000 (survey meter)
725.2	120(7)	138(3)	140(1)	
725.3	112(2)	149(3)	153(1)	
725.4	-	118(3)	-	
725.5	93(5)	-	-	
725.6	94(9)	117(2)	121(1)	
726.1	87(4)	-	92(1)	
726.1a	-	-	13700(28)	12000 (survey meter)
726.2	104(5)	118(4)	-	
727.1	91(2)	97(1)	89(1)	
727.2	93(4)	-	-	

TABLE 3

SOIL SAMPLE DATA AND RADIONUCLIDE CONCENTRATION (Bq kg^{-1} dry)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration (Bq kg^{-1} dry)	1σ
719.1	Area of soil core (cm^2) = 46.5:						
S-4264	0-5	1413.5	1341.8	1.62	^{241}Am	450.9	3
					^{152}Eu	8791	68
					^{154}Eu	4027	35
					^{155}Eu	146.9	4.1
					^{60}Co	6829	13
					^{137}Cs	7805	8
S-4265	5-10	826.2	776.7	1.70	^{241}Am	1056	2
					^{152}Eu	28198	52
					^{154}Eu	16156	44
					^{155}Eu	586.0	4.9
					^{60}Co	27554	17
					^{137}Cs	24783	15
S-4266	10-15	827.5	775.2	1.70	^{241}Am	669.3	2
					^{152}Eu	16898	65
					^{154}Eu	11431	54
					^{155}Eu	393.9	5.5
					^{60}Co	21836	27
					^{137}Cs	21549	15
719.2	Area of soil core (cm^2) = 46.5:						
S-4267	0-5	726.2	723.7	1.44	^{226}Ra	24.24	0.52
					^{228}Ra	17.87	0.70
					^{40}K	684.5	7.4
					^{137}Cs	6.9	0.3
S-4268	5-10	1097.5	963.0	1.51	^{226}Ra	25.57	0.48
					^{228}Ra	20.42	0.67
					^{40}K	662.3	7.8
					^{137}Cs	ND MDC 0.07	-
S-4269	10-15	1117.7	1041.7	1.49	^{226}Ra	24.94	0.48
					^{228}Ra	21.09	0.67
					^{40}K	636.4	7.4
					^{137}Cs	0.518	0.148

TABLE 3 (Cont'd)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration (Bq kg^{-1} dry)	1σ
720.1	Area of soil core (cm^2) = 46.5:						
S-4270	0-5	539.6	497.5	1.21	^{226}Ra	33.49	0.67
					^{228}Ra	26.90	0.89
					^{40}K	651.2	8.9
					^{137}Cs	72.15	0.74
S-4271	5-10	852.1	805.3	1.34	^{226}Ra	32.56	0.96
					^{228}Ra	26.97	1.33
					^{40}K	710.4	14.8
					^{137}Cs	19.98	0.74
S-4272	10-15	982.0	923.4	1.45	^{226}Ra	32.26	0.52
					^{228}Ra	23.72	0.74
					^{40}K	673.4	7
					^{137}Cs	2.220	0.370
S-4273	15-30	1369.8	1267.3	1.52	^{226}Ra	27.97	0.63
					^{228}Ra	23.64	0.85
					^{40}K	658.6	11.1
					^{137}Cs	3.811	0.259
720.2	Area of soil core (cm^2) = 46.5						
S-4274	0-5	575.6	541.9	1.17	^{226}Ra	24.24	0.52
					^{228}Ra	17.87	0.70
					^{40}K	684.5	7.4
					^{137}Cs	6.882	0.296
S-4275	5-10	697.3	643.0	1.09	^{226}Ra	25.57	0.48
					^{228}Ra	20.42	0.67
					^{40}K	662.3	7.8
					^{137}Cs	ND MDC 0.7	-
S-4276	10-15	800.9	718.3	1.29	^{226}Ra	24.94	0.48
					^{228}Ra	21.09	0.67
					^{40}K	636	7
					^{137}Cs	0.518	0.148

TABLE 3 (Cont'd)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration	1σ
						(Bq kg^{-1} dry)	
720.3	Area of soil core (cm^2) = NA						
S-4277	NA	NA	NA	1.38	^{241}Am	315774	37
					^{239}Pu	2371930	207400
721.1	Area of soil core (cm^2) = 46.5:						
S-4279	0-5	642.3	609.0	1.22	^{226}Ra	43.03	0.59
					^{228}Ra	40.81	0.81
					^{40}K	913.5	8.8
					^{137}Cs	19.35	0.37
S-4280	5-10	737.1	672.0	1.16	^{226}Ra	44.47	0.26
					^{228}Ra	43.51	0.37
					^{40}K	977.2	4.1
					^{137}Cs	3.70	0.111
S-4281	10-15	814.8	754.9	1.10	^{226}Ra	45.58	0.63
					^{228}Ra	44.14	0.93
					^{40}K	954.2	9.6
					^{137}Cs	1.036	0.222
721.2	Area of soil core (cm^2) = 46.5:						
S-4282	0-5	482.3	284.9	0.71	^{226}Ra	33.86	0.48
					^{228}Ra	29.42	0.70
					^{40}K	427.4	5.9
					^{137}Cs	51.43	0.44
S-4283	5-10	520.8	267.5	0.60	^{226}Ra	35.00	0.63
					^{228}Ra	27.12	0.93
					^{40}K	384.1	7.5
					^{137}Cs	2.368	0.259
S-4284	10-15	632.6	383.4	0.78	^{226}Ra	44.77	0.37
					^{228}Ra	38.48	0.48
					^{40}K	493.2	4.0
					^{137}Cs	0.999	0.148

TABLE 3 (Cont'd)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration (Bq kg^{-1} dry)	1σ
722.2	Area of soil core (cm^2) = 46.5:						
S-4285	0-5	666.2	643.2	1.47	^{226}Ra	26.38	0.52
					^{228}Ra	25.49	0.67
					^{40}K	734.1	8.1
					^{137}Cs	12.91	0.30
S-4286	5-10	862.6	834.9	1.41	^{226}Ra	25.97	0.52
					^{228}Ra	23.90	0.70
					^{40}K	720.4	8.3
					^{137}Cs	1.073	0.185
S-4287	10-15	926.7	895.3	1.42	^{226}Ra	25.83	0.52
					^{228}Ra	25.90	0.70
					^{40}K	715.2	8.1
					^{137}Cs	1.036	0.185
725.2	Area of soil core (cm^2) = 46.5:						
S-4288	0-5	720.1	693.9	1.65	^{226}Ra	40.70	0.74
					^{228}Ra	26.01	0.85
					^{40}K	654.9	8.5
					^{137}Cs	257.2	1.1
					^{152}Eu	18.13	1.85
					^{155}Eu	0.888	0.259
					^{241}Am	290.8	1.5
					^{60}Co	4.070	0.370
S-4289	5-10	757.0	729.2	1.50	^{226}Ra	32.75	0.48
					^{228}Ra	24.49	0.63
					^{40}K	640.1	8.5
					^{137}Cs	19.24	0.37
					^{152}Eu	7.77	1.11
					^{155}Eu	ND MDC 1.1	-
					^{241}Am	10.14	0.22
					^{60}Co	0.888	0.222

TABLE 3 (Cont'd)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration (Bq kg^{-1} dry)	1σ
725.2	(continued)						
S-4290	10-15	899.0	860.4	1.58	^{226}Ra	20.31	0.26
					^{228}Ra	26.12	0.04
					^{40}K	647.5	4.1
					^{137}Cs	4.440	0.740
					^{152}Eu	ND MDC 3.3	-
					^{155}Eu	ND MDC 0.74	-
					^{241}Am	3.108	0.111
					^{60}Co	ND MDC 0.11	-
725.3	Area of soil core (cm^2) = 46.5:						
S-4291	0-5	681.5	664.0	1.65	^{226}Ra	25.83	2.44
					^{228}Ra	28.12	0.67
					^{40}K	677.1	6.7
					^{137}Cs	334.5	1.1
					^{152}Eu	62.53	3.33
					^{155}Eu	5.291	0.259
					^{241}Am	173.2	0.7
					^{60}Co	5.254	0.407
S-4292	5-10	897.0	859.4	1.44	^{226}Ra	29.05	2.22
					^{228}Ra	29.60	0.56
					^{40}K	666.4	5.9
					^{137}Cs	62.16	0.37
					^{152}Eu	18.87	2.59
					^{155}Eu	3.959	0.259
					^{241}Am	11.84	0.37
					^{60}Co	1.258	0.222

TABLE 3 (Cont'd)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration	1σ
						(Bq kg^{-1} dry)	
725.3	(continued)						
S-4293	10-15	812.1	773.0	1.32	^{226}Ra	29.97	1.48
					^{228}Ra	29.56	0.41
					^{40}K	696	4
					^{137}Cs	18.43	0.22
					^{152}Eu	14.80	0.74
					^{155}Eu	0.37	0.07
					^{241}Am	1.665	0.111
					^{60}Co	0.814	0.185
725.6	Area of soil core (cm^2) = 46.5:						
S-4294	0-5	577.6	563.8	1.33	^{226}Ra	49.95	0.74
					^{228}Ra	28.27	0.85
					^{40}K	699.3	8.5
					^{137}Cs	162.8	1.1
					^{152}Eu	4.810	1.110
					^{155}Eu	2.183	0.222
					^{241}Am	110.6	0.8
					^{60}Co	1.258	0.185
S-4295	5-10	739.2	685.2	1.13	^{226}Ra	58.46	0.93
					^{228}Ra	30.64	0.74
					^{40}K	795.5	9.6
					^{137}Cs	9.361	0.333
					^{152}Eu	ND MDC 6.6	-
					^{155}Eu	0.629	0.185
					^{241}Am	6.512	0.296
					^{60}Co	ND MDC 0.55	-

TABLE 3 (Cont'd)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration (Bq kg^{-1} dry)	1σ
725.6	(continued)						
S-4296	10-15	792.5	717.2	1.14	^{226}Ra	58.09	0.33
					^{228}Ra	28.97	0.37
					^{40}K	747.4	4.4
					^{137}Cs	4.033	0.185
					^{152}Eu	ND MDC 3	-
					^{155}Eu	0.481	0.185
					^{241}Am	3.071	0.111
					^{60}Co	ND MDC 0.3	-
726.GZ	Area of soil core (cm^2) = 62.0:						
S-4297	0-5	880.1	838.9	1.58	^{226}Ra	20.05	2.70
					^{228}Ra	58.46	1.48
					^{40}K	773.3	18.5
					^{137}Cs	24205	100
					^{152}Eu	39220	185
					^{154}Eu	1109	25
					^{155}Eu	365.2	20.0
					^{241}Am	435.9	3.3
					^{60}Co	1650	7
S-4298	5-10	963.3	914.3	1.45	^{226}Ra	24.20	1.48
					^{228}Ra	31.19	2.07
					^{40}K	758.5	7.4
					^{137}Cs	2980	21
					^{152}Eu	30118	148
					^{154}Eu	679.3	24.8
					^{155}Eu	35.52	4.81
					^{241}Am	61.05	2.59
					^{60}Co	1100	9

TABLE 3 (Cont'd)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration (Bq/kg -dry)	1σ
726.GZ	(continued)						
S-4299	10-15	1282.7	1192.7	1.51	^{226}Ra	25.01	1.26
					^{228}Ra	29.01	2.22
					^{40}K	466.2	7.4
					^{137}Cs	1534	13
					^{152}Eu	19610	37
					^{154}Eu	311.2	11.5
					^{155}Eu	27.38	4.44
					^{241}Am	24.79	1.48
					^{60}Co	691.2	4.8
726.1	Area of soil core (cm^2) = 46.5:						
S-4300	0-5	367.6	361.4	1.50	^{226}Ra	44.84	0.07
					^{228}Ra	22.42	0.74
					^{40}K	584.6	7.4
					^{137}Cs	18.61	0
S-4301	5-10	551.5	521.1	1.24	^{226}Ra	44.70	0.07
					^{228}Ra	19.68	0.07
					^{40}K	642.0	8.5
					^{137}Cs	3.811	0.259
S-4302	10-15	526.4	468.0	1.21	^{226}Ra	46.36	0.07
					^{228}Ra	18.91	0.07
					^{40}K	605.0	7.8
					^{137}Cs	1.369	0.370

TABLE 3 (Cont'd)

EML ID	Depth (cm)	Wet wgt. (g)	Dry wgt. (g)	Dry density (g/cc)	Nuclide	Concentration (Bq kg^{-1} dry)	1σ
727.1	Area of soil core (cm^2) = 46.5:						
S-4303	0-5	455.7	448.4	1.58	^{226}Ra	20.05	0.49
					^{228}Ra	23.09	0.67
					^{40}K	700.4	8.0
					^{137}Cs	47.51	0.52
S-4304	5-10	472.7	457.6	1.59	^{226}Ra	18.39	0.33
					^{228}Ra	20.61	0.48
					^{40}K	721.9	5.9
					^{137}Cs	31.15	3
S-4305	10-15	634.1	604.4	1.60	^{226}Ra	17.87	0.22
					^{228}Ra	20.50	0.33
					^{40}K	709.3	4.1
					^{137}Cs	21.16	1.85

TABLE 4

INFERRED RADIONUCLIDE INVENTORY (kBq m^{-2})
FROM SOIL SAMPLES

Location ID	Nuclide	Relaxation mass per unit area (g cm^{-2})	Inventory (kBq m^{-2})	SD (kBq m^{-2})
719.2	^{137}Cs	8.55	1.31	0.10
720.1	^{137}Cs	6.71	6.32	0.09
720.2	^{137}Cs	5.88	4.23	0.24
721.1	^{137}Cs	9.17	3.24	0.06
721.2	^{137}Cs	3.85	3.37	0.03
722.2	^{137}Cs	11.8	2.18	0.06
725.2	^{137}Cs	6.25	42.1	0.2
	^{152}Eu	16.7	10.7	0.5
	^{155}Eu	29.4	0.44	0.23
	^{241}Am	5.08	45.5	0.2
	^{60}Co	9.62	0.77	0.07
725.3	^{137}Cs	10.0	61.7	0.2
	^{152}Eu	18.9	14.9	0.7
	^{155}Eu	21.7	1.55	0.09
	^{241}Am	6.10	27.2	0.1
	^{60}Co	15.2	1.12	0.08
725.6	^{137}Cs	6.67	21.7	0.1
	^{152}Eu	20.4	2.02	1.09
	^{155}Eu	15.2	0.43	0.05
	^{241}Am	5.32	14.9	0.1
	^{60}Co	14.9	0.27	0.09
726.GZ	^{137}Cs	10.3	4010	14
	^{152}Eu	23.3	13500	34
	^{154}Eu	18.9	310	5
	^{155}Eu	6.10	54.7	2.8
	^{241}Am	9.52	67.7	0.6
	^{60}Co	22.2	555	2
726.1	^{137}Cs	5.41	1.87	0.03
727.1	^{137}Cs	15.6	10.4	0.41

TABLE 5

INFERRED ABSORBED DOSE RATES IN AIR BY NUCLIDE ($nGy\ h^{-1}$) FROM SOIL SAMPLES

Location ID	Nuclide	Dose Rate ($nGy\ h^{-1}$)	SD ($nGy\ h^{-1}$)	Fraction of Total Terrestrial	Fraction of Total with Cosmic
719.2					
	^{226}Ra	9.76	0.33	0.20	0.12
	^{228}Ra	12.51	0.47	0.25	0.15
	^{40}K	26.42	0.55	0.53	0.31
	^{137}Cs	1.17	0.12	0.02	0.01
	Total Terrestrial	49.85	0.81		
	Total with cosmic	84.02			
720.1					
	^{226}Ra	12.61	0.57	0.20	0.13
	^{228}Ra	15.59	0.78	0.25	0.16
	^{40}K	28.36	0.61	0.46	0.30
	^{137}Cs	5.32	0.14	0.09	0.06
	Total Terrestrial	61.88	1.15		
	Total with Cosmic	96.04			
720.2					
	^{226}Ra	13.54	0.56	0.22	0.14
	^{228}Ra	16.74	0.77	0.28	0.18
	^{40}K	24.78	0.78	0.41	0.26
	^{137}Cs	5.23	0.17	0.09	0.06
	Total Terrestrial	60.28	1.24		
	Total with Cosmic	94.45			
721.1					
	^{226}Ra	17.74	0.36	0.21	0.15
	^{228}Ra	27.03	0.51	0.31	0.22
	^{40}K	38.32	0.54	0.45	0.32
	^{137}Cs	2.88	0.16	0.03	0.02
	Total Terrestrial	85.96	0.84		
	Total with Cosmic	120.13			

TABLE 5 (Cont'd)

Location ID	Nuclide	Dose Rate (nGy h^{-1})	SD (nGy h^{-1})	Fraction of Total Terrestrial	Fraction of Total with Cosmic
721.2					
	^{226}Ra	9.77	0.21	0.27	0.14
	^{228}Ra	13.26	0.30	0.36	0.19
	^{40}K	11.26	0.24	0.31	0.16
	^{137}Cs	2.14	0.10	0.06	0.03
	Total Terrestrial	36.43	0.45		
	Total with Cosmic	70.60			
722.2					
	^{226}Ra	10.75	0.37	0.22	0.13
	^{228}Ra	16.23	0.49	0.33	0.19
	^{40}K	29.66	0.58	0.59	0.35
	^{137}Cs	1.46	0.09	0.03	0.02
	Total Terrestrial	58.09	0.85		
	Total with Cosmic	92.25			
725.2					
	^{226}Ra	10.19	0.38	0.10	0.07
	^{228}Ra	16.70	0.47	0.16	0.12
	^{40}K	26.68	0.48	0.25	0.19
	^{137}Cs	37.33	0.38	0.35	0.27
	^{152}Eu	10.90	0.53	0.10	0.078
	^{155}Eu	0.01	0.01	<.0001	<.0001
	^{241}Am	1.32	0.007	0.012	0.009
	^{60}Co	2.41	0.210	0.023	0.017
	Total Terrestrial	105.56	1.03		
	Total with Cosmic†	139.7			

† Cosmic dose rate

TABLE 5 (Cont'd)

Location ID	Nuclide	Dose Rate (nGy h^{-1})	SD (nGy h^{-1})	Fraction of Total Terrestrial	Fraction of Total with Cosmic
725.3					
	^{226}Ra	13.38	0.22	0.11	0.09
	^{228}Ra	19.75	0.23	0.17	0.13
	^{40}K	27.71	0.30	0.23	0.18
	^{137}Cs	41.08	0.59	0.34	0.27
	^{152}Eu	13.80	0.63	0.12	0.09
	^{155}Eu	0.07	0.009	<.0001	<.0001
	^{241}Am	0.72	0.001	0.006	0.005
	^{60}Co	2.71	0.189	0.023	0.018
	Total Terrestrial	119.2	1.0		
	Total with Cosmic	153.4			
725.6					
	^{226}Ra	22.48	0.44	0.26	0.19
	^{228}Ra	17.77	0.45	0.20	0.15
	^{40}K	29.09	0.54	0.33	0.24
	^{137}Cs	14.85	0.23	0.17	0.12
	^{152}Eu	1.76	0.95	0.020	0.014
	^{155}Eu	0.024	0.003	<.0001	<.0001
	^{241}Am	0.42	0.003	0.005	<.0001
	^{60}Co	0.67	0.227	0.008	0.006
	Total Terrestrial	87.06	1.30		
	Total with Cosmic	121.2			
726.GZ					
	^{226}Ra	8.55	1.15	0.001	0.001
	^{228}Ra	39.03	0.99	0.003	0.003
	^{40}K	32.77	0.78	0.002	0.002
	^{137}Cs	2943	10	0.22	0.21
	^{152}Eu	10434	26	0.76	0.76
	^{155}Eu	14.5	0.3	0.001	0.001
	^{241}Am	1.46	0.07	<.0001	<.0001
	^{60}Co	214.4	2.0	0.02	0.02
	Total Terrestrial	13688	28		
	Total with Cosmic	13722			

TABLE 5 (Cont'd)

Location ID	Nuclide	Dose Rate (nGy h^{-1})	SD (nGy h^{-1})	Fraction of Total Terrestrial	Fraction of Total with Cosmic
726.1					
	^{226}Ra	18.39	0.45	0.32	0.20
	^{228}Ra	13.59	0.44	0.24	0.15
	^{40}K	24.96	0.46	0.43	0.27
	^{137}Cs	0.80	0.16	0.01	0.01
	Total Terrestrial	57.75	0.79		
	Total with Cosmic	91.91			
727.1					
	^{226}Ra	7.48	0.26	0.14	0.08
	^{228}Ra	13.41	1.02	0.24	0.15
	^{40}K	28.99	0.44	0.53	0.32
	^{137}Cs	5.16	0.56	0.09	0.06
	Total Terrestrial	55.04	1.27		
	Total with Cosmic	89.21			

† Cosmic Dose rate

TABLE 6

RADIONUCLIDE INVENTORY (kBq m^{-2}) FROM *IN SITU* SPECTRA

Location ID	Nuclide	Relaxation mass per unit area (g cm^{-2})	Inventory (kBq m^{-2})	SD (kBq m^{-2})
719.2	^{137}Cs	8.55	1.47	0.09
720.1	^{137}Cs	6.71	5.96	0.17
720.2	^{137}Cs	5.88	5.55	0.21
721.1	^{137}Cs	9.17	3.75	0.23
721.2	^{137}Cs	3.85	1.93	0.09
721.3	^{137}Cs	6.67†	3.90	0.79
721.4	^{137}Cs	6.67†	4.97	1.00
725.2	^{137}Cs	6.25	40.7	0.4
	^{152}Eu	16.7	13.8	2.4
	^{60}Co	9.62	0.53	0.18
725.3	^{137}Cs	10.0	56.1	1.7
	^{152}Eu	18.9	13.3	1.70
	^{60}Co	15.2	1.47	0.20
725.5	^{137}Cs	7.69†	27.2	4.1
	^{152}Eu	13.2†	4.95	1.53
	^{60}Co	16.9†	0.53	0.12
725.6	^{137}Cs	5.26	15.1	0.1
	^{152}Eu	20.4	2.36	1.79
	^{60}Co	14.9	0.31	0.13
726.1	^{137}Cs	5.41	0.83	0.17
726.2	^{137}Cs	6.67†	25.4	0.3
	^{152}Eu	13.2†	3.16	1.66
	^{60}Co	16.9†	0.53	0.18
727.1	^{137}Cs	15.6	9.31	1.68

† Estimated

TABLE 7

ABSORBED DOSE RATES IN AIR BY NUCLIDE (nGy h^{-1})
FROM *IN SITU* SPECTRA

Location ID	Nuclide	Dose Rate (nGy h^{-1})	SD (nGy h^{-1})	Fraction of Total Terrestrial	Fraction of Total with Cosmic
719.2					
	^{226}Ra	13.14	0.35	0.23	0.14
	^{228}Ra	15.94	0.70	0.28	0.17
	^{40}K	27.68	1.14	0.48	0.30
	^{137}Cs	1.17	0.12	0.02	0.01
	Total Terrestrial	57.93	1.39		
	Total with Cosmic†	92.10			
720.1					
	^{226}Ra	14.28	0.44	0.23	0.15
	^{228}Ra	16.29	0.70	0.26	0.17
	^{40}K	25.75	0.70	0.42	0.27
	^{137}Cs	5.32	0.14	0.09	0.06
	Total Terrestrial	61.65	1.09		
	Total with Cosmic	95.81			
720.2					
	^{226}Ra	13.49	0.35	0.22	0.14
	^{228}Ra	17.43	0.61	0.28	0.18
	^{40}K	25.67	5.26	0.42	0.27
	^{137}Cs	5.23	0.17	0.08	0.05
	Total Terrestrial	61.82	5.31		
	Total with Cosmic	95.98			
721.1					
	^{226}Ra	15.94	0.44	0.21	0.14
	^{228}Ra	23.91	0.70	0.31	0.22
	^{40}K	34.25	0.70	0.44	0.31
	^{137}Cs	2.88	0.16	0.04	0.03
	Total Terrestrial	76.99	1.10		
	Total with Cosmic	111.15			

TABLE 7 (Cont'd)

Location ID	Nuclide	Dose Rate (nGy h^{-1})	SD (nGy h^{-1})	Fraction of Total Terrestrial	Fraction of Total with Cosmic
721.2					
	^{226}Ra	9.64	0.35	0.25	0.13
	^{228}Ra	14.28	0.53	0.37	0.20
	^{40}K	12.61	0.44	0.33	0.17
	^{137}Cs	2.14	0.10	0.06	0.03
	Total Terrestrial	38.67	0.77		
	Total with Cosmic	72.83			
721.3					
	^{226}Ra	15.59	0.44	0.19	0.14
	^{228}Ra	24.79	0.70	0.31	0.22
	^{40}K	36.27	0.44	0.45	0.32
	^{137}Cs	3.48	0.53	0.04	0.03
	Total Terrestrial	80.13	1.08		
	Total with Cosmic	114.29			
721.4					
	^{226}Ra	15.68	0.26	0.25	0.16
	^{228}Ra	16.82	0.53	0.27	0.17
	^{40}K	25.05	0.44	0.40	0.26
	^{137}Cs	4.44	0.67	0.07	0.05
	Total Terrestrial	61.99	0.99		
	Total with Cosmic	96.16			
725.2					
	^{226}Ra	10.16	0.35	0.10	0.07
	^{228}Ra	15.68	0.61	0.15	0.11
	^{40}K	24.27	0.53	0.23	0.18
	^{137}Cs	37.33	0.38	0.36	0.27
	^{152}Eu	13.86	2.41	0.13	0.10
	^{60}Co	2.91	0.48	0.03	0.02
	Total Terrestrial	104.20	2.64		
	Total with Cosmic†	138.4			

TABLE 7 (Cont'd)

Location ID	Nuclide	Dose Rate (nGy h^{-1})	SD (nGy h^{-1})	Fraction of Total Terrestrial	Fraction of Total with Cosmic
725.3					
	^{226}Ra	10.95	0.37	0.10	0.07
	^{228}Ra	20.06	0.62	0.17	0.13
	^{40}K	27.24	0.58	0.24	0.18
	^{137}Cs	41.08	0.59	0.36	0.28
	^{152}Eu	12.20	2.41	0.11	0.08
	^{60}Co	3.51	0.627	0.03	0.02
	Total Terrestrial	115.0	2.7		
	Total with Cosmic	149.2			
725.5					
	^{226}Ra	11.83	0.35	0.14	0.10
	^{228}Ra	17.26	0.61	0.21	0.15
	^{40}K	25.67	0.61	0.31	0.22
	^{137}Cs	22.77	2.50	0.27	0.19
	^{152}Eu	4.98	1.54	0.06	0.04
	^{60}Co	1.41	0.38	0.02	0.01
	Total Terrestrial	83.90	3.10		
	Total with Cosmic	118.1			
725.6					
	^{226}Ra	17.70	0.44	0.21	0.15
	^{228}Ra	18.92	0.61	0.23	0.16
	^{40}K	28.21	0.61	0.34	0.24
	^{137}Cs	14.85	0.23	0.18	0.13
	^{152}Eu	2.37	1.80	0.03	0.02
	^{60}Co	0.82	0.40	0.01	0.01
	Total Terrestrial	82.86	2.10		
	Total with Cosmic	117.0			

TABLE 7 (Cont'd)

Location ID	Nuclide	Dose Rate (nGy h⁻¹)	SD (nGy h⁻¹)	Fraction of Total Terrestrial	Fraction of Total with Cosmic
726.1					
	^{226}Ra	14.63	0.35	0.29	0.17
	^{228}Ra	12.61	0.53	0.25	0.15
	^{40}K	22.95	0.53	0.45	0.27
	^{137}Cs	0.80	0.16	0.02	0.01
	Total Terrestrial	51.00	0.84		
	Total with Cosmic	85.16			
726.2					
	^{226}Ra	16.47	0.35	0.20	0.14
	^{228}Ra	16.99	0.61	0.21	0.15
	^{40}K	23.56	0.53	0.28	0.20
	^{137}Cs	22.57	3.02	0.27	0.19
	^{152}Eu	3.18	1.67	0.04	0.03
	^{60}Co	1.41	0.58	0.02	0.01
	Total Terrestrial	84.18	3.61		
	Total with Cosmic	118.3			
727.1					
	^{226}Ra	19.53	0.44	0.30	0.20
	^{228}Ra	15.59	0.61	0.24	0.16
	^{40}K	27.33	0.61	0.42	0.27
	^{137}Cs	3.31	0.14	0.05	0.03
	Total Terrestrial	65.77	0.98		
	Total with Cosmic	99.93			

† Cosmic dose rate estimated

TABLE 8

FRACTION OF TOTAL DOSE RATE FROM ANTHROPOGENIC SOURCE FOR SEVERAL TOWNS

Site ID	Location	Fraction of Total Terrestrial Dose Rate from Anthropogenic Sources
719.2	Berioska	0.02 (^{137}Cs)
720.1	Sarzhal	0.09 (^{137}Cs)
720.2	Sarzhal	0.08 (^{137}Cs)
721.1	Kainar	0.04 (^{137}Cs)
721.2	Kainar	0.06 (^{137}Cs)
721.3	Kainar	0.04 (^{137}Cs)
722.2	Akzhar	0.09 (^{137}Cs)
726.2	Farm	0.33 (0.27 ^{137}Cs, 0.04 ^{152}Eu, 0.02 ^{60}Co)
727.1	Dolon (soil)	0.05 (0.09) (^{137}Cs)

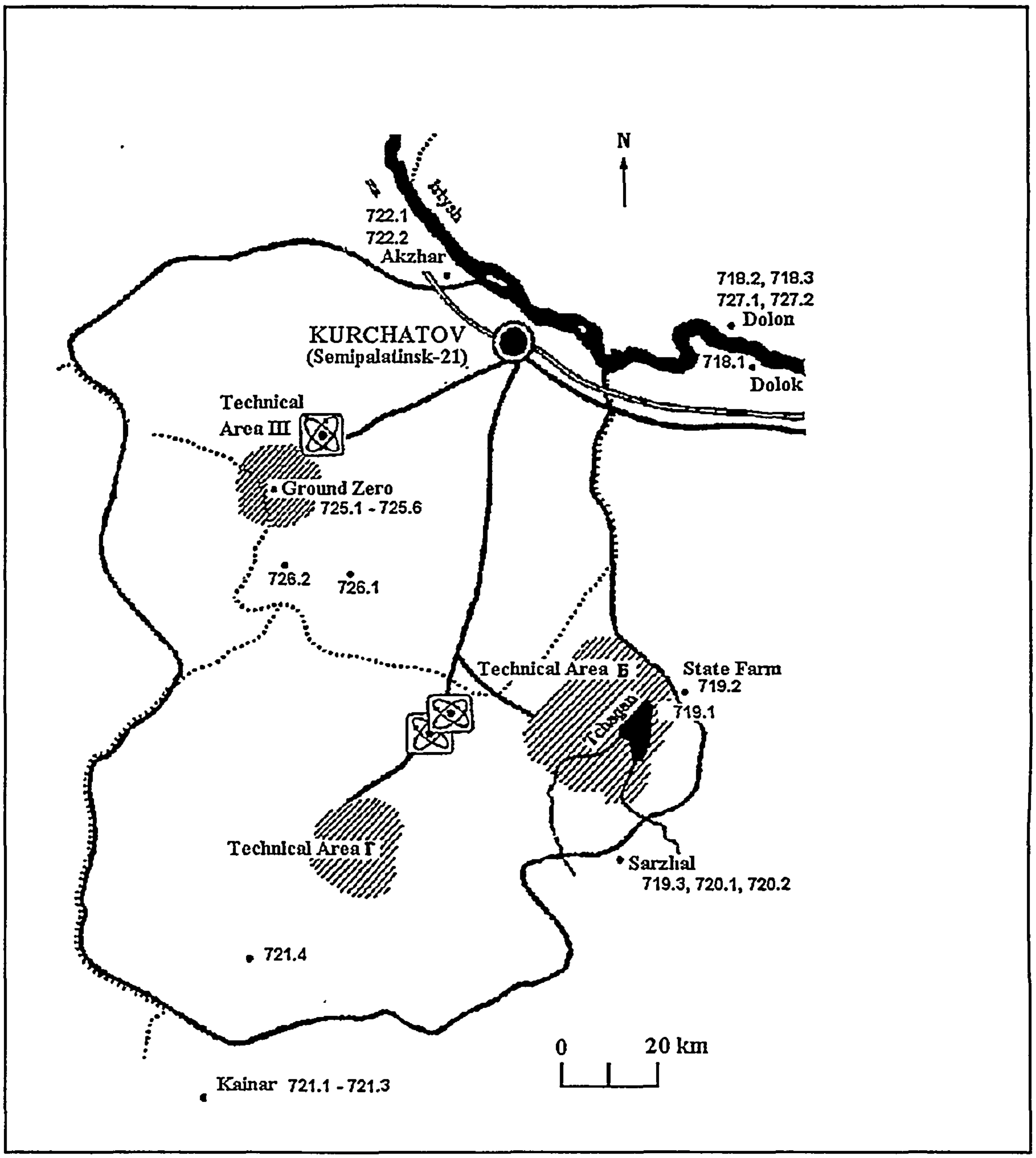

Figure 1 Map of sampling locations. Numbers refer to site identifications described in Table 1.

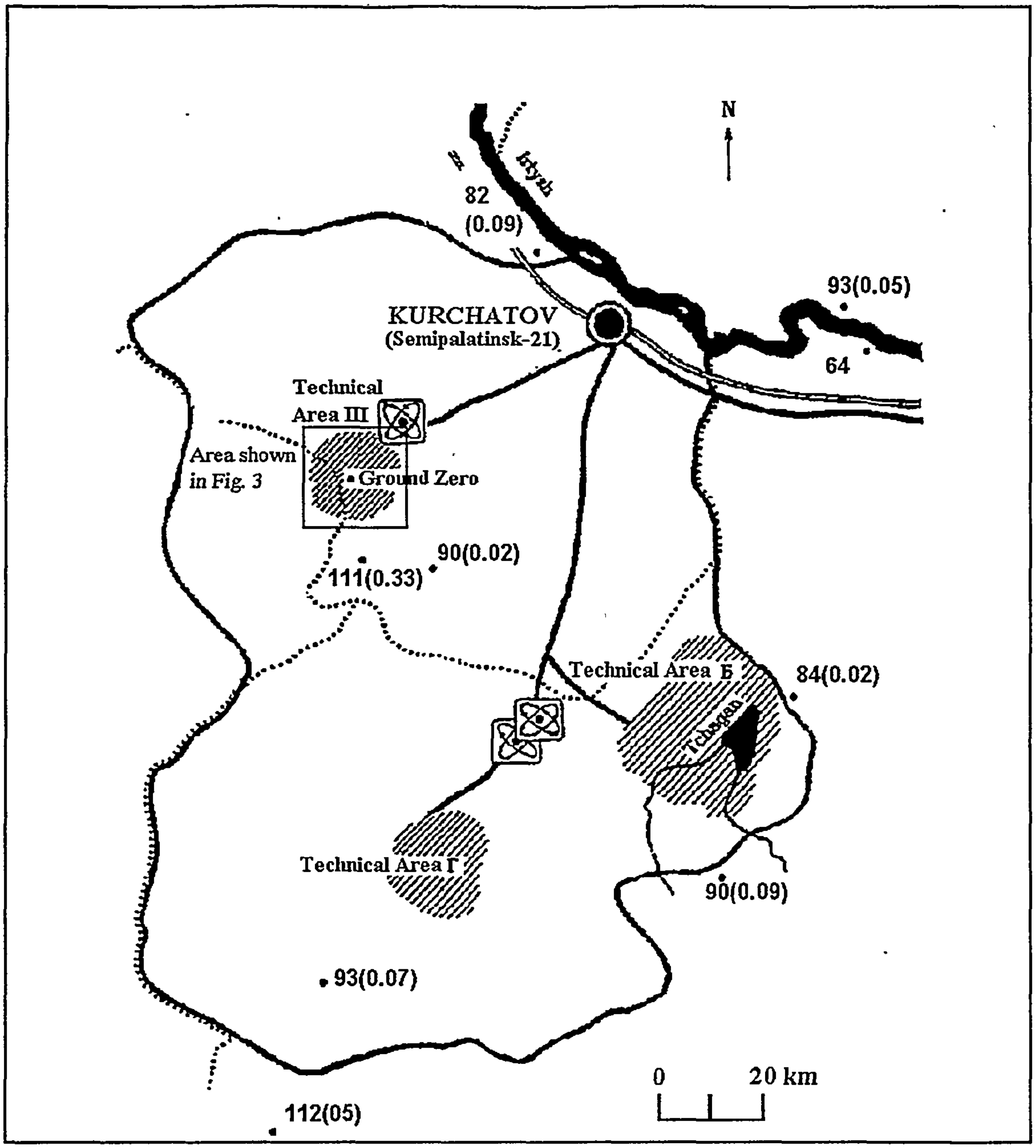

Figure 2 Map (excluding area surrounding ground zero) of absorbed dose rates in air in nGy h^{-1} of sites visited. Values are averages from pressurized ionization chamber measurements, in situ gamma spectrometry measurements, and analyses of soil samples. In parentheses is the ratio of the anthropogenic contribution to the given absorbed dose rate.

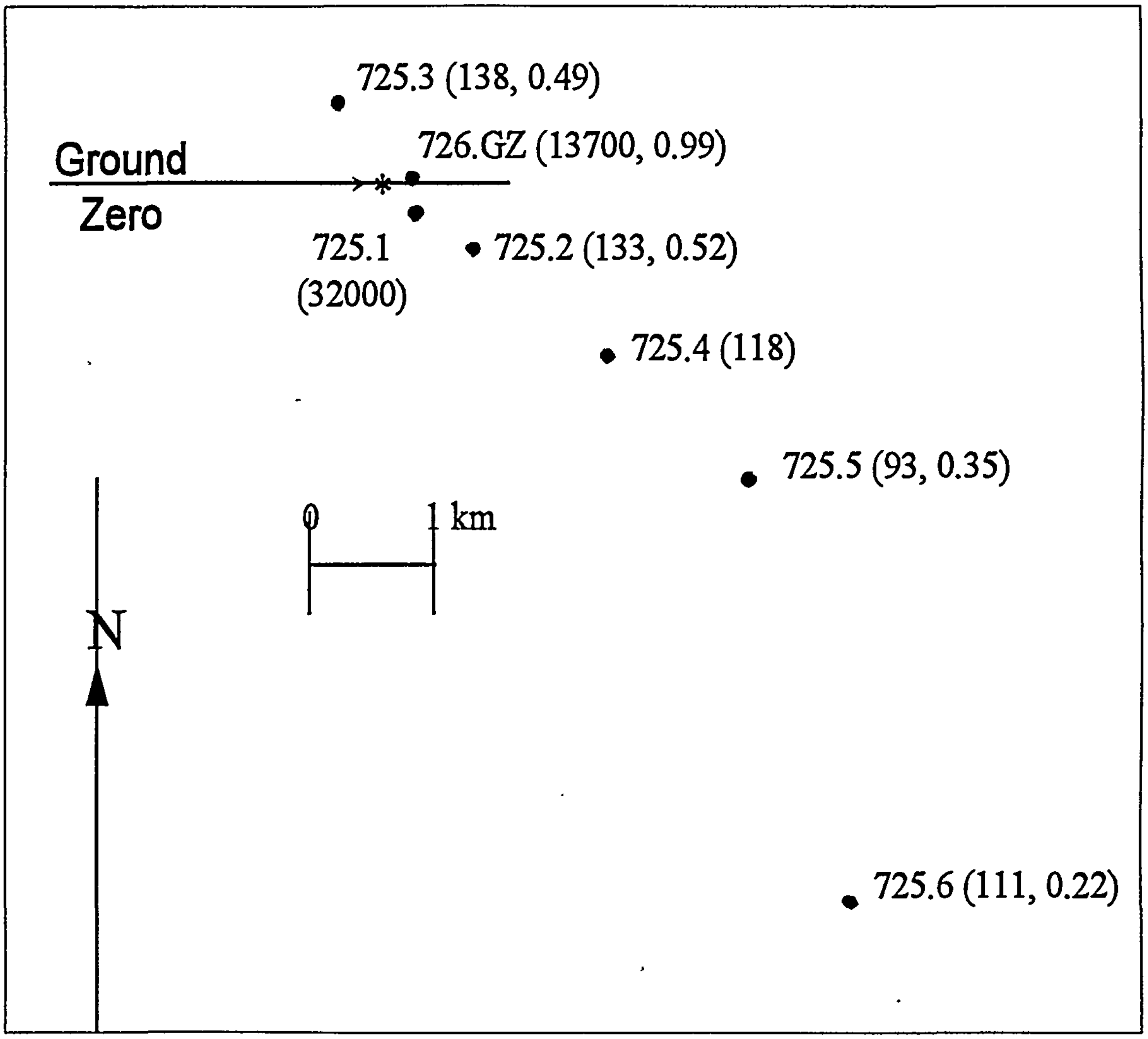

Figure 3 Map of area surrounding ground zero showing location ID's (refer to Table 1 for description). The first value in parentheses is an average value of absorbed dose rates in air in nGy h^{-1} from pressurized ionization chamber measurements, in situ gamma spectrometry measurements, and analyses of soil samples, where available (see Table 1). The second value in parentheses, where available, is the ratio of the anthropogenic contribution to the given absorbed dose rate.

APPENDIX

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