THIRTIETH ANNIVERSARY OF REACTOR ACCIDENT IN A-1 NUCLEAR POWER PLANT JASLOVSKE BOHUNICE

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Abstract

The facts about reactor accidents in A-1 Nuclear Power Plant Jaslovské Bohunice, Slovakia are presented. There was the reactor KS150 (HWGCR) cooled with carbon dioxide and moderated with heavy water. A-1 NPP was commissioned on December 25, 1972. The first reactor accident happened on January 5, 1976 during fuel loading. This accident has not been evaluated according to the INES scale up to the present time. The second serious accident in A-1 NPP occurred on February 22, 1977 also during fuel loading. This INES level 4 of reactor accident resulted in damaged fuel integrity with extensive corrosion damage of fuel cladding and release of radioactivity into the plant area. The A-1 NPP was consecutively shut down and is being decommissioned in the present time. Both reactor accidents are described briefly. Some radioecological and radiobiological consequences of accidents and contamination of area of A-1 NPP as well as of Manivier Canal and Dudvah River as result of flooding during the decommissioning are presented.

Keywords (INIS)

Bohunice A-1 reactor; reactor accident; INES; reactor decommissioning; radioactive wastes; surface contamination; contamination monitors; soils; ground water; Manivier Canal; Dudvah River; Vah River, radioactivity transport, radiation doses; dose equivalents; radioecology; Slovakia; experimental data

Introduction

Prototype nuclear power plant A-l located in Jaslovské Bohunice was a HWGCR with channel type reactor KS 150 with natural uranium (refuelling during operation) and capacity of 143 MW_e. The steam rising from primary circuit of the reactor with temperature 410°C move ahead into 6 modules of steam generators and then into turbines with generators. Fuel change was realised during the operation of reactor. The construction of the NPP started in 1958; it was commissioned on December 25, 1972. This NPP has produced 916.1 MWh of electric energy during quadrennial operation.

In this year we are memorialising the thirty-first anniversary of the first incident and the thirtieth anniversary of the second accident on nuclear reactor KS 150 in A-1 NPP. The second accident belongs to the most serious accident on the nuclear reactors in the world (it was classified into the fourth level of the *International Nuclear Event Scale* - INES). In spit of that the first accident finished tragically for two personnel workers; it has not been classified according to INES up to the present time. In this paper the course and consequences of both events as well as radioecological consequences of last breakdown of reactor and consequential activities associated with decommissioning of the A-1 NPP are described.

Short characteristics of the A-1 NPP Jaslovské Bohunice

The A-1 NPP was realised as developmental demonstration nuclear energetic source, which should be the ground for the development of Czechoslovak nuclear program. Investments on building of the A-1 NPP (2.32 milliard of Czechoslovak crowns) were fully paid by subsidy from the state budget. The first pilot A-1 NPP in the Slovak Republic is situated (Figure 1) in Jaslovske Bohunice (60 km nort-east from Bratislava). It had a nuclear reactor KS 150 (HWGCR) cooled by gaseous CO_2 and moderated by heavy water with natural (not enriched) uranium with installed capacity 143 MW_{el}. The steam rose from primary circuit of cooling system of the reactor with the temperature 410°C and got into 6 modules of steam-generators and from them into turbines with generators. Fuel replacement was realised during operation of the reactor. The construction of the NPP started in 1958; it was commissioned on December 25, 1972. This NPP produced 916.1 MWh of electric energy during quadrennial operation [1].

Obrázok 1. The A-1 NPP is situated together with objects of V-1 and V-2 NPPs on the west of the Slovak Republic in the cadastre of the village Jaslovske Bohunice [2].

Incident at the A-1 NPP Jaslovske Bohunice

Thirty-one years ago the first incident (failure of the closing mechanism of technological channel) happened on January 5, 1976 (Nuclear Regulatory Authority of the Slovak Republic, 1996 [3]). The fresh fuel assembly (together with technological plug) was ejected into the reactor hall. Coolant (carbon dioxide) was flowing out from the reactor during short time until the refuelling machine was reconnected with open technological channel and stopped coolant leakage. Immediately the personnel were not irradiated. Two people out of hall, which did not respond on warning system, were suffocated by the carbon dioxide. No radioactive substances escaped to atmosphere. The public was not informed about the progress of incident, while the population was not endangered.

This incident was described in detail only in the paper of Frišová, M., et al. (1998) [4]. Viliam Pačes, head of work shift changed a fuel element by new one. During the changing of the fuel element the electronic regulation showed, that connection of fuel element is tight. Consecutively, operator Martin Slezák rose up lightly the fuel element according to the instruction. However, the conjunction was not tight. Carbon dioxide, which was used for cooling, spewed out the twelve-meters long fuel assembly into the reactor hall. Immediately nobody was irradiated or injured. However, two men outside of the hall which did not respond on emergency signal, stifled by the carbon dioxide. The fresh fuel assembly (together with the technological plug) was ejected to the reactor hall, has clashed into a ceiling. The cooling gas (radioactive contaminated and unbreathable carbon dioxide) started to spill out from opened canal. The steel cubes were flying out from the cover of the reactor. During this moment Viliam Paces was dazed for a while, then he sifted through and he could get into block control room. Second operator Martin Slezák was injured more seriously. In block control room Paces obtained a gasmask and one dosimetry man and he was sent back into reactor hall. He was the only one who could try to close the opened canal again. Only after ten - fifteen minutes he could by manoeuvring in strong gas flow to push away the fallen fuel assembly that was lying on refuelling machine. He could not communicate with the control room because he had a gasmask. Only after some minutes he could close the reactor canal by the help of refuelling machine. The action of the head of work shift Viliam Pačes after accident can be evaluated as a heroic act.

Officially, in the representative publication [5] it is written “The first more serious disorder was the 'shooting' of fuel assembly from one canal of the reactor during fuel replacement during operation. The failure was immediately liquidated by personnel of the transport technology by tightness of opened canal by charge machine“. However, it is not written in this publication that during this accident two maintenance workers died, which stifled by leaking gaseous carbon dioxide. It is written in no accessible special publication that the melting of the active zone of the reactor threatened during this first accident. This incident on the reactor A-1 NPP has not been evaluated according to the INES scale up to the present time (INES, 2001) [6]. According to our opinion the incident on the reactor A-1 of 1976 year should be classified at least as third level of INES scale.

The reactor was consecutively unplanned shutted down and reconstructed up to end of 1976.

The second accident at A-1 NPP Jaslovske Bohunice

During refuelling, the insufficiently transmissive fuel assembly was charged into the reactor core on February 22, 1977. Local overheating of fuel, technological channel and heavy water circuit tube caused the loss of barriers integrity between heavy water moderator and fuel with cooling gas. The cladding and steam generator tube corrosion under water saturated by carbon dioxide occurred and resulted into the contamination of primary and secondary circuit (Burclova, 1998) [7] as well as reactor hall. During this accident nobody was injured or excessively irradiated.

This serious complication made impossible to reactivate the power station. Although in 1979 the Czechoslovak government decided, that A1 NPP should be decommissioned, real steps proceeded only very slowly. Released finances were used mainly for different studies, tasks of science and technical development, recommendations. In reality, the liquidation of the accidents was realised only in minimal extent due to lack of finances. However, the technologies for fixation of radioactive wastes were missing objectively. Nuclear fuel left in the reactor.

In 1979 the final decision was made to decommission this plant. 439 of total 571 spent fuel assemblies were transported to the former Soviet Union since 1984 to 1990. Damaged 132 fuel assemblies were sent to PA Mayak (Russia) in 1999 (Nuclear Regulatory Authority of the Slovak Republic, 1996) [3].

In 1991 the International Atomic Energy Agency introduced INES scale (The International Nuclear Event Scale, 1999 [8 - 12]) with 7 levels. Subsequently, the second accident on A-1 NPP was classified as accident of 4th level of INES scale. During the accident no leakages of radioactivity into environment proceeded reportedly (Nuclear Regulatory Authority of the Slovak Republic, 1996) [3].

The fact that the second accident on A-1 NPP is not known in the world is proved, because it is rarely put into statistics and tables of accidents, for example, in Greek handbook of the INES [13], it is not given also in the Czech handbook of the INES [14], not even in leaflet of the IAEA about INES scale [8], eventually it is not included into Slovak handbook of the INES [15]. We cannot get to know about the accident on A-1 NPP either in the database *List of civilian nuclear accidents* [16]. We can come to know about this accident at the reactor KS 150 for example in free encyclopaedia *Wikipedia* [17], or in the *List of civilian nuclear accidents* [18].

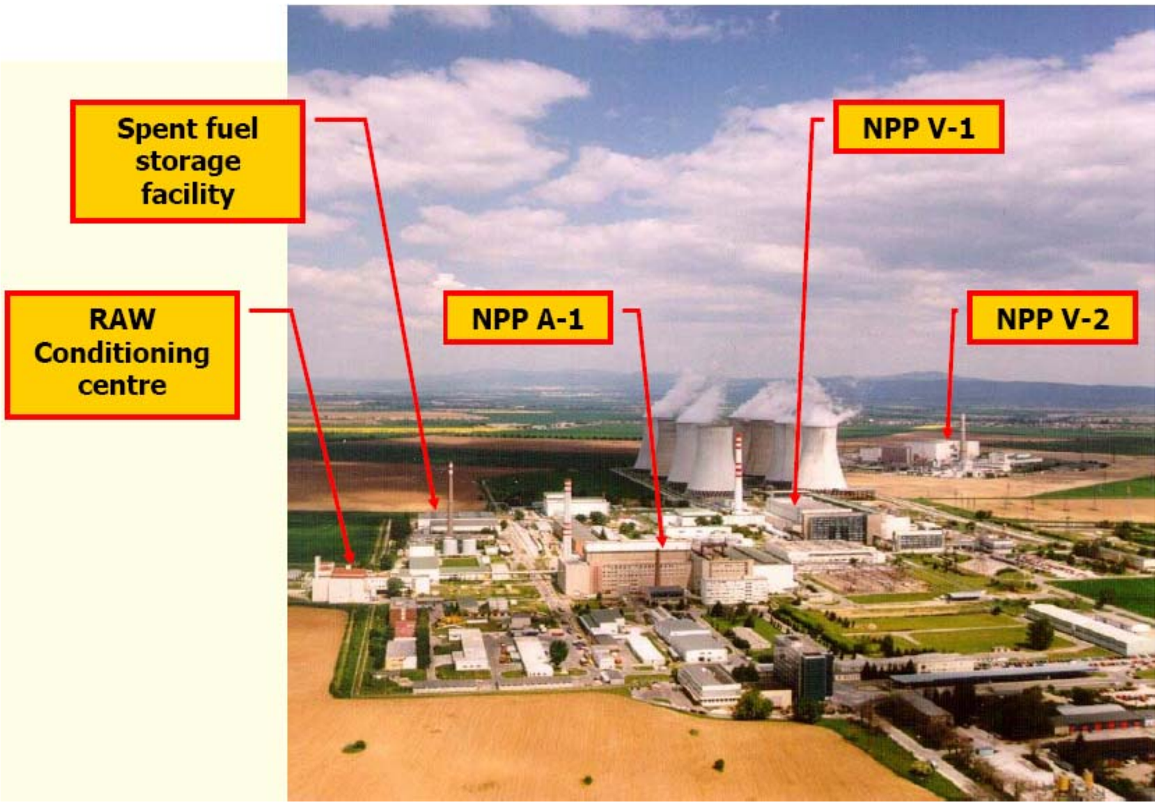

Figure 2. The view on objects of the A-1 NPP, V-1 NPP and V-2 NPP (cooling towers of the V-1 NPP and V-2 NPP on background) in Jaslovske Bohunice [2].

Abnormal rainfall on A-1 NPP site and insufficient flood-protection countermeasures led to flooding of rooms in the plant-controlled area in June 1978. A huge amount of contaminated water originated. The contaminated water was released subsequently into the recipient of Dudvah River and then into Vah River. In spite of increased radioactivity of the effluents no immediately countermeasures for the mitigation of consequences had to be done. Water from these rivers is used for irrigation of fields (Petrášová, M., 2003) [19].

Progress after accident on A-1 NPP Jaslovske Bohunice in 1977

After the second accident the Government of the former CSSR decided about decommissioning of A-1 NPP by the resolution No. 135 of May 17, 1979.

The source of financing of decommissioning was own financial resources of the Slovenske elektrarne, j.s.c. (SE) and financial sources from the state budget. Since January 1, 1996 the plant SE-VYZ Jaslovske Bohunice has been responsible for realisation of the project in the frame of the SE [20]. Bohunice NPP (EBO) was responsible till then. In the present time no spent nuclear fuel from the A-1 NPP is in Jaslovske Bohunice [21].

In 1992 the contract with the AEA Technology was signed for development of technical documentation of decontamination of the reactor hall. During the planning of the project some technical problems were identified which needed engineering solution [22].

439 spent nuclear fuel assemblies of total 571 were transported to the former Soviet Union since 1984 to 1990. Remaining 132 fuel assemblies were heavy damaged, therefore it was impossible to manipulate with them during that time [26].

A big signification for activities in the field of decommissioning of the A-1 NPP had an adoption of law No. 254/1994 Coll. Law on the state fund for decommissioning of nuclear energetic devices. In 1995 the financing of decommissioning works started on the basis of this law [25]. Spent nuclear fuel from accidental A-1 NPP was exported to Russian Federation on the basis of old contracts. The last consignment was sent to PA Mayak‘ in Ural in 1999, when the method how to take out the rest of damaged fuel from the accidental reactor was developed in VUJE, j.s.c. [23].

The real decommissioning activities started in 1995 [23]. The Government of the Slovak Republic decided that NPP must get out into safe state up to 2007. Radioactive wastes should be treated and storaged in the Mochovce Radioactive Waste Repository. Not even the decommissioning works will end. Then less contaminated parts of the A-1 NPP will be dismantled and decontaminated [24]. Until in 2070 it will be possible to isolate definitively the pressure vessel of the reactor and steam-generators [23].

Around 8 milliard of Slovak Crowns (~267 million $) were spent on decommissioning of A-1 NPP since 1995 to the end of 2005 (Beer, G., et al., 2005) [23]. It is also necessary to add the finances spent up to 1995 to the expenditures for decommissioning of the A-1 NPP.

The finances, which were spent up to 1995, should be added to the expenses for decommissioning. Nobody is familiar with exact sum of money because finances came from more sources, from the concern as well as from Federal Ministry of Fuels and Energetic. The precise evidence does not exist.

Accidental A-1 NPP is under supervision of state company JAVYS, j.s.c., Jaslovske Bohunice (before GovCo, j.s.c.) [20], which also auspices the shutted down V-1 NPP.

Radiation consequences of the accident on A-1 NPP

Pražská et al. estimated [27] total contamination of primary circuit of A-1 NPP:

- total contaminated area of devices of primary circuit (pipelines, steam-generators and turbocompresors): 48,000 m^2
- total gamma activity of contamination: $10^{14} \div 10^{15}$ Bq
- total alpha activity of contamination: $10^{11} \div 10^{13}$ Bq
- total mass of deposits in gaseous circuit: about 14.3 tonnes.

Krištofová and Vaško pointed [2] the specifically values about wide-ranging contamination of primary circuit by fissile products. Corrosive cooling medium of spent nuclear fuel - chrompik (Cr + K + water) and later dowtherm (organic liquid) – damaged protective layer of fuel assemblies in storage tanks and consecutively caused the corrosion of metallic uranium. It led to formation of liquid radioactive wastes: chrompik (10^{11} Bq.dm^{-3}, 13 m^3), dowtherm (10^7 Bq.dm^{-3}, 40 m^3), water from long-term interim storage of spent nuclear fuel (10^6 Bq.dm^{-3}, 220 m^3), and sludge (10^{10} Bq.dm^{-3}, 50 m^3).

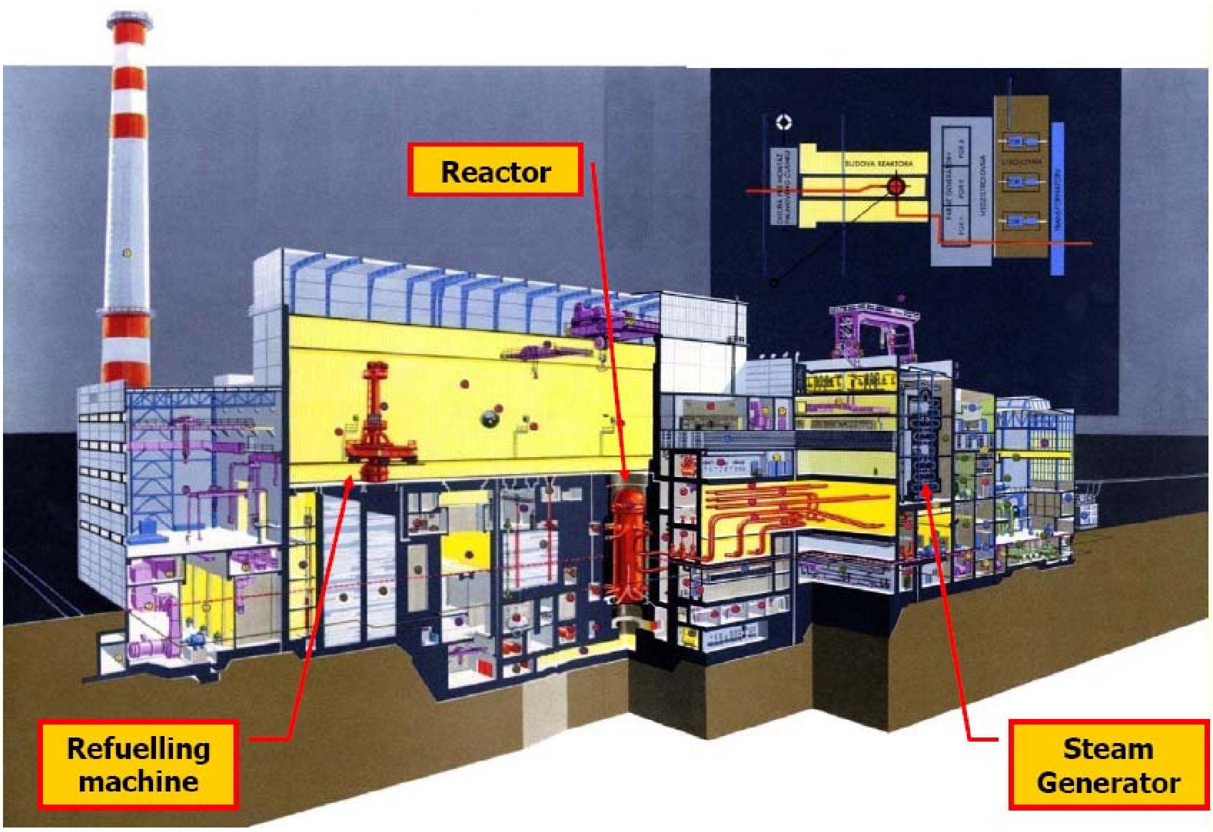

Figure 3. Design of the A-1 NPP [2].

Total collective dose in 1999 year was 1.000 man·Sv (employees 0.545 man·Sv, outside workers 0.455 man·Sv). Maximum individual effective dose was 16.57 mSv [28].

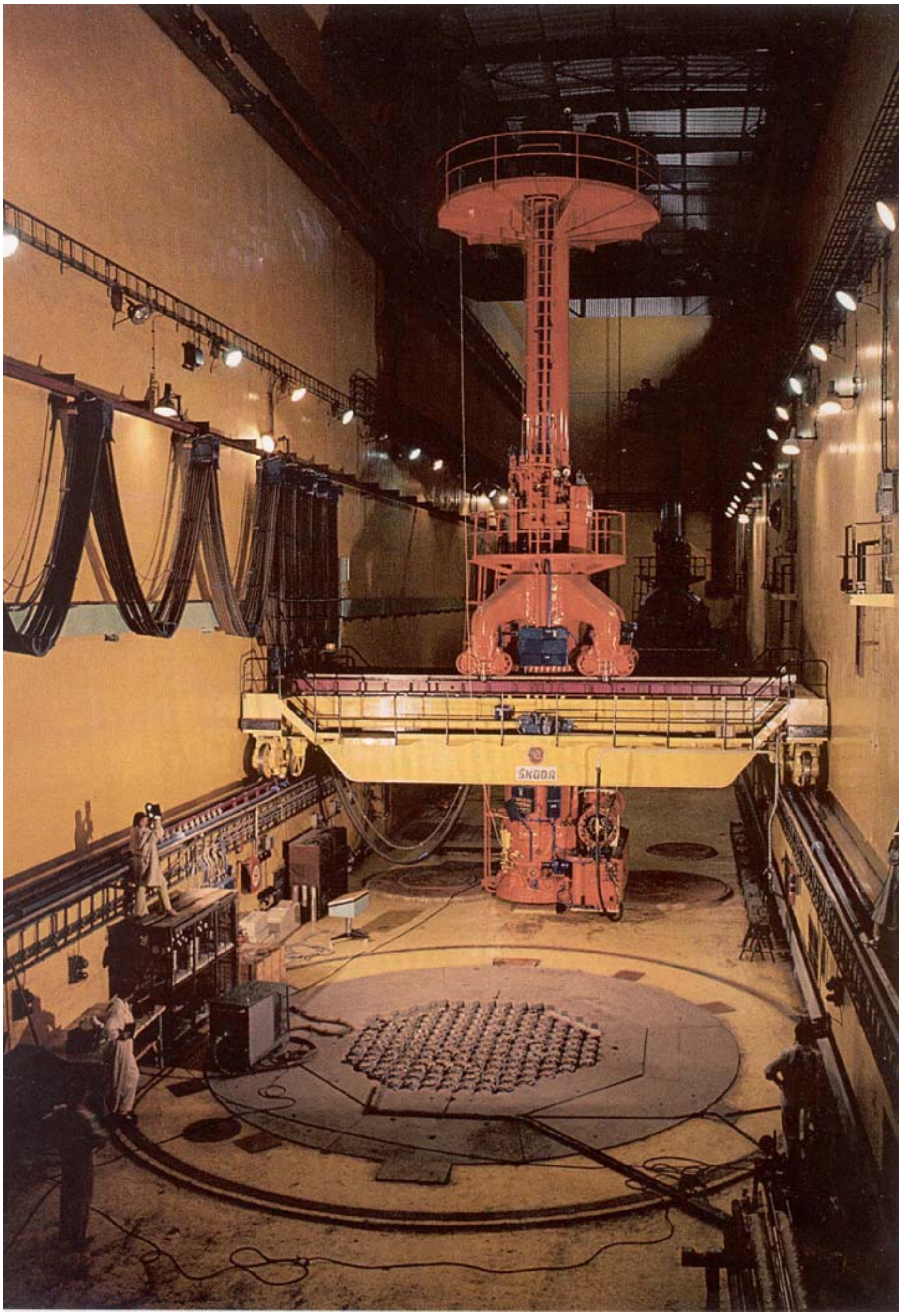

Figure 4. The reactor hall of the A-1 NPP [5].

Treatment of radioactive wastes during decommissioning

List of decontaminated rooms during decommissioning of the A-1 NPP were published in National Report of the Slovak Republic, 2004 [29].

Decommissioning of the A-1 NPP proceeded in the following stages [29]:

1977: definitively shut down of the A-1 NPP,
1979: start of decommissioning of the A-1 NPP,
1979 – 1994: liquidation of contaminated moderator and cleaning of dismantled damaged fuel canals, fuel assemblies were removed from reactor, situated into storage tanks, decontamination of devices and partially dismantlement of uncontaminated technology,
1991 – 1999: spent nuclear fuel was transported to Russian Federation,
1994: development of Project of the First Phase of decommissioning of the A-1 NPP, implementation should be finished in 2007.

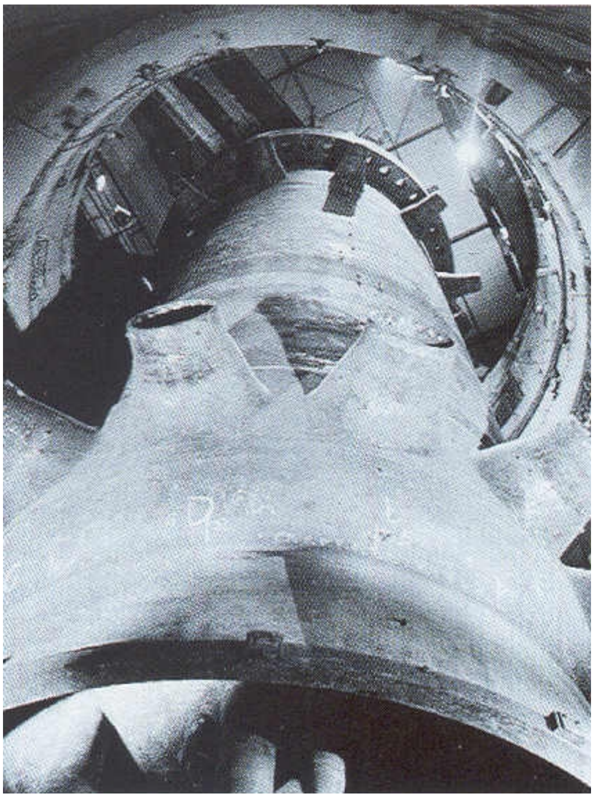

Figure 5. The reactor vessel KS-150 [5].

Figure 6. Landfill of fuel assembly into reactor KS-150 [5].

The preliminary calculation for preferred scenarios “Running decommissioning” (Pražská, 2005, [27]) or so-called “Modified direct dismantlement after 2007” suppose the treatment:

1. Metallic radioactive wastes – 7,100 tonnes

2. Liquid radioactive wastes – 6,230 m^3

3. Number of fibrous-concrete containers (FCC) (volume 3.1 m^3) for surface radioactive waste repository – 3,050 pieces

4. Number of FCC (volume 3.1 m^3) for underground geological radioactive waste repository – 520 pieces.

Monitoring of ground and surface water and surroundings of the A-1 NPP

After second accident the radiation monitoring of the territory and river-basin started which continues up to this day. The soils in the area of the decommissioned A-1 NPP are the most contaminated [30].

Results of monitoring of contaminated soils of rehabilitated locality in a part of area of the A-1 NPP are shown on the Figure 7.

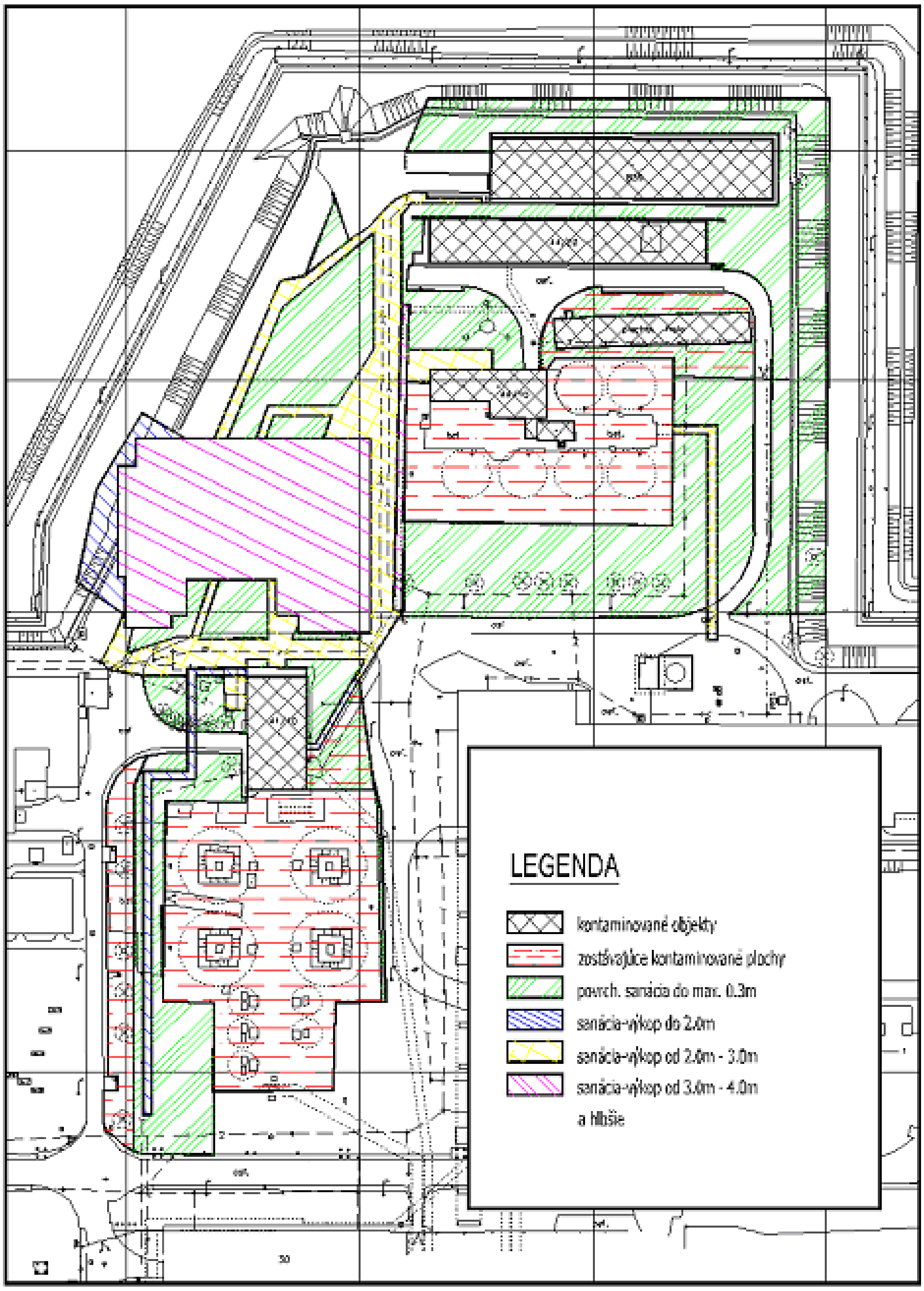

Figure 7. The area of contaminated soils, rehabilitated locality in a part of area of the A-1 NPP [30].

Surface contamination of soils by cesium-137 in the area of the A-1 NPP is shown on the Figure 8.

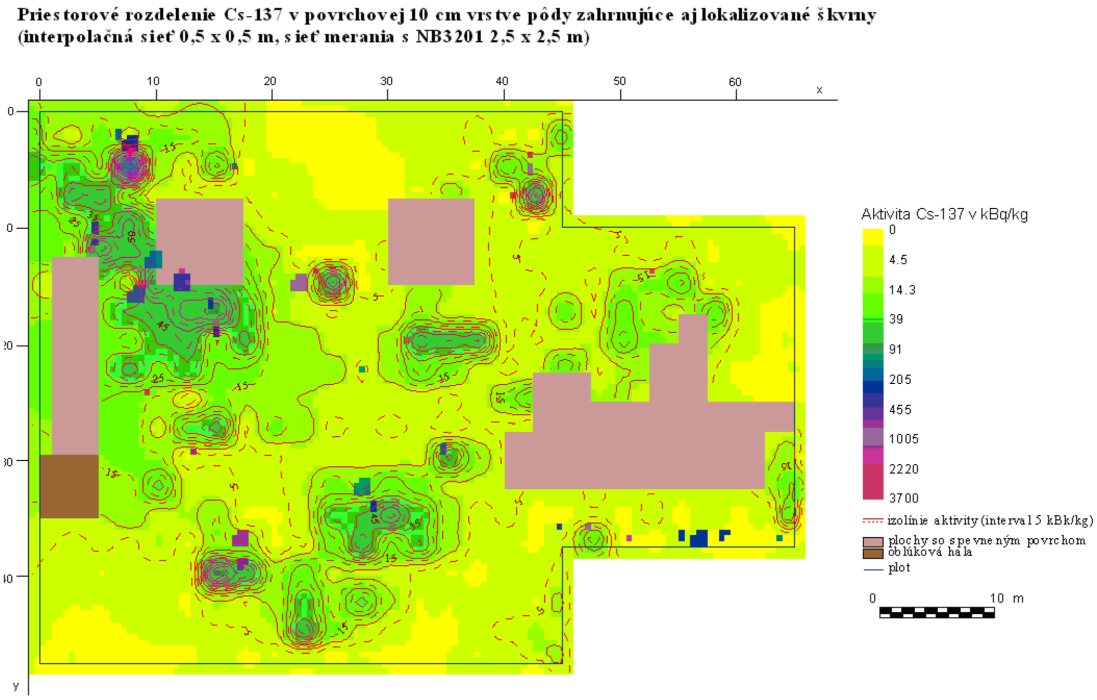

Figure 8. Surface contamination of soil by Cs-137 in area of the A-1 NPP [30].

From 1999 is in exploitation persistent system of rescue drawing off underground water from drilling N-3 in closeness of the garden object 41 with aim to prevent dissemination of contamination beyond boundary of area of the A-1 NPP.

Radiation situation in underground waters of area of A-1 NPP is stabilized since 2000 year, or by standard exploitation of rescue drawing off of underground water from drilling N-3 the dissemination of contamination from the area is retarded [30].

Results of monitoring of air, soil and underground water in area of Jaslovske Bohunice NPPs were published in the report of VUJE in 1998 [31]. Integral year dose of gamma radiation in water in 1998 in the height 1 m above surface of terrain in the point of measurement was 0.78 mGy·year^{-1}. Effective dose, which obtained the individual of population on this site from terrestrial and cosmic component of external irradiation is 0.549 mSv·year^{-1}, that is practically equal value to the dose from external radiation on arbitrary site outside of locality with nuclear-energetic device.

The workers of the Department of Nuclear Chemistry, Comenius University participated in monitoring of the environment in locality of the A-1 NPP. New method of ^{239,240}Pu determination in soil was developed on this department (Mátel, Ľ., Mikulaj, V., Rajec, P., 1993) [32]. In sediments of Canal Manivier the specific activity of ^{239,240}Pu was (5÷40) Bq.kg^{-1} and specific activity of ^{137}Cs was (3÷240) kBq.kg^{-1}, in sediments of Dudvah River specific activity of ^{239,240}Pu was (0,5÷10) Bq.kg^{-1} and specific activity of ^{137}Cs was (3÷30) kBq.kg^{-1} (Mátel, Ľ, et al, 1993) [33]. The collecting sites are shown on the Figure 9.

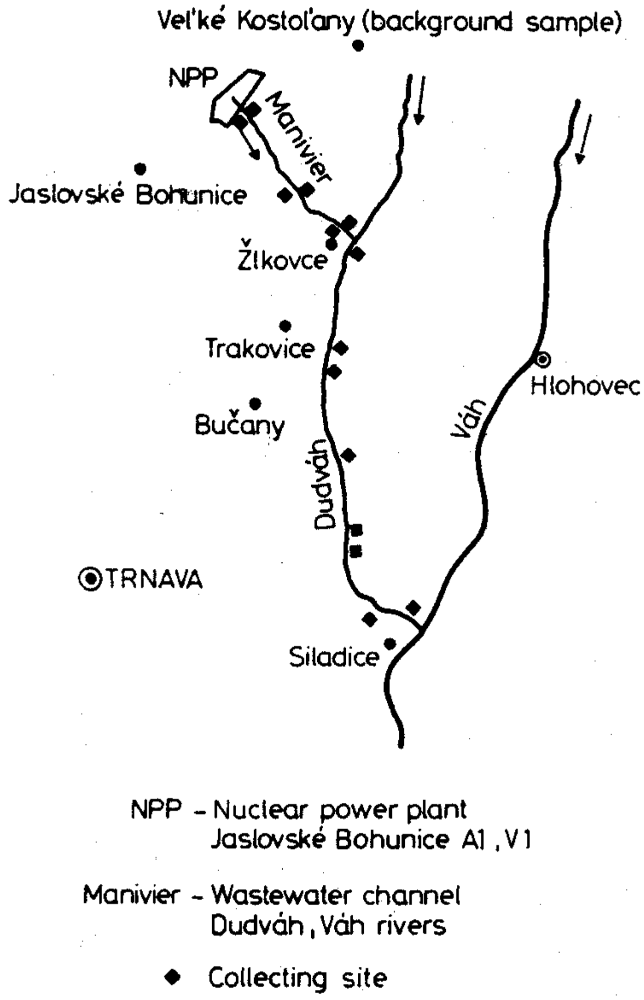

Figure 9. Collecting sites on the territory in surroundings of the Bohunice NPPs (Mátel, Ľ., et al., 1994; Macasek, F., 1995) [34, 36].

The results of two-year measurements (Mátel, Ľ., 1995) [35] of ^{90}Sr, $^{239,240}Pu$ and ^{241}Am in 20 g samples are presented in the Table 1.

Presence of these radionuclides in soils, sediments and aqueous plants can be explained by global fall-out and influence of the A-1 NPP, shutted down in 1979.

Methods of liquid extraction were developed for separation of Sr-90 and Pu-239/240 for their quick and reproducible determination. Since 1992 these methods were applied for systematic measurements of both radionuclides in samples of neighbourhood of the A-1 NPP (and V-1 NPP and V-2 NPP) [36]. Collecting sites of taken samples are shown on the Figure 10.

Table 1. Results of determination of ^{90}Sr, $^{239,240}Pu$ and ^{241}Am in 20 g samples (Mátel, Ľ., et al., 1995) [35].

Sample, No.	DEPTH	$^{239,240}Pu$ [Bq.kg^{-1}]	^{137}Cs [Bq.kg^{-1}]	^{90}Sr [Bq.kg^{-1}]
Sediments				
V. Kostoľany	0 – 5	0.28	15.7	<1.2
Žlkovce	0 – 20	0.28	45.7	<1.2
Bučany	0 – 20	0.43	222	2.9
Sereď	0 – 20	<0.11	45.9	4.8
Aqueous plants				
Bučany	0 – 5	0.43	108	0.7
V. Kostoľany	0 – 5	0.11	2.6	<4.9
Soils				
Žlkovce	0 – 5	0.22	30.8	<1.2
V. Kostoľany	0 – 5	0.11	11.1	<1.2
Radošovce	0 – 5	0.16	10.9	2.4
Pečeňady	0 – 5	0.31	10.6	<1.2
Katlovce	0 – 5	0.29	7.7	<1.2
Krakovany	0 – 5	0.14	12.7	<1.2
Nižná	0 – 5	0.23	9.9	1.6
Žlkovce-2	0 – 5	0.22	30.8	1.6
JE Bohunice	0 – 5	<0.18	29.8	2.5
Trnava	0 – 5	<0.18	25.7	<1.2

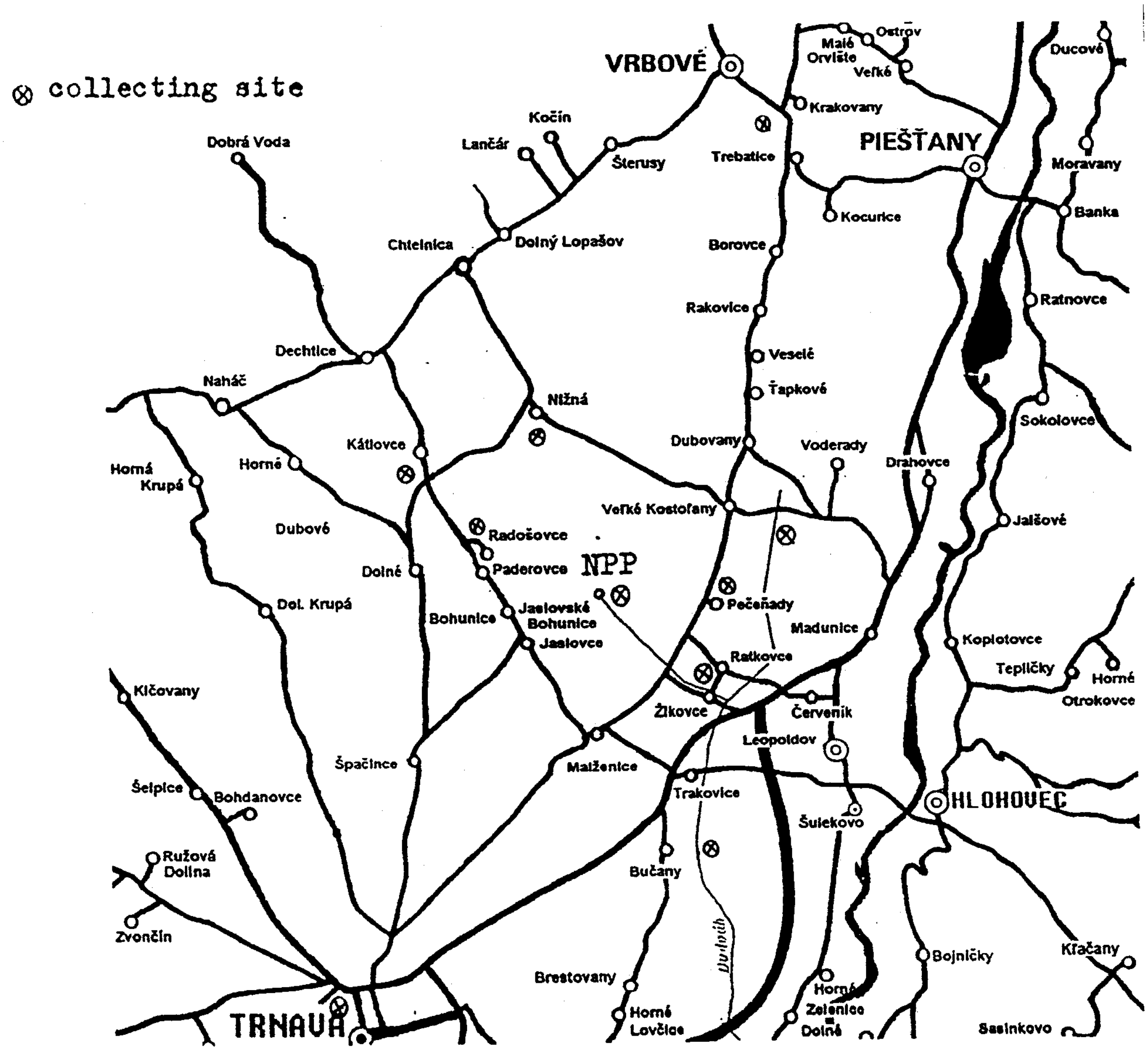

Figure 10. The system of collection sites of samples in neighbourhood of the A-1 NPP [36].

In the Table 2 the results of determination of strontium-90 and plutonium-239/240 in samples of sediments, aqueous plants and soils from surroundings of the A-1 NPP are presented, which were measured by Macášek F. et al. [36]. Samples were collected from the environment in different parts of surroundings of the Bohunice NPPs and from waste-water of channel Manivier, discharged from Bohunice NPPs. Water from Manivier Canal flows into Vah River after 5.2 km. Inorganic as well as organic samples (soils, sediments, aerosols, grass, clover, cereals, corn, sugar beet, aquatic plants) were analysed [36].

Table 2. Results of determination of strontium-90 and plutonium-239/240 in samples of soils from surroundings of A-1 NPP [36].

Sample No.	Depth, cm	Ash, g	Content of radionuclides in dry sample			
			Pu-239/240 Bq·kg^{-1}	Cs-137 Bq·kg^{-1}	Ratio Pu-239,240/Cs-137	Sr-90 Bq·kg^{-1}
Sediments:						
1. V. Kostoľany	0÷5	20	0.28±0,08	15.7±0.6	1.8·10^{-2}	<1.2
2. V. Kostoľany	0÷5	20	0.21±0,03	25.7±0.4	8.2·10^{-3}	7.2±1.0
3. Žlkovce	0÷5	20	0.28±0,05	45.7±1.9	6.1·10^{-3}	<1.2
4. Bučany	0÷5	20	0.43±0,05	221.8±8.9	1.9·10^{-3}	2.9±0.8
5. Sereď	0÷5	20	<0.11	45.9±1.9	-	4.8±1.0
Aqueous plants						
6. Bučany		20	0.43±0.05	108.0±4.36	4.0·10^{-3}	0.7±0.3
7. V. Kostoľany		20	<0.11	2.6±0.18	-	<4.9
Soils						
8. Žlkovce	0÷5	20	0.22±0.06	30.8±1.3	7.1·10^{-3}	<1.2
9. V. Kostoľany	0÷5	20	0.11±0.04	11.1±0.48	9.9·10^{-3}	<1.2
10. Radošovce	0÷5	20	0.16±0.02	10.9±0.29	1.5·10^{-2}	2.4±0.6
11. Pečeňady	0÷5	20	0.31±0.08	10.6±0.24	2.9·10^{-2}	<1.2
12. Ninná	0÷5	20	0.23±0.07	9.9±0.25	2.3·10^{-2}	1.6±0.5
13. Katlovce	0÷5	20	0.29±0.05	7.7±0.38	3.8·10^{-2}	<1.2
14. Krakovany	0÷5	20	0.14±0.04	12.7±0.57	1.1·10^{-2}	<1.2
15. Žlkovce	0÷5	20	0.22±0.03	30.8±1.3	7.4·10^{-2}	1.6±0.9
16. JE Bohunice	0÷5	20	<0.18	29.8±1.2	-	2.5±0.5
17. Trnava	0÷5	20	0.15±0.03	25.7±0.4	5.8·10^{-3}	5.7±0.6

In the Table 3 the typical values of activities of the Sr-90 and Pu-239,240 in different group of samples are summarized [36].

Table 3. Typical values of activities of the Sr-90 in different group of samples [36].

Type of sample	Sr-90 MDA	Min. – max Measured values	Pu-239,240 MDA	Min. – max Measured values
Aerosols	930 nBq.m^{-3}	(930 ÷ 1460) nBq.m^{-3}	11.5 nBq.m^{-3}	(11.7 ÷ 42.9) nBq.m^{-3}
Soil, sediments	1.2 Bq.kg^{-1}	(1.6 ÷ 4.7) Bq.kg^{-1}	0.31 Bq.kg^{-1}	(0.31 ÷ 0.43) Bq.kg^{-1}
Precipitation	99 mBq.m^{-2}	(99 ÷ 110) mBq.m^{-2}	5.9 mBq.m^{-2}	(5.9 ÷ 15.9) mBq.m^{-2}
Grass, clover	0.3 Bq.kg^{-1}	(0.35 ÷ 3.7) Bq.kg^{-1}	9.1 mBq.kg^{-1}	(9.3 ÷ 19.2) mBq.kg^{-1}
Aqueous plants, cereals, corn, sugar beet	0.17 Bq.kg^{-1}	(0.17 ÷ 25.2) Bq.kg^{-1}	2.7 mBq.kg^{-1}	(2.9 ÷ 3.5) mBq.kg^{-1}

Result of two-year measurements of ^{90}Sr and ^{239,240}Pu in the samples of the environment shown [36], that levels of activity in these samples are low (Table 2). Their occurrence in soils, sediments and aquatic plants can be explained by global precipitation and influence of decommissioned A-1 NPP in 1979. Values of radioactivity in aerosols and precipitations were generally under detection limit and they were detected only exceptionally. Radioactivity of samples of food chain was on level of detection limits. Samples taken from Manivier Canal had the highest values of activity of all samples of the environment. Activities of $^{239,240}Pu$ correlate with activities of ^{137}Cs.

In the Table 4 the results of radiochemical analysis of reservoir of long-time storage of radwastes from accidental A-1 NPP (Mátel, Ľ., et al., 1997) 37] are presented, which contained 530 m^3 of radwastes of spent fuels in caskets.

Table 4. Results of radiochemical analyses of tanks of long-term storage of radioactive wastes from accidental A-1 NPP [37].

Nuclide	Activity, MBq·dm^{-3}
$^{239,240}Pu$	$(47 \pm 3).10^{-6}$
^{238}Pu	5.10^{-6}
^{241}Pu	$(29 \pm 3).10^{-6}$
^{90}Sr	$(48 \pm 4).10^{-3}$
^{99}Tc	$<8\cdot10^{-6}$
^{137}Cs	196 ± 2
^{129}I	$(170 \pm 40).10^{-6}$

Morávek J. et al in 1998 monitored [31] radioactivity of aerosols in surroundings of the Bohunice NPPs. Presence of the ^{60}Co was already only sporadic, what is evidence about fact that activity of aerosols is only minimally influenced by the closeness of the A-1 NPP in the present time. Activity of the ^{137}Cs and ^{60}Co in locality of Jaslovske Bohunice (in area of the A-1 NPP) is gently higher in consequence of local influences. Volume activity of ^{137}Cs in atmospheric aerosols in Prague ranged [38] in 1996 on the level (0.5 ÷ 1.5) µBq.m^{-3} with maximal activity 2.8 µBq.m^{-3} in January, what are the values at average less than tenfold lower than values measured in the locality of the A-1 NPP.

Rehabilitation of territory, affected by accident at A-1 NPP

In the present time it is working on rehabilitation of territory [39]. 19 km long banks of collecting channel of waste-water of Bohunice NPP (Manivier Canal (0.3 m^3.s^{-1}) and of Dudvah River (0.8 m^3.s^{-1}) were contaminated by ^{137}Cs in consequence of two accidents in A-1 NPP in 1976 and 1977 years. Till 1992 the waste-water from NPP were dissipated through 5 km long canal into Dudvah River (Q_a 1.8 m^3.s^{-1}), flowing after 13 km into Vah River (150 m^3.s^{-1}), which flows into Danube River after 90 km. Between 1976 and 1978, when the both accidents happened, the project of construction of devices for control of floods in Dudvah River in the length of 8 km upstream from its mouth. On the another part of upstream of Dudvah River on the section with length about 5 km, influences by NPP, the control of conditions of floods is insufficient and it attracts an attention of public up to this day. Contamination of the banks and its impact was founded in 1991 in connection with preparation of project of realisation of regulation of floods. In consequence of finding of contamination the realisation of project of regulation of floods was stopped. In 1992 NPP Bohunice, which are considered as responsible for contamination of the locality, initiated project of rehabilitation of the bank including shallow digging of removed soil. Supervisory authority accepted level of contamination 1 Bq.g-1 for 137Cs *ad hoc*. Repository of contaminated soil was projected as subsurface concrete construction with planned capacity of

5,000 m^3 within area of NPP. This area was selected as the most acceptable place of disposal site for neighbouring inhabitants [39].

Radioecological characterisation of contaminated riverbanks

Detailed radioecological survey realised since 1992 to 1994 showed [39], that upper layer of soil on river banks is contaminated by ^{137}Cs in wide range from level of background up to approximately 20 $kBq.kg^{-1}$ (3.8 $MBq.m^{-2}$) at Dudvah River and runs until up to 250 $kBq.kg^{-1}$ on some irregular contaminated limited segments of banks of the Manivier Canal. Mean activity of ^{137}Cs in upper part of banks reaches 6.3 $kBq.kg^{-1}$ in upper 10 cm layer of soil. Total contaminated area of sites with activities of ^{137}Cs exceeding 1 $kBq.kg^{-1}$ (selected as preliminary working limit by inspection organ) represents the area about 67,000 m^2. Volume of soil, which is necessary to be removed, is about 13,000 m^3 [39].

Slávik and Morávek estimated [39], that contaminated banks are accessible for 16,000 inhabitants living along 3.5 km wide zone along river. According to scenario they evaluated risk of persisting of people on the banks (300 hours of fishing, food consumption). The effective dose did not exceed (in 1993) 0.35 $mSv.r^{-1}$, although the potential risk of irradiation in consequence of using of contaminated soils reached an effective dose up to 2 - 3 $mSv.y^{-1}$. They evaluated year collective dose from persisting on the banks maximally up to (100 ÷ 200) manSv on the basis of low intensity of using of the banks. Potential risk from irradiation for critical group of persons on contaminated banks must not exceed the limit 1 $mSv.y^{-1}$.

Average level of contamination by ^{137}Cs of upper layer of soil (10 cm) of banks was AL_{50} = 7.1 $kBq.kg^{-1}$ continually along 80 m long segments, that is equal to critical potential dose of limiting requirements [39]. The activity of ^{137}Cs equal to 25 $kBq.kg^{-1}$ for isolated spots was proposed for irregularly contaminated banks of the Manivier Canal. In according to principles of supervising organ it was determined that it is necessary to clean the layer of the soil on the area of 9500 m^2 of contaminated inundation territory [40]. It was proposed to remove only isolated contaminated spots on irregularly contaminated zones of canal. It means that final volume of soil, which is necessary to be removed from banks and deposited safely in concrete repository within area of the Bohunice NPP, represents about 1,100 m^3 [39]. Total price of works was evaluated up to approximately 100 000 U.S.A. dollars [41].

The worst contaminated soils have already been removed and are stored in drums nowadays; however, some hot spots still remain. As a mitigation measure, water is being pumped out of the aquifer underneath and discharged into the river [42].

Quite a large amount of the contaminated soil removed during excavation of the groundworks for the new waste processing centre in Bohunice has been tentatively stored in old unused concrete basins and landscaped to a ‘green field’ condition. Yet, it is still part of a nuclear facility under regulatory control [42].

The dominant radionuclide in underground water in area of the A-1 NPP is tritium. Since 1997 EKOSUR realises rescue pumping of contaminated underground water [43]. Results of monitoring and rescue pumping are shown on the Figure 11.

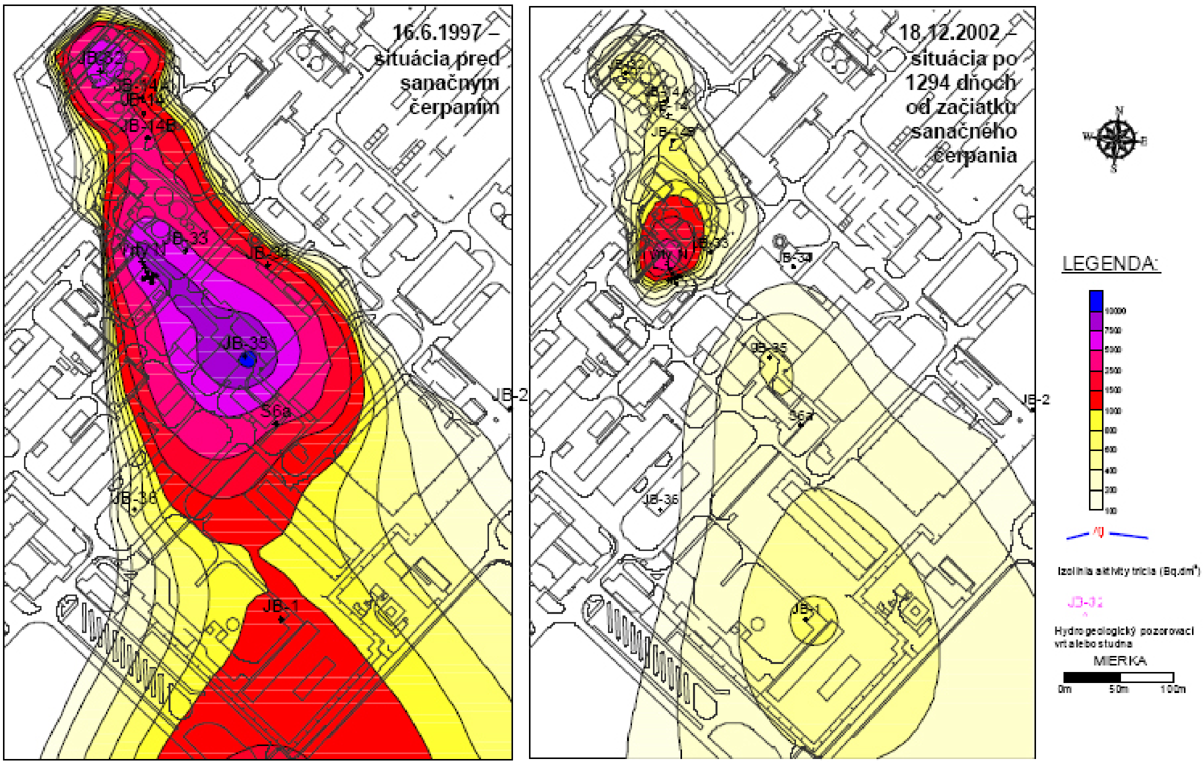

Figure 11. Results of standard monitoring of underground water in area of SE VYZ [43]. Isolinies of tritium volume activities [Bq·dm^{-3}] – situation of June 16, 1997 and December 18, 2002.

For damages caused by secret accident at A-1 NPP in 1977 the village Jaslovske Bohunice requires from Slovenske elektrarne, j.s.c. the compensation in amount of 2 milliards Slovak crowns (about 80 millions U.S.A. dollars) [44]. The self-government is ready to appeal on law-court with complaint.

Letkovičová M. et al. has studied [45] health state of inhabitant in the neighbourhood of the NPPs Jaslovske Bohunice, totally by 43 criteria. According to 15 health criteria the existence of nuclear power plants in this locality has a positive influence on health state of inhabitants. They explained it mainly by influence of NPPs on employment rate and improvement of living standard of local population.

In the present time the intensive decommissioning of the A-1 NPP Jaslovske Bohunice is realised [46 – 50].

Mičieta K. and Murín G. studied [51] bio-indication of radioactive-contaminated sites around Jaslovske Bohunice nuclear power plants. In total, more than 67,000 m^2 of riverbanks have been found as contaminated at levels exceeding 1 Bq ^{137}Cs g^{-1} of soil. Used phytotoxic and cytogenetic “in situ” tests were extended by analyses of pollen grains. Although the dose of some samples of radioactive soil was relatively high (322 kBq·kg^{-1}) no significant impact on the biological level of tested wild plant species was observed [51].

Conclusion

Thanks to fact that during some years the first incident as like as the second accident at A-1 NPP were more or less guarded, it may be noted, that about the second reactor accident what happened on February 22, 1977, and which belongs to the most serious accidents at civil nuclear reactors, up to the present time is unknown not only among public but also among specialists in the world. Recently the article of Gustav Murín about development of incident and accident on A-1 NPP was published in newspaper [52]. Behaviour of both incident and accident indicates the imperfect construction of nuclear reactor KS 150 as well as the mistakes of operating personnel at on-load changing of spent nuclear fuel.

Contamination of area of the A-1 NPP and consecutively of the riverbanks and sediments of Manivier Canal and Dudvah River in consequence of excessive rainfalls in the locality of Jaslovske Bohunice indicates the deficiency of project of A-1 NPP, pertinently the mistakes of personnel. In the present time the decommissioning of the A-1 NPP is realised with progressive decontamination of devices, rooms and facilities. It will be evidently long-term process, which will need high financial costs yet.

Contamination of the environment by radionuclides from accidental A-1 NPP needs permanent monitoring of underground water, sediments, soils and aerosols and consistent realisation of measures for remediation and isolation of mostly contaminated soils as well as permanent outflow of underground water in neighbourhood of area of the A-1 NPP.

Materials introduced in this paper were presented partially in our previous papers [53÷55].

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