THE STATE AND SAFETY ASSESSMENT OF THE LOW LEVEL WASTE REPOSITORIES IN THE TERRITORY OF BELARUS

N. M.Shiryaeva, V.V. Skurat, N.K. Myshkina, A.A. Gvozdev, S.E. Starobinets, M.L. Zhemzhurov

Institute of Radioecological Problems/National Academy of Sciences of Belarus
Sosny, Minsk, 220109, Republic of Belarus
Fax (375-172) 467017; e-mail: air@sosny.bas-net.by

Abstract

Two types of radioactive waste are found in the territory of Belarus at present. The first type is radioactive waste (RAW) which results from using radioactive sources in industry, medicine and at research institutions. This waste is placed in near-surface type repositories at the State facility "Ecores" (the Ecores facility). The industrial site of the Ecores facility has two repositories with RAW. Waste has been placed in two trenches that are isolated now with two other repositories currently in the stage of filling. The waste coming into the repositories is not compacted or sorted by the extent of its toxicity. Assessments of the potential danger from the repositories at the Ecores facility have shown that under the destruction of an engineered barrier the threat of radioactive contamination appears especially with long-lived radioisotopes in the upper aquifer with concentrations exceeding their maximum permissible values inside the sanitary-protection zone and beyond its boundaries.

The second type of waste is radioactive waste from decontamination of the territory of Belarus after the Chernobyl Nuclear Power Plant (ChNPP) accident. At present more than 90 repositories of decontamination waste (DW) are registered in the Republic which are placed in foundation pits, quarries, natural depressions, and frequently in flood-lands of rivers. Most of these repositories have no engineered barrier and many of them are flooded when seasonal fluctuations of the ground water occur. Assessments of the potential danger of the ground water contamination due to radionuclide migration from the repositories of the near-field zone (Pripyat trace) have shown a real threat of contamination. The maximum radius of the repositories influence zone beyond which the concentration of ^{90}Sr in water is smaller than the national permissible level is about 300 m.

Introduction

After the Chernobyl NPP accident radioactive waste has been classified into two types in the Republic of Belarus. Each type demands an independent approach to standardization, regulatory control and waste management process.

The first type of waste results from "small producers" of low and intermediate level activity. This waste usually is due to the use of radioactive sources in more than 1000 firms and companies in medicine, industry and at research institutions. It is placed in near-surface repositories of the Ecores facility.

The second type of waste in Belarus consists of so-called "Chernobyl" waste. It results from decontaminating the territory of Belarus from radioactive fall-out of the Chernobyl origin.

The paper describes the state and condition of radioactive waste storage in repositories in Belarus and assessment of their potential danger to the environment.

Repositories of Radioactive Waste at the Ecores Facility

The Ecores facility is designed to dispose radioactive waste of low and intermediate activity levels in near-surface type repositories. This waste results from using radioactive sources in industry, medicine and at research institutions.

The disposal site of the Ecores facility is located in a wooded region south-east of Minsk-city, 2 km north-east from Sosny settlement, Minsk region. The minimum distance to the Slouch river (a tributary of the Volma river) is 2 km, the nearest pond is at 1.6 km.

Hydrogeological conditions of the site are characterized by the presence of an upper aquifer which is opened at the depth of 27.56 to 41.78 m. The ground water gradient is in a south-east direction to the Slouch river, the mid hydraulic gradient is 0.001m/m.

The level of the aquifer depends on hydrogeological factors and is characterized by seasonal fluctuations. The annual amplitude of fluctuations in the ground water level is approximately 0.9 to 1.0 m. The aquifer is charged by infiltration of atmospheric precipitation. The host rocks of the aquifer and vadose zone soils are mid-sized sands with small and large sands seldom encountered. Unfavorable geological processes are not observed within the site.

The Ecores facility is functioning as a Republican facility for radioactive waste. From 1964 to 1977 at the facility radioactive waste was stored in reinforced concrete trenches using simplified technology without its treatment prior to loading. At present these repositories, known as the old ones, are isolated and banked-off.

In 1977 after the reconstruction of the facility a special laundry and two repositories for solid waste were put into operation. Now they are in the process of being filled.

These repositories are the main ones at the Ecores facility at present. A sanitary-protection zone with a radius of 1000 m surrounds the Ecores facility.

The first old repositories (trench No. 1 and trench No. 2) of the Ecores facility each have a capacity of 225 m^3. Each trench is 5.0x15.0 m with the bottom at least 3 m deeper than the surface of the ground. The thickness of lateral repository walls is 250.0 mm and the thickness of its bottom is 100.0 mm. After filling these repositories with RAW the junctions of covering slabs were covered with cement solution. This covering was coated by hot bitumen and banking was made with turf. The characteristics of waste in the repositories during this period were inadequately documented by today's standards.

An approximate inventory of the isotopic composition and activity of RAW by each radioisotope in trenches of the old repository has been established.

According to the inventory the total activity of waste stored in trench No. 1 of the old repository constituted ~8214 GBq. The isotopic composition of radioactive waste placed in trench No. 1 involves 15 isotopes, four of which are long-lived (^{14}C, ^{36}Cl, ^{239}Pu, ^{226}Ra), and five radioisotopes that have the half-lives of less than a year (^{45}Ca, ^{192}Ir, ^{210}Po, ^{75}Se, ^{170}Tm).

The activity of the major isotopes includes: cobalt-60 ~75%, C_t = 27.38 GBq/m^3 ; cesium-137 ~13.6%, C_t = 4.958 GBq/m^3; radium-226 ~6.0%, C_t = 2.187 GBq/m^3; strontium-90 ~1.69%, C_t = 0.618 GBq/m^3 and plutonium-239 ~1.374%, C_t = 0.418 GBq/m^3. The total sum of the remaining radioisotopes in RAW in trench No. 1 is ~2.36% of the total inventory activity.

The total inventory activity of waste placed in trench No. 2 of the old repository constituted ~$3.885 \cdot 10^4$ GBq. This activity is distributed among 24 radioisotopes, from which four are long-lived (^{14}C, ^{239}Pu, ^{226}Ra, ^{232}Th) , and 11 radioisotopes that have half-lives of less than a year (^{110m}Ag, ^{57}Co, ^{192}Ir, ^{32}P, ^{210}Po, ^{35}S, ^{124}Sb, ^{75}Se, ^{119m}Sn, ^{170}Tm, ^{65}Zn). The activity of the major isotopes involves: cobalt-60 ~41.0%, C_t = 70.8 GBq/m^3; cesium-137 ~40.38%, C_t = 69.7 GBq/m^3; iridium -192 ~8.87%, C_t = 15.3 GBq/m^3; tritium ~4.28%, C_t = 7.4 GBq/m^3 and selenium-75 ~2.46%, C_t = 4.26 GBq/m^3. The contribution of the remaining radionuclides to the total activity of RAW placed in trench No. 2 does not exceed 3%.

Two solid waste repositories began operating in 1977 and currently are in the stage of being filled. These repositories are of a near-surface type and have a useful volume of 820 m^3 each. The underground part of the repositories is a block of vaults made of solidified (monolith) reinforced concrete with overlapping reinforced concrete plates. Each repository has 8 vaults with dimensions of 6x6 m. The depth of two vaults from the side of the inlet is 3.92 m, the rest are 3.25 m.

The analysis of the condition of solid RAW storage at the Ecores repositories shows that

- the content of the vaults of the repositories already filled is a conglomerate of different materials (plastic, glass, metal, rags) contaminated with both short-lived and long-lived radioisotopes, including high activity nuclear materials, closed gamma-and neutron irradiation sources, radioisotopic notifications of smoke containing ^{239}Pu, salts of ^{226}Ra and other radionuclides;
- RAW, including ^{239}Pu, ^{241}Am and ^{226}Ra, is disposed in vaults with the rest of the waste, which excludes the possibility of being stored anew;
- some of the solid RAW is combustible material, which presents potential fire hazard especially when vaults are loaded.;
- significant amounts of RAW are directly stored in concrete vaults without containerization which excludes the second barrier to radionuclide migration beyond the boundaries of the vaults.

The analysis of the operating condition of the Ecores repositories indicates that waste is being stored in violation of International regulations on RAW safe storage.

By 1997 the total activity of solid RAW located in the operating repositories was $7.548 \cdot 10^4$ GBq. The total weight of waste was ~ $6.3 \cdot 10^5$ kg. Trench No. 1 was filled-in by ~ 95%, trench No. 2 by 65%.

The isotopic composition of radioactive waste placed in the repositories during 1977 to 1997 included 28 radioisotopes, five of which are long-lived (^{239}Pu, ^{241}Am, ^{226}Ra, ^{14}C, ^{238}U); ten radioisotopes (^{45}Ca, ^{57}Co, ^{125}I, ^{192}Ir, ^{54}Mn, ^{99}Mo, ^{210}Po, ^{119m}Sn, ^{88}Y, ^{65}Zn) have the half-lives of less than a year. The major isotopes in the filled repositories include ^{137}Cs - 72.55%, C_t =48.8 GBq/m^3, ^{3}H - 25.73%, C_t =17.3 GBq/m^3, ^{90}Sr -0.385%, C_t =0.259 GBq/m^3, ^{239}Pu - 0.315%, C_t =0.212 GBq/m^3. The total activity of the rest of the radioisotopes constitutes about 1%.

An assessment of the radioecological danger from the RAW repositories of the Ecores facility has been carried out. The main scenario assumed migration of radionuclides from the repositories into the ground water due to disruption of hydroisolation and destruction of the engineered barrier. To assess the extent of RAW repository danger, the annual effective individual dose from supplying drinking water contaminated with radionuclides has been selected as the primary criterion of safety. Additional criteria and indicators of safety, such as the concentration of radionuclides in natural media compared with national permissible levels (NPL) and the time of the potential danger of waste have been used. In our approach the time of the potential danger of each radioisotope of RAW depends on the half-life of the radioisotope, its concentration in the RAW, permissible concentration in drinking water and is found to range from 0 to $6{,}3 \cdot 10^{10}$ years. The lower limit of this range relates to short-lived isotopes, the upper one is determined by the ^{238}U and ^{232}Th contents in RAW.

For considering the repository to be safe at the outer boundary of the investigated region the radionuclide concentration in the ground water and the total individual dose in terms of all radionuclides should be less than their limited values ($C_w \leq C_w$ (NPL); $D \leq 1$mSv/year) within the period of potential danger from the waste. We have studied migration characteristics of radionuclides released into the environment from RAW repositories at the Ecores facility in the area of the sanitary-protection zone with a radius of 1000 m and the time interval of 20000 years.

In assessments of radionuclide transfer from RAW repositories into the ground water we have used a multibox model with lumped values (1).

This model includes an arbitrary number of vertical and horizontal control volumes with the mixing volume being the conjugation chamber between them.

The model is based on the following assumptions:

- a porous medium in the separated control volumes where radionuclide migration occurs is uniform and isotropic;
- radionuclides are washed out from the waste by atmospheric precipitation under hydraulically stationary conditions;
- radioactive contamination is transferred in a soluble form;
- interaction of the radioactive admixture in water-RAW and water-soil systems is equilibrium and is described by the Henry linear law;
- dilution of contamination in the aquifer occurs in the layer of a finite thickness;
- the possibility of radioactive contamination of the upper aquifer is only considered;
- the rate of water infiltration is determined from the balance of atmospheric precipitation, its evaporation and infiltration to the ground water;
- the velocity of the ground water is determined by the Darsi law using the data of hydrogeological investigations.

Under these assumptions the processes in the boxes are described by a system of ordinary differential equations of mass transfer with averaged parameters. The model allows for the fact that washing out and convective transfer of the radionuclide admixture by water infiltration and the ground water, interaction of the radioactive admixture with soils and radioactive decay occur under chemically equilibrium and hydraulically stationary conditions. The computation program for the multibox model has been verified according to the American program GW SCREEN (2).

The forecasting assessments of the rate of radionuclide migration from RAW repositories into the aquifer have been performed under the following conservative assumptions:

- radionuclides from repository vaults can percolate into the underlying ground due to the destruction of their foundation and the cap, disturbance of hydroisolation and direct penetration of atmospheric precipitation into radioactive waste;
- radioactive waste is in a humid state and water permanently penetrates with atmospheric precipitation;
- radionuclides are completely washed out from RAW by atmospheric precipitation and migrate with the infiltrated water through the natural barrier (the vadose zone) into the aquifer;
- migration of radionuclides having half-lives less than a year is limited by the volume of waste in the repositories and is not considered beyond its boundaries.

As initial information the characteristics of RAW repositories and results of geological and hydrological investigations in the area of the Ecores facility have been used alongwith literature data on physical and chemical properties of host rocks and migration characteristics of radionuclides.

The forecasting assessments allowed for the uncertainty of the initial information about the properties of natural media where radionuclide migration occurs. This uncertainty owes to the variety of the characteristics of the geosphere and their insufficient study as well as to the complex investigation of migration properties of radionuclides in natural media. The analysis of uncertainty demands multi-variant calculations. The following model variants have been considered:

1. Combination of characteristics to give maximum migration rate of radionuclides in the geosphere, these resulting in the highest values of the specific activity in the aquifer (conservative or high values).
2. Combination of mid migration characteristics (mid values).
3. Combination of migration characteristics yielding the lowest rate of radionuclide migration in the geosphere (low values).

The potential danger of RAW stored in old repositories has been assessed for each trench (No. 1 and No. 2).

The initial data used in the forecasting calculations ranged typical for the geological medium, as well as for the migration features of RAW radioisotopes.

In the analysis the ranking of RAW radioisotopes was made in terms of the distance and duration of their migration. Below are the results obtained for trench No. 1 of the old repository:

1. A number of radioisotopes practically remain within the repository. Such radionuclides had a short half-lives and/or low concentrations and included ^{45}Ca, ^{192}Ir, ^{75}Se.
2. A number of radioisotopes migrate within the vadose zone: ^{137}Cs, ^{147}Pm, ^{210}Po, ^{204}Tl, ^{170}Tm.
3. A number of radioisotopes reach the boundary of the sanitary-protection zone with concentrations in the ground water lower than their permissible values for drinking water: ^{14}C, ^{36}Cl, ^{60}Co, ^{3}H, ^{90}Sr.
4. A number of radioisotopes can migrate beyond the boundaries of the sanitary-protection zone with concentrations exceeding their permissible values for drinking water :^{239}Pu, ^{226}Ra.

The ranking of radioisotopes in terms of the duration of their migration from trench No.1 of the isolated repository yielded the following results:

- radioisotopes migrating in the aquifer within 20 to 1000 years: ^{14}C, ^{36}Cl, ^{60}Co, ^{3}H, ^{90}Sr.
- radioisotopes migrating within the period of 10000 years and more: ^{239}Pu, ^{226}Ra.

The calculations showed that according to conservative assessments permissible concentrations in the ground water (in the layer of dilution of 1 m) were exceeded for the following radionuclides ^{36}Cl, ^{60}Co, ^{90}Sr, ^{239}Pu, ^{226}Ra within the sanitary-protection zone. Dilution of radioactive contamination through the aquifer depth resulted in decreasing mid level concentration of radionuclides in the ground water by a factor of approximately 20.

A similar investigation was carried out for trench No. 2 of the old repository. The ranking of radioisotopes as to the distance of their migration from the repository gave the following results:

1. Radioisotopes migrating within the repository include ^{110m}Ag, ^{57}Co, ^{192}Ir, ^{32}P, ^{35}S, ^{75}Se, ^{119m}Sn, ^{124}Sb.
2. Radioisotopes migrating within the vadose zone include^{134}Cs, ^{137}Cs, ^{147}Pm, ^{210}Po, ^{204}Tl, ^{65}Zn.
3. Radioisotopes that reach the aquifer in insignificant concentrations include ^{238}Pu, ^{170}Tm.
4. Radioisotopes that reach the boundary of the sanitary-protection zone with concentrations not exceeding their permissible values for drinking water include ^{133}Ba, ^{14}C, ^{60}Co, ^{3}H, ^{90}Sr.
5. Radioisotopes that can release beyond the sanitary-protection zone with concentrations exceeding their permissible values for drinking water include ^{239}Pu, ^{226}Ra, ^{232}Th.

The ranking of radioisotopes in terms of the duration of their migration from trench No. 2 to the boundary of the sanitary-protection zone yielded the following results:

- migration of radioisotopes ^{133}Ba, ^{14}C, ^{60}Co, ^{3}H, ^{90}Sr in the aquifer within the boundaries of the sanitary-protection zone is limited by a period of 20 to 1000 years;
- migration of radioisotopes ^{239}Pu, ^{226}Ra, ^{232}Th in the aquifer covers a period of 10000 years and more.

The analysis of the results shows that the permissible concentrations of the following radionuclides ^{14}C, ^{60}Co, ^{3}H, ^{90}Sr, ^{239}Pu, ^{226}Ra, ^{232}Th may be exceeded in the ground water within the boundaries of the sanitary-protection zone.

Conservative assessments evidence that within the sanitary-protection zone the maximum permissible individual dose (1 mSv/year) may be temporarily exceeded by a factor of 10 to 10^3 from supply of drinking water contaminated with radionuclides migrating from the old repository. Beyond the boundaries of the sanitary-protection zone this is possible within 2000 to 20000 years and later on due to ^{239}Pu, ^{226}Ra, ^{232}Th leakage from the repository.

Potential danger from RAW repositories which are currently being filled has been evaluated for a total volume of solid RAW disposed within 1977 to 1997.

The ranking of RAW radioisotopes as to the distance of their migration has been carried out with the following results:

1. A number of radioisotopes remain in the repositories: ^{57}Co, ^{152}Eu, ^{54}Mn, ^{99}Mo, ^{32}P, ^{147}Pm, ^{119m}Sn, ^{88}Y, ^{65}Zn.
2. A number of radioisotopes migrate within the vadose zone: ^{45}Ca, ^{109}Cd, ^{137}Cs, ^{55}Fe, ^{125}I, ^{192}Ir, ^{210}Po, ^{106}Ru, ^{204}Tl, ^{238}Pu.
3. The migration of ^{63}Ni is limited by the mixing zone with the ground water.
4. A number of isotopes can reach the boundary of the sanitary-protection zone but with concentrations lower than their permissible values for drinking water: ^{14}C, ^{60}Co, ^{90}Sr, ^{238}U, ^{241}Am.
5. A number of isotopes can penetrate beyond the boundaries of the sanitary-protection zone with concentrations exceeding their permissible values for drinking water: ^{3}H, ^{239}Pu, ^{226}Ra.

The ranking of radioisotopes as to the duration of their migration in the aquifer from the operating repositories within the boundaries of the sanitary-protection zone yielded the following results:

- migration in the aquifer is limited by the period of 20 to 1000 years for the following radionuclides: ^{14}C, ^{60}Co, ^{3}H, ^{90}Sr, ^{238}U.
- migration in the aquifer during the period of 1000 to 10000 years occurs for the following radionuclides: ^{63}Ni, ^{239}Pu, ^{241}Am, ^{226}Ra.

According to conservative assessments within the boundaries of the sanitary-protection zone permissible concentrations in water may be exceeded for the following radionuclides: ^{3}H, ^{90}Sr, ^{238}U, ^{239}Pu, ^{226}Ra. The forecasting estimates for two other model variants differ from the conservative estimates by a factor of 10^2 to 10^4. Calculations of the annual individual dose from supplying water contaminated with radionuclides which migrate from the operating RAW repositories have shown that temporary excess above the maximum permissible dose (MPD = 1 mSv/year) is possible both inside the sanitary-protection zone and beyond its boundaries.

From our point of view the radioisotopes ^{14}C, ^{36}Cl, ^{90}Sr, ^{238}U, ^{3}H which are weakly sorbed by a geological medium are most dangerous within the period of 20 to 1000 years. Their high migration ability can result in contamination of the lower aquifer used for municipal water supply. The radionuclides ^{239}Pu, ^{241}Am, ^{226}Ra, ^{232}Th are hazardous for future generations as long-lived radiotoxic isotopes which can contaminate the aquifer with hazardous concentrations in the distant future.

A possible temporary excess of the maximum permissible dose within such a long period (20 to 1000 years and more) means the violation of the main International principles of safety for RAW repositories and demands constructive decisions on improvement of the conditions for RAW storage at the Ecores facility.

Disposal Sites of Decontamination Waste of the Chernobyl Origin

After the accident at the Unit-IV of the Chernobyl NPP the majority of the released radioactive isotopes have deposited in the territory of the Republic of Belarus. An area equal to $4.65 \cdot 10^4$ km^2 (almost 23% of the territory of Belarus) has been contaminated.

In 1986 and 1987 decontamination activities resulted in large amount of radioactive waste generated in the populated areas of the Gomel and Mogilev regions. The decontamination waste (DW) mainly included removed soil, roofing of buildings, planks, waste of stock-

breeding farms, household articles, domestics garbage etc. The waste was brought into interim storage sites arranged near the places of decontamination. Natural depressions were used for this purpose including ravines as well as quarries, foundation pits and other manmade structures (1,3).

In 1990 on the basis of the State Program of the Republic of Belarus on Elimination of the Consequences of the Accident at the ChNPP the decisions were made to establish the inventory and define the location of the disposal sites for radioactive DW (3).

As a result the locations of 92 disposal sites were specified, 27 of them being in the zone of the Pripyat trace of radionuclide fall-out (near-field zone) and 65, in the zone of the Sozh trace (far-field zone). The total volume of DW amounted to 400,000 m^3; total inventory of cesium-137 was $2.4 \cdot 10^3$ GBq and strontium-90 was $2.5 \cdot 10^2$ GBq.

Analysis of the operating conditions of these repositories shows that the majority of DW disposal sites have no engineered barriers. Part of them are arranged in the water area of marshes, in floodlands of the Pripyat and Sozh rivers and their tributaries located in places with a high ground water level and some are periodically flooded. Thus, most of these disposal sites are of potential ecological danger because of possible secondary radioactive contamination of the ecosystems and intake of radioactive contamination to population.

The forecasting assessments of the potential danger due to DW disposal sites have been performed based on the models proposed.

The supporting data were obtained by inspection and certification of waste, from sampling and analyzing DW, host rocks and the ground water, from the data monitoring near the control objects using a network of hydrogeological holes, on the basis of laboratory and field modeling, and from literature data as well. Some characteristics were specified through calibration of the mathematical model on radionuclide wash-out from DW placed in disposal sites.

When inspecting DW disposal sites, engineering and radiation surveys have been performed and the radionuclide content in samples waste has been determined. The total state and size of disposal sites, location, characteristics and the roads to repositories have been evaluated by an engineering survey. The levels of gamma and beta-radiation on the surface of disposal sites and the surrounding territories have been determined by a radiation survey. Samples have been analyzed through radiochemical and spectral surveys under laboratory conditions.

Laboratory investigations have been run to determine the form and state of strontium-90 and cesium-137 as well as distribution coefficients in DW-water and soil-water systems. The rate of radionuclide wash-out from DW by atmospheric precipitation was studied both under field and laboratory conditions.

A network of hydrogeological wells in 11 large radioactive waste disposal sites has been developed to study radionuclide contamination of the ground water and hydrogeological characteristics of the vadose zone and aquifer. These monitoring systems cover various typical natural and technological conditions of DW storage and permit continuos monitoring of soils, grounds and the ground water in waste disposal sites. Preliminary safety assessment of the 16 main DW disposal sites located in the near-field zone of radionuclide fall-out of ChNPP in the Gomel region has been performed.

This safety assessment is connected with the forecast of the environmental conditions within the influence area of repositories during the period of waste potential danger in terms of the calculated radionuclide concentrations in the ground water. The influence area of the repository corresponds to the area where radionuclide concentrations in the ground water are decreased by migration processes to the values permissible for drinking water ($C_{w,NPL}$ (^{137}Cs) = 10 000Bq/m^3, $C_{w,NPL}$ (^{90}Sr) = 370 Bq/m^3).

The characteristics of the 16 main disposal sites located in the Pripyat's trace of Gomel region are given in Table I. The analysis of the operating conditions of these repositories shows that only the "Savichy-1" repository has an engineered barrier. Six repositories can be flooded by the ground water in case of seasonal fluctuations of the level and the rest have a natural barrier thickness from 0.3 to 4.7m.

Table I: Characteristics of the Main Disposal Sites of Decontamination Waste of the Near-Field Zone (Pripyat Trace, the Gomel Region)

N	Repositories	Conditions of disposal	DW area, 10^3m^2	DW volume 10^3m^3	Minimum barrier thickness, m	DW average specific activity, kBq/kg		DW activity inventory, GBq	
						^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
1	2	3	4	5	6	7	8	9	10
Choiniky district									
1	Babchin-1	Trenches up to 1.6m in depth	5,6	3,6	0	2,7	0,3	33,2	3,5
2	Babchin-2	Quarry 1-3m in depth	2,3	3,7	1,5	2,6	0,3	13,0	1,5
3	Babchin-3	Founda-tion pit up to 5m in depth	3,4	12,2	4,7	4,1	0,7	63,1	10,1

Table I (cont.)

1	2	3	4	5	6	7	8	9	10
4	Tulhovichy	Foundation pit up to 4.5m in depth	9,7	11,3	0	3,2	0,3	44,5	3,6
5	Kogushky	Foundation pit up to 1.5m in depth	1,2	7,2	0	2,2	0,1	21,1	1,1
6	Omelkovschina	Pits up to 2.5m in depth	0,6	1,0	1	2,9	0,1	3,7	0,2
7	Novociolky	Foundation pit up to 5m in depth	6,7	6,0	3	1,9	0,05	15,0	3,7
8	Poselichy	Trenches up to 2.5m in depth	1,6	2,1	0	1,8	0,2	4,8	0,5
Bragin district									
9	Savichy-1	Foundation pit up to 5.5-8m in depth	5,9	16,8	2	4,4	0,4	102,6	10,1
10	Savichy-2	Quarry 3m in depth	5,9	4,6	0	1,3	0,2	7,8	1,2
11	Moriton	Foundation pit up to 7m in depth	13,0	41,0	0,3	5,3	1,3	271,0	67,0
12	Mickulichy	Quarry 3m in depth	4,6	4,1	0,4	0,2	0,3	12,0	1,4
13	Petkovschina	Foundation pit up to 6m in depth	2,2	5,3	4	2,3	0,3	15,5	1,85
14	Pirky	Foundation pit up to 4.6m in depth	5,5	7,3	2,5	1,4	0,23	18,5	3,03
15	Bragin	Quarry 2.3m in depth	0,85	1,2	0	1,7	0,31	2,6	0,48
16	Nudichy	Dump in forest	59,8	31,2	1,5	0,96	0,09	1,5	0,4

The results of conservative forecasting estimates are presented in Table II.

Table II: Predicted Radionuclide Migration from Disposal sites of Decontamination Waste of the Near - Field Zone (Conservative Assessment)

N	Repositories	T_{pd}, years	T_{gw}, years		C_{wmax}, Bq/m^3, L=0 m		C_{wmax}, Bq/m^3, L=100 m	T, years, L=100m	Z, m
			^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{90}Sr	^{90}Sr
1.	Babchin-1	320	0	0	$4.0\cdot10^4$	290	$9.3\cdot10^3$	40	~300
2.	Babchin-2	335	≥ 50	>335	$2.1\cdot10^3$	0	224	130	~100
3.	Babchin-3	370	≥ 100	>370	$2.0\cdot10^3$	0	370	230	~100
4.	Tulhovichy	320	0	0	$2.4\cdot10^4$	$1.3\cdot10^3$	$4.2\cdot10^3$	80	~300
5.	Kogushky	320	0	0	$2.6\cdot10^4$	320	$5.1\cdot10^3$	70	~300
6.	Omelkovschina	310	≥ 40	>310	$6.6\cdot10^3$	0	6.0	300	~100
7.	Novociolky	310	≥ 70	>310	$9.7\cdot10^3$	0	0	310	~100
8.	Poselichy	330	0	0	$3.2\cdot10^4$	300	$6.0\cdot10^3$	70	~300
9.	Savichy-1	340	≥ 84	> 340	$6.6\cdot10^3$	0	$2.0\cdot10^3$	~ 170	~240
10.	Savichy-2	310	0	0	$7.5\cdot10^4$	$1.0\cdot10^5$	$1.0\cdot10^4$	50	~330
11.	Moriton	370	≥ 17	> 200	$4.4\cdot10^4$	0	$1.3\cdot10^3$	170	~150
12.	Mickulichy	310	≥ 20	> 310	$3.4\cdot10^4$	0	96	300	~ 100
13.	Petkovschina	320	≥ 20	> 320	5700	0	1200	50	~200
14.	Pirky	310	≥ 20	> 310	$2.0\cdot10^4$	0	1000	60	~200
15.	Bragin	310	0	0	$3.5\cdot10^3$	$2.0\cdot10^3$	800	10	~ 150
16.	Nudichy	245	≥ 60	> 245	200	0	-	-	~ 100

These assessments show that the period of potential danger of repositories ($T_{p.d.}$) covers from 245 to 370 years (Table II).

As seen from the analysis the natural barrier increases the time for radionuclides to reach the ground water level ($T_{g.w}$) and decreases the concentrations of radionuclides penetrating into the ground water. Here, the migration of cesium-137 is limited either by vadose zone in the case of a natural barrier, or by the mixing area of radioactive contamination with the ground water directly under the repository in the case of its flooding.

Strontium-90 has a greater mobility than cesium-137. In this connection its concentration in the ground water directly under the repository can reach the values of $C_{w\,max}$ (L = 0) = (0.02 - 7.5)$\cdot10^4$ Bq/m^3, and at a distance L = 100m from repository, $C_{w\,max}$ = 0 - 10^4 Bq/m^3 (Table II). The migration rate of strontium-90 depends on both the barrier thickness, absorbed properties of host rock, and hydrogeological characteristics of the aquifer. The dimensions of the influence area of the analyzed disposal sites (Z) do not exceed Z = 330m (Table II).

The results of the calculations on radioactive contamination release from DW disposal sites and surrounding territories into the ground water were compared with the results of the analyses of soil, ground and the ground water samples taken during 1994 and 1995 near

"Babchin-1", "Babchin-2", "Babchin-3", "Kogushky", "Savichy-1", "Moriton", "Mickulichy". The comparison shows that the calculated values and the experimental data are in a good agreement within the uncertainty of the initial information. The best agreement was between the calculated concentrations in the vadose zone and the result of soil and ground sample analyses. The worst agreement is observed for calculated results and experimental data on the ground water. Such a disagreement can be attributed to both the imperfect mathematical model, uncertain initial information and the complex qualitative ground water sampling in field conditions as well as to the precision of measurements, analysis of samples in laboratory conditions and limited measurements. The latter demands development of more hydrogeological wells in DW disposal sites, annual radiation monitoring of the ground water and improvement of the methods to calculate radionuclide migration into geosphere.

Conclusions

The analysis of the conditions of RAW storage and operation of repositories at the Ecores facility revealed the violation of the International regulations of safe RAW storage. The evaluation of the potential danger of these repositories has shown that within the sanitary-protection area the concentrations of the following radioisotopes ^{14}C, ^{36}Cl, ^{60}Co, ^{3}H, ^{239}Pu, ^{226}Ra, ^{90}Sr, ^{232}Th, ^{238}U may exceed their permissible values for drinking water.

Within 20 to 1 000 years radioisotopes ^{14}C, ^{36}Cl, ^{3}H, ^{90}Sr, ^{238}U which are weakly absorbed by host rocks are most dangerous. Their high migration ability may result in contamination of the lower aquifers used for municipal water supply. Radionuclides ^{241}Am, ^{239}Pu, ^{226}Ra, ^{232}Th, in spite of their small contents in radioactive waste, present a danger for future generations as long-lived radiotoxic isotopes that can contaminate aquifers in the distant future.

Possible temporary exceeding of the permissible concentration of radionuclides and the permissible dose from supplying contaminated drinking water during such a long time (200 to 10 000 years and more) contradicts the main International principles of safe RAW storage and demands constructive decisions on isolation of waste and localization of radionuclide release to the environment.

Analysis of the operating conditions of DW disposal sites of the Chernobyl origin has shown that only one of from 16 sites has an engineered barrier and 6 repositories can be flooded by the ground water under seasonal fluctuations of level. The rest of the sites have natural barriers of thickness 0.3 to 4.7m. Assessments of the extent of the potential danger of DW disposal sites have shown that ^{137}Cs migration from repositories is limited by the vadose zone in the presence of a natural barrier or by mixing area of radioactive contamination with the ground water just under repository in the case of their flooding.

Because of high mobility of ^{90}Sr its concentrations in the ground water can reach the values of $(0.02 - 7.5)\cdot 10^4$ Bq/m^3 in mixing area, and 10^4 Bq/m^3 at a distance of 100m from disposal sites. Conservative assessments have shown that the influence area of repositories ranges between 100 and 300m.

Comparison of calculation results with field data collected through sampling of soil, ground and the ground water has shown their agreement within of uncertainty of initial information and the precision of measurements.

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