Restoration and Assessment of the Extent of Contamination of the National Radioactive Waste Storage and Disposal Centre in Tajikistan - 11481

Nazirzhon T. Buriev*, Dzhamshed A. Abdushukurov* and Tjalle T. Vandergraaf**

* Physical-Technical Institute of the Academy of Sciences of the Republic of Tajikistan, Dushanbe, Tajikistan
** Providence College, Otterburne, Canada

ABSTRACT

The National Radioactive Waste Storage and Disposal Centre (Republican Point of Burial for Radioactive Waste [RPBRW in Tajik]) was established in 1960 in the Faizabad region, which is approximately 50 km east of the capital, Dushanbe. The site is located in a sparsely populated area of the Gissar Valley. The nearest villages are located a few km from the site. The site was designed and built to accept a wide range of contaminated materials, including obsolete smoke detectors, sealed radioactive sources, waste from medical institutions, and radioactive liquids.

Between 1962 and 1976, 363 tonnes and 1146 litres of material, contaminated with a range of radionuclides, were shipped to the site. Between 1972 and 1980 and between 1985 and 1991, ~4.8 x 10^{14} and 2 x 10^{13} Bq, respectively, were shipped to the site. An additional 7 x 10^{14} Bq was shipped to the site in 1996. Partly as a result of the dissolution of the former Soviet Union, the disposal site has fallen into disrepair and currently presents both an environmental hazard and a potential for the proliferation of radionuclides that could potentially be used for illicit purposes.Remediation of the disposal site was started in 2005. New security fences were erected and a new superstructure over an in-ground storage site was constructed. A central alarm monitoring and observation station has been built.

Information on the geology, flora, and fauna of the region has been compiled. Radiation surveys of the buildings and the storage and disposal sites have been carried out. Samples of soil, surface water and vegetation have been collected and analyzed by gamma spectrometry. Results show a slight extent of contamination of soils near the filling ports of the underground liquid storage container where a ^{137}Cs concentration of 2.3 x 10^4 Bq/kg was obtained. Similar values were obtained for ^{226}Ra. Radiation fields of the in-ground storage site were generally <1 μSv/h with 8% exceeding this value. Neutron radiation levels at the same location were also low with a few reading exceeding 10 μSv/h. No contamination was detected in any of the flora sampled. Recommendations for future action are presented.

INTRODUCTION

The National Radioactive Waste Disposal Centre was established in Tajikistan in 1960 by order of the Council of Ministers of USSR for industrial and medical radioactive waste from its capital, Dushanbe. The Centre is located.in the Faizabad region, 44 km east of Dushanbe in the foothills of the Gissar Ridge. The site is located in a sparsely populated area of the Gissar Valley. The nearest villages are located a few km from the site. The site was designed an built to accept a wide range of contaminated materials, including obsolete smoke detectors, sealed radioactive sources, waste from medical institutions, and radioactive liquids. In 1976, the Centre became the storage and disposal site for the entire country. The site encompasses 71 hectares, of which 6 hectares are set aside as fenced controlled and restricted zones (Fig.1). The blue cross-hatched area is the observation zone; the smaller area in red is the fenced-off area. The centre was renamed "Republican Point of Burial Radioactive Waste" (RPBRW) in 1990.

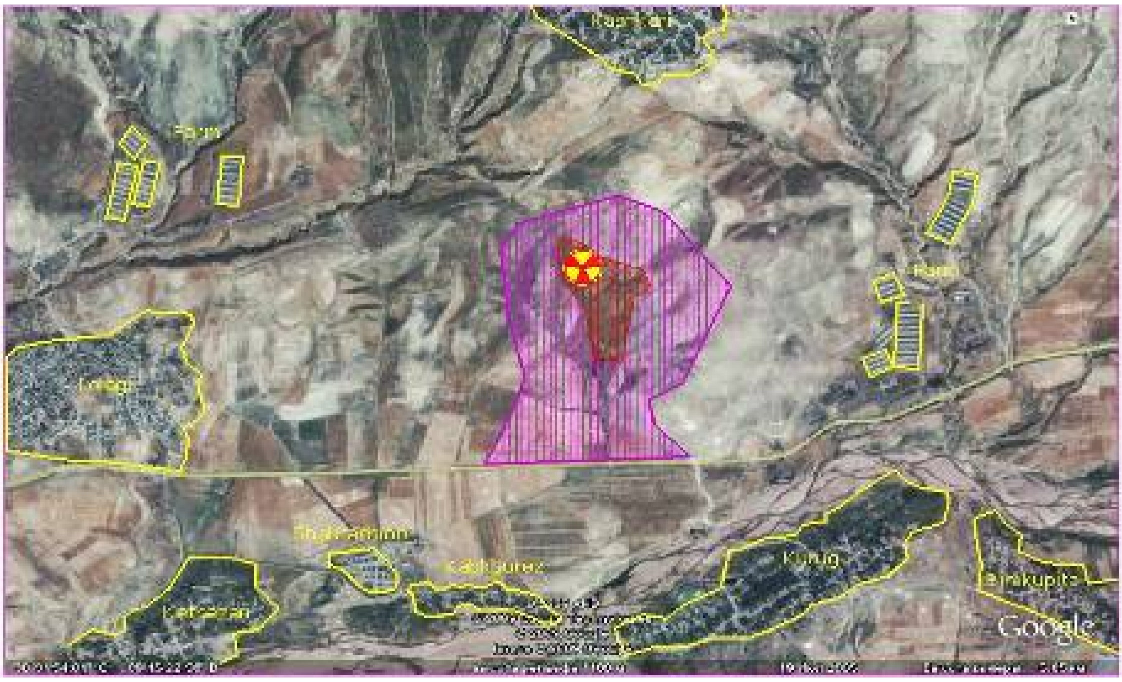


Figure 1. Location of the RPBRW relative to local communities. The map covers an area of 5.3 x 3.4 km. The capital of Tajikistan, Dushanbe, is located 44 km west of the RPBRW site

A layout of the buildings on the RPBRW site is shown in Fig. 2.

Figure 2. Location of the RPBRW facilities inside the restricted zone. The structures inside the restricted zone are defined in the text. The small numbers indicate sampling locations.

The restricted zone includes the following facilities:

1 - Combined Solid and Liquid Radioactive Waste (SRW and LRW) Storage Facility
2 – Solid Radioactive Waste (SRW) Storage Facility
3 – Liquid Radioactive Waste (LRW) Storage Tank
4 - Biological Radioactive Waste (BRW) Storage Facility
5 - High Level Waste (HLW) Storage Facility
6 - Solid Radioactive Waste (SRW) Disposal Site
7 – Contaminated Soil Burial Site

8 - Concrete Storage Site
9 - Personnel Decontamination Building;
10 - Special Transport Decontamination Building;
11 – Reception Area for Radioactive Waste Containers;
12 – Location for the Central Alarm Monitoring and Observation Station (now completed)

GEOGRAPHY

The RPBRW is situated in the Faizabad District, 44 km east of Dushanbe, and 1.5 km north of the highway that links Faizabad to Dushanbe. The region is mainly agricultural and, hence, relatively sparsely populated. The nearest villages include Lolagis, ~3 km west of the RPBRW, Kashkari, ~2 km to the north, and the district center Faizabad ~7 km to the east. Lolagis and Kashkari contain poultry plants. A few small villages, Katnazari, Shakhtachiyon, Kabkgurez, Kurug and Binikupita, are located on the other side of the Ilyak River to the south of the RPBRW. A small underground spring, located 2 km north of the site, provides water to the mountain village of Kashkari. The Faizabad district lies east of the Kafirnigan River, in the Gissar Valley. This valley stretches ~70 km from east to west and is bordered by the Gissar Ridge on the west, the Gissar and Karategin Ridges on the north, and the Badakhshan Ridge to the east. A vast region of low mountains forms the southern boundary of the Gissar Valley.

A typical feature of this area is the explicit asymmetrical structure of small, parallel ridges. Orographically, these low altitude (1000- 2000 m) ridges are the extension of the Karategin Ridge, from which it is separated by the relatively shallow Kafirnigan River valley.

TOPOGRAPHY AND GEOLOGY

Topographically, the RPBRW is located in an area with low hills that are cut by shallow canyons, which may contain streams with low hydraulic gradients (Fig. 3). The RPBRW is situated on the south slope of a gently sloping hill at an elevation of 1120 to 1220 m. Lithologically, the area consists of loamy soils ranging in thickness between 5 and 30 m and of diluvial sediments bearing small and big limestone fragments with loamy aggregates. The parent rocks are represented by the dense palaeogenic limestones. The local topography controls the flow of rainwater and melt water from snow, which moves from the RPBRW via deep ravines and into the Ilyak River valley and from there into the Kafirnigan River. The combination of the topography and the precipitation rate results in periodic runoff with rainwater pooling in shallow depressions. However, most of the rain and snow tends to be absorbed by the soil. Little is known about groundwater flow, but it can be assumed that the groundwater eventually reaches the Ilyak River, approximately 2 km from the site.

Outcroppings of highly brecciated and fissured palaeogenic limestones lie to the north and northeast of the RPBRW. These outcroppings are bridged over by quaternary sediments to the south and west. In general, there are diluvial and proluvial sediments – loess-like argillaceous sand grounds with bands, pockets and inclusions of coarse rock fragments, alluvial cones (diluvial and proluvial terrains) that are composed of limestone arena and lumps, slightly rolled boulders, breakstone, fragments of sandstones and siltstones, marl with loamy aggregates from the chalk and palaeogenic era, as well as of coarse rock fragments that consist of limestones, slates, and granites of the palaeozoic era with clay and loamy aggregates. Seismically, the region in which the RPBRW is located is a highly active seismic region, Zone 5, and earthquakes with a magnitude of 9 on the Richter scale can be expected [1].

Figure 3: Topography of the Region. The structure to the right is the newly erected cover for the Solid Radioactive Waste Disposal Site.

METEOROLOGY AND CLIMATE

The climate in Tajikistan is continental with large seasonal and daily variations of both temperature and humidity. According to the information supplied by the meteorological station of the Hydrometeorology Service of Tajikistan at Faizabad, the average air temperature, measured over the past 68 years, is 12.8°C. The average temperature in January, the coldest month, is 0.4°C. The average minimum air temperature is -4.3°C, but readings as low as -26°C have been recorded. Daytime temperatures may reach 15°C during the winter. The frost-free period is 230 days. The average daytime temperature in July is 25.5°C but temperatures of 41°C have been recorded. The average nighttime temperature in the summer is ~17°C but can drop as low as 6°C. The average humidity is 51%.

The annual precipitation is 841 mm, with most of this falling in March and April (~55%) and in the winter (30%). The summers and autumns are generally dry, with only 3-12% precipitation falling during these seasons. Snow tends to fall from end November through early March and may accumulate to up to 26 cm, although the average depth is 11 cm. The prevailing winds in the RPBRW are from the northeast. The average monthly wind velocity ranges from 1.6 to 6.7 m/s but, because of the mountainous environment, wind velocities may reach values up to 26 m/s with a once-per-20-year occurrence of 36 m/s (130 km/h).

FLORA AND FAUNA

The vegetation at the RPBRW and surrounding area is varied and benefits from ample precipitation. The most common grasses include orchard grass (*Dactulis glomerata*), smooth brome (*Bromus inermis*), meadow grass (*dasas*), diego (*diego*), dandelion (*Taraxacum officinale*), hypericum (*Hypericum perforatum*), wheatgrass (*Agropyron trichophorum*), prangos (*Prangos pabularia*), and other wild herbs. Trees include hawthorn (*Crataegus pontica*), pistachio (*Pistacia vera*), baldjuan wormwood (Artemisia *balbshuanica*), thorny almond (*Amygdalus spinosissima*), apricot (*Prunus armeniaca*), wild apple (*Malus sieversii*), maple (*Acer regelii*), common acacia or locust tree (*Robinia pseudoacacia*) and Oriental Planetree (*Platanus orientalis*). Bushes are represented by wild plum (*Prunus sogdiana*) and dog rose (*Rosa canina*). Both wild and cultivated grapes (*Vitis vinifera*) grow within the restricted zone. No grass cutting or grazing is allowed in the restricted zone and in the northern section of the controlled zone. However, mowing is allowed in the southern part of the controlled zone. Lack of grazing has resulted in a lush grass cover on the site.

Mammals in the region include Porcupine (*Hystrix leucura Sykes*); Turkestan rat (*Rattus turkestanicus satunin*), House mouse (*Mus musculus L.*), Field vole (*Microtus arvalis Pallas*), Hare (*Lepus tolai buchariensis Ognev*), Northern mole vole (*Ellobius talpinus Pallas*), and Red or Common fox (*Vulpes vulpes*). Of these, the porcupine is probably of most concern in the context of the spread of contamination because it lives in burrows and roots into the soil for bulbs and roots. This activity can result in the spread of radioactive contaminants. Rats and mice as less of a problem in that respect. In addition to the mammals, turtle, non-poisonous and poisonous snakes and lizards are found in the area. Birds include Eurasian tree swallows (*Passer montanus*), Laughing doves (*Stigmatopelia cambayensis ermanni*) and Indian myna (*Acridotheres tristis*). During the winter, rock partridges (*Alectoris graeca Meisner*) migrate from higher elevations.

HISTORY

During the Soviet era, Tajikistan was one of the Soviet Socialist Republics. With the breakup of the Soviet Union is 1991, Tajikistan became an independent republic. Civil unrest between 1992 and 1997 claimed 20,000 lives and led to the displacement of 600,000 people. [2] As the result of the breakup of the Soviet Union and the subsequent unrest, much of the information regarding the identity and quantities of the radioactive material has become lost. A considerable amount of research, including interviews with staff from the disposal centre has uncovered a substantial amount of information, although data on wastes disposed of prior to 1970 are limited to volumes and mass of wastes. [2]

GOALS OF THE PROJECT

The current project has two major goals: (1) to identify the wastes stored or buried at the disposal site and (2) to assess the extent of the contamination of the site. An ancillary goal is to improve the security of the site in light of the current political situation in the countries bordering Tajikistan.

IMPROVEMENTS IN SECURITY

Considerable concern was expressed during the early 1990s that the wastes stored at the Centre could be removed by terrorist groups and used in the construction of "dirty bombs." This concern led to an initiative by the International Atomic Energy Agency (IAEA) to embark on a program to secure the facilities. This program includes the construction of a structure to cover the solid, low-level, disposal trenches, the erection of a perimeter security wall around the controlled and restricted zones, and a Central Alarm Monitoring and Observation Station. The perimeter wall is equipped with motion detectors and video cameras. Information from this facility is sent by radio waves to Dushanbe and then to the IAEA headquarters in Vienna via satellite.

RADIONUCLIDE INVENTORY

One burial site contains 363 tonnes of low-level waste with a volume of 362 m^3 that was buried between 1972 and 1976, but, other than the isotopic composition, no other data is available. Isotopes such as P-32 and S-35 have decayed since that time, and the activity of Sr-90 has decayed by a factor of two. A further 1150 litres of liquid waste was shipped to the disposal site and placed in an underground liquid storage tank. A total of 341 TBq was buried at another location at the site between 1970 and 1980, but there is no information on the isotopic composition of this waste. Most of the radioactivity originated from the Oncological Health Centre in Dushanbe. A further 11 TBq was buried between 1985 and 1991, with 54% of the activity due to Cs-137 and 18% due to Co-60. Information on wastes sent for disposal between 1991 and 2008 is also incomplete with some waste characterized only by isotopic composition and radiation levels, typically <1mR/h with the exception of one shipment containing Sr-90 with a radiation level of 750 mR/h. Where information on the activity of the shipments was reported, a total of 8 TBq was buried, mainly as Sr-90 and Cs-137.

ASSESSMENT OF THE EXTENT OF CONTAMINATION

Experimental

Prior to embarking on a sampling campaign, sampling methods were adopted from existing documentation or developed if no previous methods were available. These documents were written in Russian and subsequently translated into English. The following documents were prepared:

- Procedures for sampling of soil and silt, their packaging, marking, transportation, preparation for study and storage
- Procedures for sampling vegetation, their packaging, marking, transportation and storage
- Procedures for sampling of water, precipitation, runoff waters and other liquids, their packaging, marking, transportation, preparation for study and storage
- Procedures for swab samples from the metallic, painted and other smooth and hard surfaces
- Procedures for radiation survey of the site area and buildings
- Procedures for sampling from liquid radioactive waste tank

Common to these procedures is a strict protocol for sample control and identification. Samples were identified as to location, type of material, coordinates, date, and depth.

Sampling

A total of 243 samples were taken in 2009, 5 samples from the controlled zone, 99 from the observation zone, 117 from the restricted zone and 22 background samples from the Varzob Gorge located ~50 km north of Dushanbe. These samples comprise 196 soil samples, 22 vegetation samples, 13 rainwater and snow samples, 5 silt samples from ponded water, and 3 samples from the liquid waste tank (1 sediment sample and 2 samples from the airspace above the liquid in the tank). The samples were packaged, labelled and sent to the Physical-Technical Institute (PTI) of the Academy of Sciences of the Republic of Tajikistan in Dushanbe for radiometric analysis.

Because of the limited access to electrical services, a manual tire pump, modified to act as a vacuum pump, was used to obtain gaseous, liquid, and solid samples from the Liquid Waste Storage (LWS) tank (No 3 in the restricted area; Fig. 2). Samples were withdrawn from the storage tank into 5-L steel cylinders using an evacuated compressed air tank. The arrangement is shown in Fig. 4.

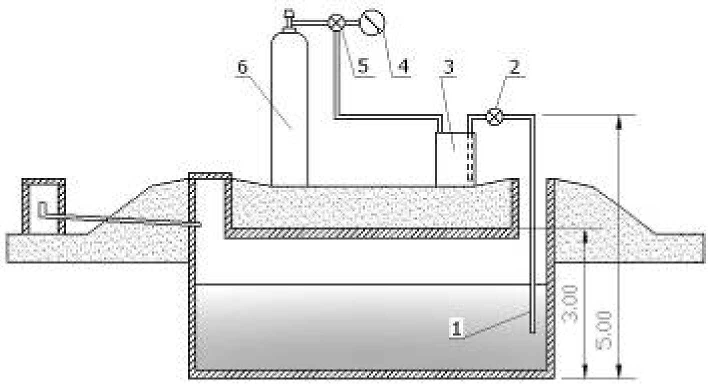


Figure 4. Arrangement to withdraw gaseous, liquid, and solid samples from the underground liquid waste storage tank

Radiometric Analysis

The geological samples were dried, and, if required, ground with a mortar and pestle, sieved, and weighed into 100-ml Marinelli beakers. The samples were analyzed using a Canberra GGX 1020 high-resolution gamma spectrometer. The spectral resolution of this detector is 0.9kev full-width half maximum (FWHM) over a range of 40-120keV, and ~2keV at 1330 keV. Total beta activity on swiped samples was counted using a portable universal radiometer.

Radiometric Surveys

The neutron and gamma radiation fields at the sites where wastes were buried, in buildings and in the observation, controlled, and restricted zones were surveyed using an ICP RM1401 K-01 and an MKS-A033 gamma/neutron detector. Each burial location and the surfaces or each structure were surveyed using a route with a pitch of 5 m, with the exception of the ports to the liquid waste tank where the entire ports and surrounding area were surveyed more closely. Field surveys in the controlled and observation zones were surveyed at a pitch of 10 m and 20 m, respectively. Along the roads, surveys were taken every 5 metres.

All surfaces in the buildings were swiped using damp tissues; these tissues were submitted for beta analysis.

RESULTS AND DISCUSSION

Radiometric Analysis

Of the 243 samples collected during the course of this investigation, 237 were analyzed for total beta activity and 173 by gamma spectrometry. Lack of a reliable and stable supply of liquid nitrogen has impacted the gamma spectrometric analyses.

Beta Counting

Three samples showed much higher total beta counts than average. These samples consisted of leaves from an acacia tree growing in the vicinity of the SRW Storage Facility (No. 2 in Fig. 2). However, a gamma spectrum of this sample showed only low concentrations of Pb-214, Bi-214, Pb-212 and Tl-208, members of the U-238 and Th-232 decay chains. This suggests that the contamination may be due to a pure beta-emitter, most likely Sr-90 and that there is evidence that the buried wastes are being leached by groundwater. If this is indeed the case, there is a high probability that this contamination can then be spread by wind. Plans are underway to take additional samples of nearby growing acacia trees. The other two samples that showed much higher than average beta activity were soil samples taken from near the inlet for the LWS underground storage tank (No. 3 in Fig. 2). One of these two samples showed an elevated Cs-137 activity (22 700 Bq/kg) and the other a lower, but still appreciable, Cs-137 activity (2 500 Bq/kg). This second soil sample also showed the highest concentration (13,300 Bq/kg) of Ra-226 and its daughters. Excluding the three samples with the highest beta activity, the mean of the beta measurements was 721 ± 543 Bq/kg.

Gamma Spectrometry

The results obtained by gamma spectrometry are shown in Table 1. The maxima, minima, and mean were calculated using all the data; outliers were not discarded.

<u>Be-7</u>

Beryllium-7 is a cosmogenic isotope with a half life of 53 d and is formed in the upper atmosphere. It can be transported from the upper atmosphere to the Earth's surface by air currents, especially in mountainous regions. [3] With one exception, the samples with the highest Be-7 concentrations (270 - 880 Bq/kg) were those of vegetation taken from the SRW Storage Facility (No. 2 in Fig. 2). The exception was one sample of vegetation from the Varzob region that showed a Be-7 concentration of 360 Bq/kg. Although interesting, these results do not change the assessment of the radionuclide inventory of the RPBRW.

K-40

The samples with the highest K-40 concentrations (~1000 Bq/kg) were also those of vegetation taken from the SRW Storage Facility (No. 2 in Fig. 2).

Cs-137

The highest Cs-137 concentration (22,700 Bq/kg) was found soil sampled near the inlet of the LWS underground storage tank. Six other soil samples from the same area showed Cs-137 concentrations ranging from 300 to 8,500 Bq/kg, and one sample of moss taken from the Observation Zone contained 240 Bq/kg.

Table I: Results from Radiometric Analyses in Bq/kg.

	Isotope	Max.	Min.	Mean
U-238 series	Th-234	248	16.0	50±15
	Ra-226	13300	0.28	165±378
	Pb-214	5363	0.02	96±483
	Bi-214	4756	0.03	87±433
	Pb-210	10730	0.27	226±344
Th-232 series	Ac-228	237	0.10	53±31
	Pb-212	249	0.03	43±21
	Tl-208	266	0.02	34±12
Anthropogenic	Co-60	0.89	single value	
	Cs-137	22700	0.03	34±120
Natural	Be-7	880	0.15	85±123
	K-40	10300	0.18	667±164
	U-235	30	1.90	3.3±1.2

U-series Radionuclides

The highest concentrations of Ra-226 were found in the soil samples taken from the inlet of the LWS underground storage tank. These samples also showed the highest activity of the daughters of this isotope, Pb-214, Bi-214, and Pb-214. However, these isotopes show various degrees of disequilibria suggesting that some migration in the soils has taken place, most likely by flowing groundwater.

Th-series Radionuclides

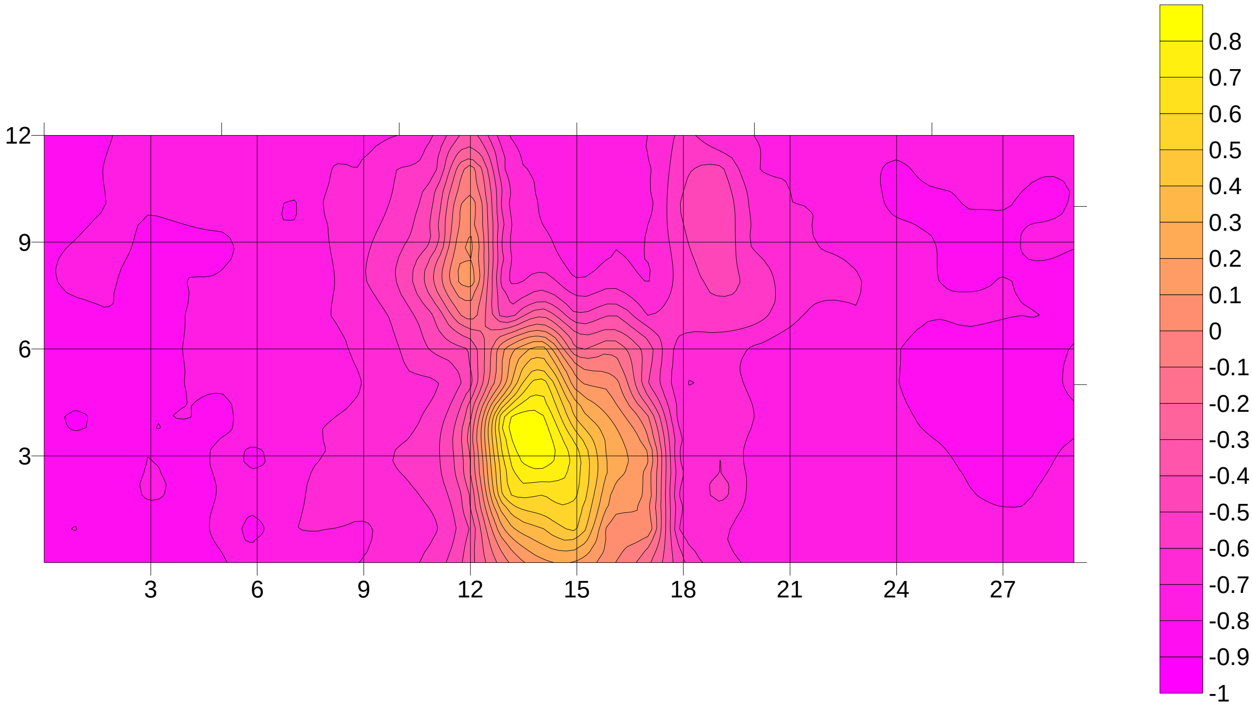
The only appreciable concentration of Th-232 daughters was found in a soil sample taken from the SRW Storage Facility. It contained ~250 Bq/kg Ac-228 and similar concentrations of Pb-212 and Tl-208 suggesting that these isotopes are in equilibrium with each other.

Liquid Storage Tank

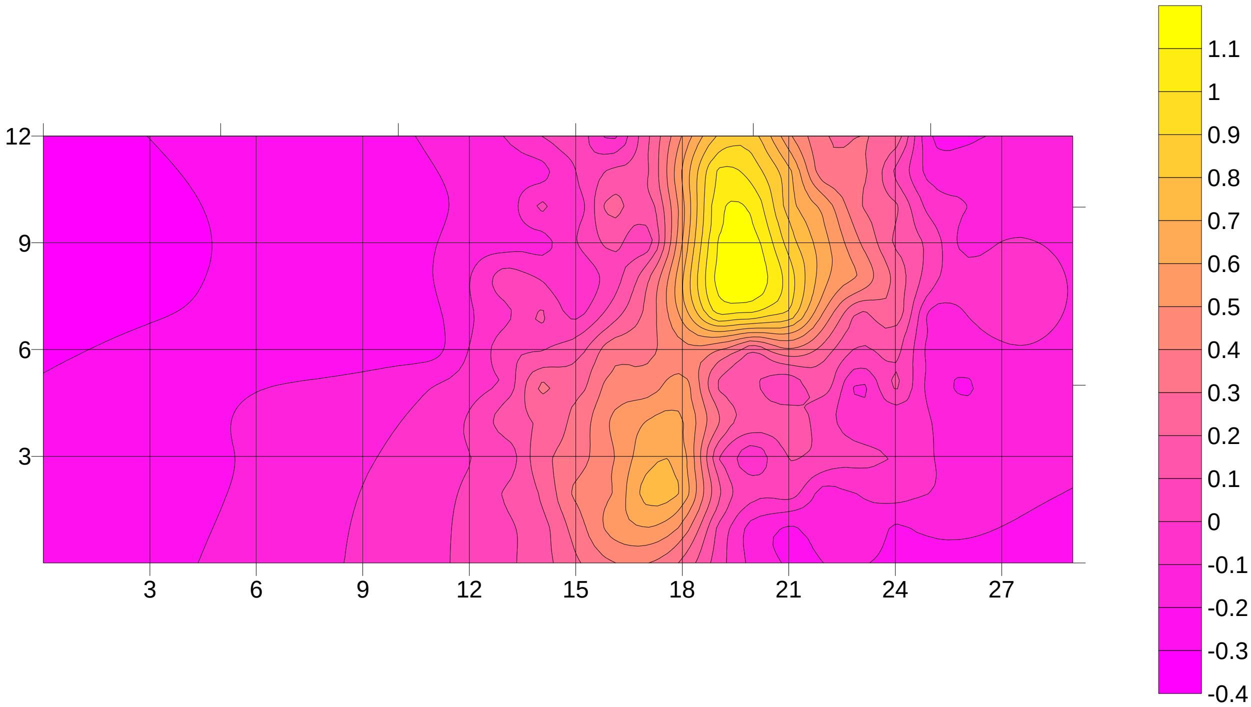
The activity of the liquid in the LWS underground storage tank was surprisingly low. U-series and Th-series daughter concentrations were <500 Bq/l. The average Cs-137 activity in the liquid was 1580 Bq/l. The Cs-137 activity in the sediment was 6780Bq/kg. Based on an estimated 5-cm thick sediment layer, the total Cs-137 inventory in the LWS tank is $<3 \times 10^8$ Bq. The sediment also contained appreciable concentrations of U-series daughters.

Radiometric Surveys

The results from gamma radiation surveys taken at the floor of the combined storage facility for solid and liquid radioactive waste (No. 1 in Fig. 3) showed a maximum reading of 7.6 μSv/h. Of the 348 readings taken, 8% exceeded 1.0 μSv/h; 68% of the readings were in the range 0.2-0.3 μSv/h. The spatial distribution is shown in Fig. 5a but is plotted as the logarithm of the radiation measurement to show some detail in the regions with low radiation. The contour plot for the neutron field is shown in Fig. 5b. The maximum observed radiation was 15 μSv/h. A comparison between the two contour plots clearly shows that the waste with the highest gamma activity is not at the same location as the neutron-emitting waste.



(a)



(b)

Figure 5. Contour plots of the gamma and neutron radiation fields measured on the floor of the combined solid and liquid storage facility in μSv/h. The contour plots for the gamma and neutron fields have been plotted as the *logarithm* of the radiation fields to show detail in regions with low radiation.

Similar surveys were performed for the SRW facility (Number 2 in Fig. 2). The maximum gamma and neutron radiation levels were 14.5 μSv/h and 13 μSv/h, respectively.

The radiometric survey of the field above the buried LWS tank (No 3 in Fig. 2) supports the radiometric information obtained on soil samples taken from around the inlet port. Whereas the gamma radiation for most of the area above the tank did not exceed 0.13 μSv/h, readings of up to 0.75 μSv/h were obtained near the inlet.

The gamma radiation field in the restricted, controlled, and observation zones ranged from 0.09-0.14 μSv/h, suggesting no significant contamination.

CONCLUSIONS

1. With the exception of the area around the inlet of the liquid waste storage tank, where elevated concentrations of Cs-137 and of members of the Ra-226 decay chain were found, and in one sample of tree leaves that showed and elevated beta activity, no contamination was found in and around the RPBRW site.
2. No radiation above background was observed in the restricted, controlled, and observation zones of the RPBRW site.
3. The presence of a large concentration of a pure beta emitter in a sample of acacia tree leaves is a concern because this material can easily become airborne and can be spread beyond the RPBRW site.
4. The liquid in the LWS underground storage tank contains relatively low concentrations of radioisotopes.

RECOMMENDATIONS

With the exception of some contamination near the inlet of the liquid waste storage tank, where elevated levels of Cs-137 were found, and a few places in the restircted site where some gamma and neutron readings were above background levels, no immediate environmental concerns appear to exist. However, the physical and chemical properties, and in some cases, the radionuclide inventories, of the buried waste are unknown and can present an environmental hazard in the future if the wastes are leached by groundwater and radionuclides and when toxic chemicals are solubilized and transported towards the Ilyak River and then further downstream. The RPBRW is located in an agricultural area, and it is conceivable that some of the leached radionuclides could be taken up by plants and, hence. introduced into the food chain. The distance between the restricted zone and the highway that forms the southern boundary is ~1000 m and the difference in elevation is ~90 m giving a slope of 9%. This extent of topographic relief would direct the flow of surface water and groundwater towards the agricultural regions.

It is probably not warranted to excacate the buried waste because the risk to workers and to the environment may be increased. However, some thought should be given to removing the liquid from the LWS underground tank, concentrating the radioisotopes on a mixed-bed ion exchange resin, and solidifying the sediments by adding grout or concrete to the tank. Since very little, if anything, is known about groundwater flow, it is expedient to consider a limited groundwater flow study that would involve drilling vertical boreholes in the overburden, upstream and downstream from the RPBRW and installing packers in these boreholes. Initially, the boreholes could be monitored to obtain hydraulic information on the RPBRW site. The boreholes could then be sampled to obtain baseline information on the chemical composition of the groundwater as a function of time. Stable tracers, including iodide, bromide, fluoride would then be injected into the boreholes upstream from the RPBRW site and water could be collected from the boreholes downstream from the RPBRW site to obtain information about the flow of groundwater. These downstream boreholes could then be sampled over time to monitor the transport of leached radionuclides from the buried wastes. If any radionuclide release were to be detected, remedial action would be needed. This remedial action could be in the form of inserting an impermeable clay curtain upstream of the RPBRW site to divert the flow of groundwater away from the buried wastes. If remedial action is not feasible or not successful, the buried wastes may have to be retrieved and repackaged for disposal.

REFERENCES

1. Probabilistic assessment of seismic hazard maps and the SRF-97 (in Russian). http://seismos-u.ifz.ru/zoning.htm, accessed 2010 November 19
2. http://news.bbc.co.uk/2/hi/asia-pacific/country_profiles/1297913.stm, accessed 2010 October 18
3. G. P. KISELEV, K. V. VARFOLOMEEV and A. M. LASTOVSKY. "Beryllium-7 in the coastal zone of the White Sea" Geology of seas and oceans. Volume 1. M.: GEOS, 2005. S. 71-72.

ACKNOWLEDGEMENTS

This two-year research project, which began in 2009, is being funded by the Government of Canada as part of the G8 Global Partnership Program through the Department of Foreign Affairs and International Trade (DFAIT), Ottawa and is being administered by the International Science and Technology Center (ISTC) in Moscow, Russia. The restoration of the existing facilities, the installation of the surveillance and security systems is being funded by the International Atomic Energy Agency.

The authors express their sincere gratitude to the Canadian Government for support of this project under the auspices of the Global Partnership Program. Assistance from Dr Michael Valentine (ISTC), from the ISTC staff in the Dushanbe office, in particular Dr Mukhabatsho Khikmatov and Mr Khusdil Bekov, from Dr Khikmat Muminov, Director of the Physical-Technical Institute of the Academy of Science of the Republic of Tajikistan, and from the staff of the DFAIT in Ottawa, Canada, is gratefully acknowledged. Dr Margaret McKenna, (DFAIT, and presently University of Ottawa), is acknowledged for initiating/facilitating this research with the Canadian collaborator, Dr Vandergraaf, for providing valuable comments throughout the duration of the project, and for editing this manuscript. Her editing has greatly improved this manuscript.