R E P O R T

ON

OPERATION OF NUCLEAR FACILITIES

IN SLOVENIA IN 1991

Ljubljana, November 1992

Republic of Slovenia
SLOVENIAN NUCLEAR SAFETY ADMINISTRATION

A B S T R A C T

Slovenian Nuclear Safety Administration (SNSA) is responsible for: nuclear safety, transport of nuclear and radioactive materials, safeguarding nuclear materials, and conducting regulatory process related to liability for nuclear damage, qualification and training of operators at nuclear facilities, quality assurance and inspection of nuclear facilities.

The major nuclear facility supervised by SNSA is the Nuclear Power Plant in Krško with a pressurized water reactor of 632 MW electric power. Beside the nuclear power plant, TRIGA Mark II Research Reactor of 250 kW thermal power operates within the Reactor Center of Jožef Stefan Institute. There is an interim storage of low and medium radioactive waste at the Reactor Center. Also the Uranium mine Žirovski Vrh was supervised by SNSA.

All the nuclear power facilities in Republic of Slovenia were operating safely in 1991. There were no significant events that could be evaluated as a safety problem or a breach of technical specifications.

A great part of activities of SNSA was focused on the next visit of the IAEA OSART team (Operational Safety Assessment Review Team) in Krško Nuclear Power Plant and on the visit of the INSARR mission (Integrated Safety Assessment of Research Reactors) for the TRIGA Mark II Research Reactor.

1. INTRODUCTION

Slovenian Nuclear Safety Administration (SNSA) is responsible for: nuclear safety, transport of nuclear and radioactive materials, safeguarding nuclear materials, and conducting regulatory process related to liability for nuclear damage, qualification and training of operators at nuclear facilities, quality assurance and inspection of nuclear facilities.
In the year 1991 Slovenian Nuclear Safety Administration became a part of Ministry for Environment and Regional Planning. In accordance with the recommendations of the International Atomic Energy Agency the SNSA is not supposed to promote nuclear power, therefore it is separate and independent from the Ministry of Energy which is in charge of power utilities.

The major nuclear facility supervised by SNSA is the Nuclear Power Plant in Krško with a pressurized water reactor of 632 MW electric power. Beside the nuclear power plant, TRIGA Mark II Research Reactor of 250 kW thermal power operates within the Reactor Center of Jožef Stefan Institute. There is an interim storage of low and medium radioactive waste at the Reactor Center. Also the Uranium mine Žirovski Vrh was supervised by SNSA.

All the nuclear power facilities in Republic of Slovenia were operating safely in 1991. There were no significant events that could be evaluated as a safety problem or a breach of technical specifications. The only significant event was the war in Slovenia when the Krško Nuclear Power Plant was shut down preventively on the SNSA request.

A great part of activities of SNSA was focused on the next visit of the IAEA OSART team (Operational Safety Assessment Review Team) in Krško Nuclear Power Plant and on the visit of the INSARR mission (Integrated Safety Assessment of Research Reactors) for the TRIGA Mark II Research Reactor.

Initiative, that Slovenia should become a member of the IAEA was given by the SNSA in October 1991.

The major competences of SNSA stipulated by laws are relevant to safe operations of Krško Nuclear Power Plant and the supervision over the operations of nuclear facilities in the Republic of Slovenia which represented the greatest part of activities of SNSA in 1991.

The operation of Krško Nuclear Power Plant was supervised by nuclear safety inspection in accordance with regulations and licences.

Totally of 51 planned inspections in the Nuclear Power Plant Krško and 3 planned inspections in TRIGA Mark II Research Reactor were performed by SNSA. Besides, unplanned inspections were carried out at Krško Nuclear Power Plant. They were performed either by the nuclear safety inspection or by the other regulatory bodies. This cooperation was successful and will continue also in the future, specially in the joint systematic inspection check-ups.

In 1991 SNSA has issued amendments to the licensee of the Krško Nuclear Power Plant relevant to meteorological and radiological monitoring of the surroundings of the Krško NPP, probabilistic safety analysis and program of permanent training and retraining of personnel.
In 1991 SNSA has also issued 3 amendments to the licensee of the Reactor Center Podgorica for the TRIGA Mark II reactor allowing reconstruction and modification of the research reactor Triga Mark II, approving Revision 2 of the Safety Analysis Report, and the Limiting Conditions for Operation after reconstruction and modification.

In 1991 SNSA employed two new professionals (Adviser to the director and Nuclear Safety Inspector). A lot of attention was given to the training of the staff.

Within SNSA there is an Advisory Commission on Nuclear Safety (22 members) which met four times in 1991 and treated the most important matters in the field of radiation protection and nuclear safety related to the operation of nuclear facilities. The Advisory Commission on Nuclear Safety also treated the Krško NPP Outage Report for the year 1990, Krško NPP Performance Report for the year 1991 and Annual Operating Report for 1990 of the TRIGA Mark II Research Reactor and the Uranium Mine Žirovski Vrh Report for the year 1990.

The Commission for Testing of Employees Skills in Nuclear Facilities held three examinations. 27 candidates have applied; 11 candidates for senior reactor operators and 16 for reactor operators. 22 candidates passed the tests successfully. Five candidates (1 candidate for senior reactor operator and 4 candidates for reactor operators) did not pass the exam, and have to reapply.

2. OPERATION OF NUCLEAR FACILITIES

2.2.1 KRŠKO NUCLEAR POWER PLANT

2.2.1.1 Main Operational Data

In 1991 Krško NPP has generated 4,950,756 MWh gross of electrical energy at the outlet of the generator, i.e. 4,718,220 MWh net. The generator was connected to the national grid 8133.6 hours or 92.85% of the total number of hours in the year. The output plan was surpassed by 8.22%. Table 2.2.1 shows the pace of output compared to the planned.

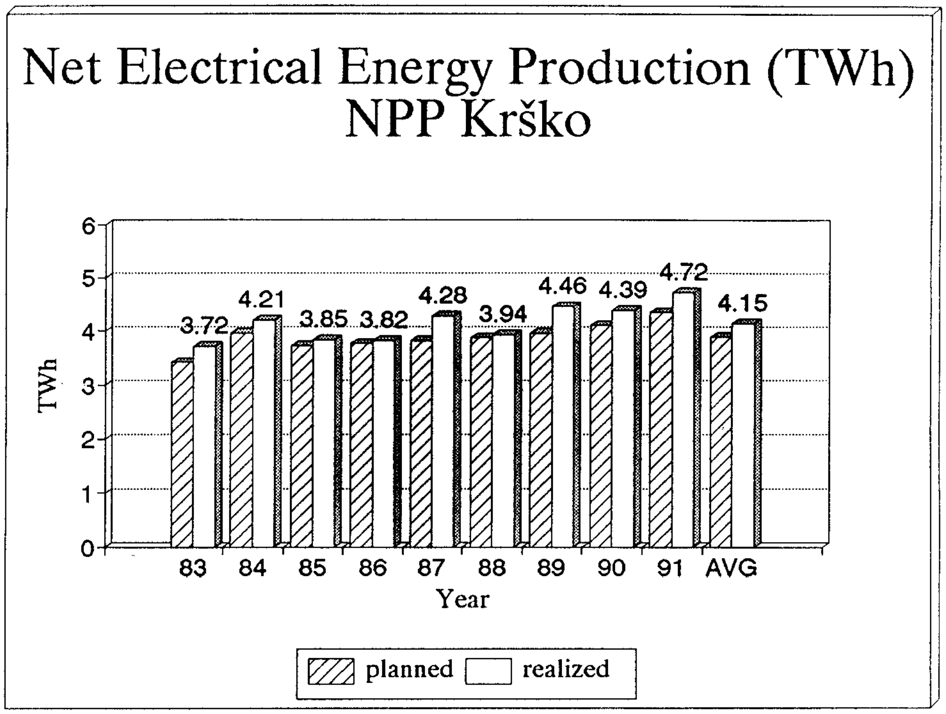
Table 2.2.1: NPP Krško net electrical energy generation in 1991

Month	Planned Output (GWh)	Actual Output (GWh)	Difference (%) **
JAN	350	366	4.7
FEB	320	415	29.8
MAR	380	431	13.5
APR	400	446	11.6
MAY	400	457	14.2
JUN	360	332	-7.7 *
JUL	340	164	-51.6 *
AUG	320	348	8.9
SEP	350	405	15.7
OCT	380	451	18.7
NOV	380	443	16.5
DEC	380	456	20.0
TOTAL	4,360	4,718	8.22

* Krško NPP did not operate in June and July or operated at reduced power because of the war in Slovenia.

** (Actual Output - Planned Output)/(Actual Output) (%)

Figure 2.2.1: NPP Krško net electrical energy production (TWh)



In 1991 the reactor was critical 8188.7 hours or 93.48% of the total number of hours in that year. The generation of thermal energy amounted to 14,420,235 MWh, the average burnout of fuel was 13,191.0 MWD/MTU.

Important indicators of good performance of the power plant are availability, capacity factor and number of forced shutdowns.

Table 2.2.2: Reliability indicators of operating of NPP Krško in 1991

	Year 1991 (%)	Average (%)
Availability factor (%)	97.37	80.14
Capacity factor (%)	86.69	76.44
Forced outage factor (%)	0.5	1.48

Figure 2.2.2: NPP Krško availability factor

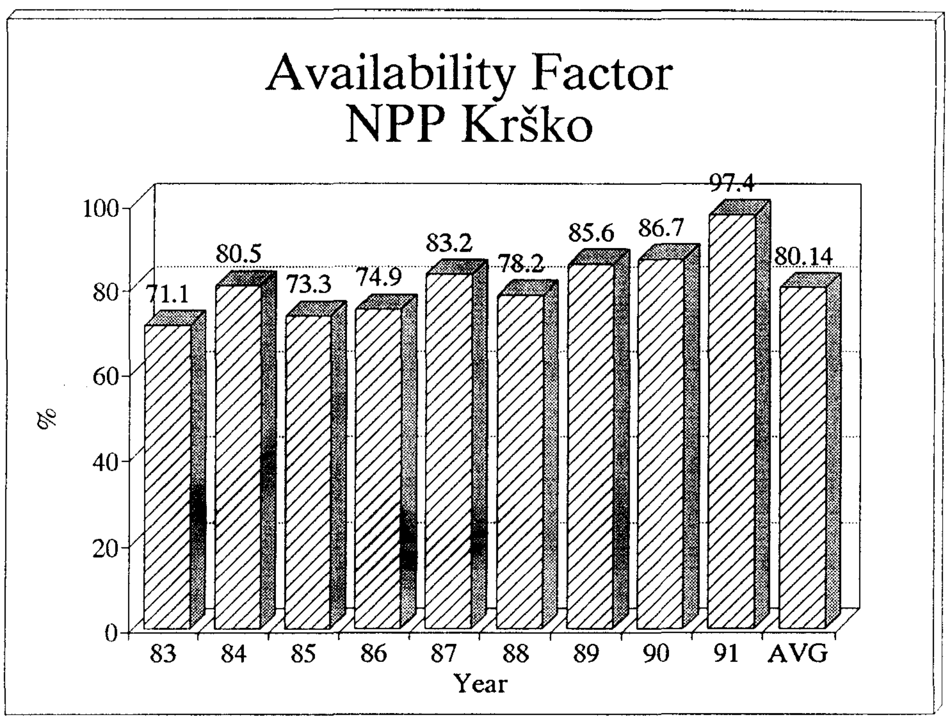


Figure 2.2.3: NPP Krško capacity factor

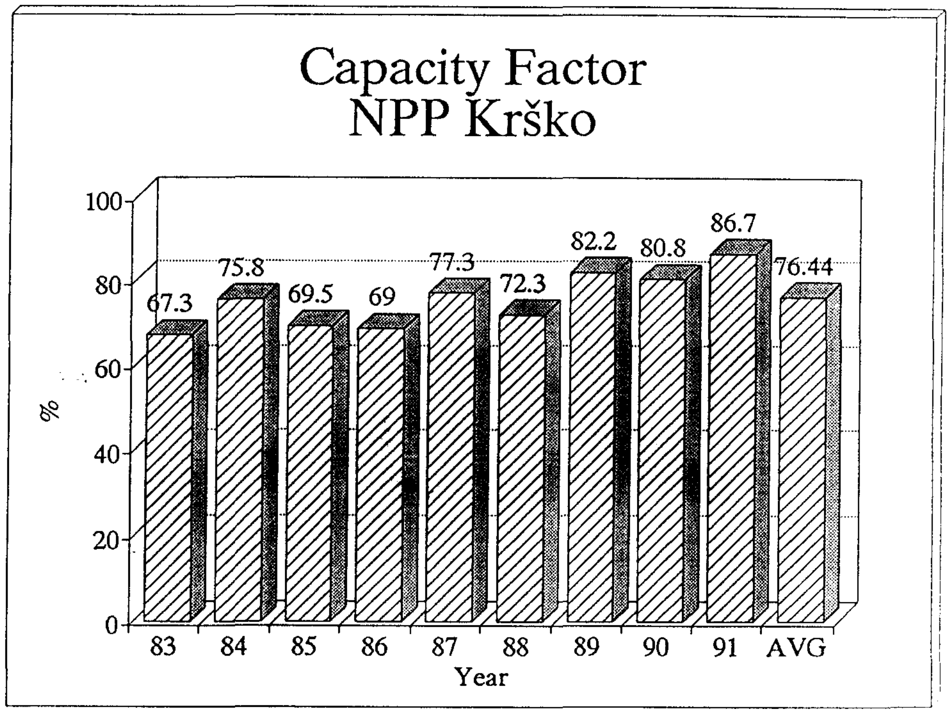


Table 2.2.3: NPP Krško time consumption in 1991 relevant to output

Time analyses of output	Hours	Percentage (%)
total available time	8760	100
plant operating time	8133.6	92.85
total outage time	626.4	7.15
maintenance	187.0	2.13
planned shutdowns	395.6	4.52
unplanned shutdowns	43.8	0.50

Table 2.2.4 shows the events due to which the Krško NPP was shutdown in 1991. It contains information on modes of shutdowns of power plant, causes of shutdowns and their duration.

Table 2.2.4 Planned and unplanned shutdowns

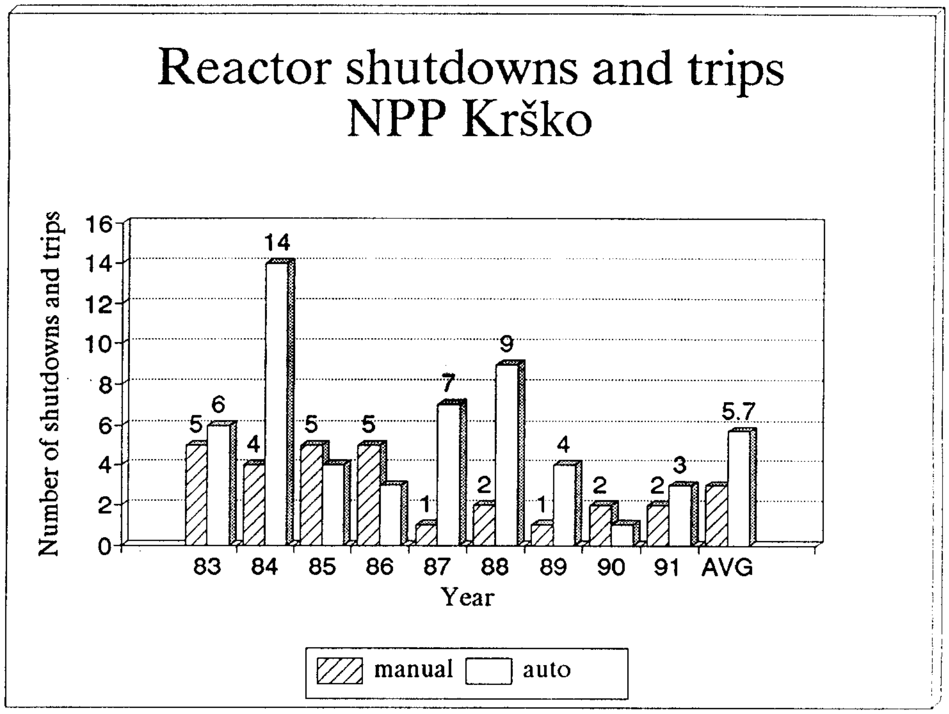
2.1.91 At 01:36 the main generator of the Krško NPP was synchronized to the electrical grid. The reactor power before synchronization was 10%. After the synchronization the reactor operator started to raise the power. The setpoint for the " Hi Neutron Flux - Intermediate Range " reactor trip was set too low which caused the reactor trip at 01:38:54, followed by the turbine trip. The reactor coolant system was stabilized at no-load parameters.(2 h)

2.1.91 During generator protection tests the generator is disconnected of the grid (the switch is in "MANUAL" and switched off). During this test the reactor power raised above 10% which caused reactor trip. The reactor protection system automatically trips the reactor, if the turbine trips at the power above 10% of either the turbine or the reactor. When the generator was disconnected at 17:25 the turbine automatically tripped (function of turbine protection system). (2.9 h)

15.3.91 Reactor operated at rated power. Due to the problems on the seal and cooling water, the circulating water pumps tripped. The circulating water pumps provide cooling of the condenser. The pressure in the condenser increased due to insufficient cooling. The plant operators immediately started to lower the the turbine power. The pressure was still raising. At the pressure value which is not allowed to operate the turbine the operator manually stopped the turbine. Turbine trip caused reactor trip. (28.5 h)

13.6.91 At 8:46 the reactor at the Krško NPP tripped due to transient in the main feedwater heaters. Hi-level in the steam generator caused turbine and reactor trip. (155 h)

Figure 2.2.4: NPP Krško reactor shutdowns and trips



2.2.1.2 Integrity of Reactor Fuel

In the process of electricity generation fuel integrity depends on reactor operation history. This year the 9th fuel cycle was going on. The 9th fuel cycle ended April 30, 1992.

The integrity of the fuel in the reactor is monitored indirectly by the reactor coolant activity. The specific activities of a greater number of isotopes are measured at stable operations as well as during transient phenomena.

In order to evaluate the type and scope of fuel damages the iodine-131 (T=8.05 days), its ratio to iodine-133 (T=20,8 hours), ratio of cesium isotopes, behavior of specific activities of iodine and xenon isotopes relevant to time and reactor power and activities of iodine-134 (T=53 min) are measured.

The activity of iodine-131 is an indicator of the scope of damages in the core and it is due to different half-lives in the ratio of iodine-131/iodine-133 being a very good indicator of the size or type of damages. The diffusion time for a given isotope is a function of damage size. In relatively small damages we may expect smaller concentrations of isotope 133 and an increased ratio of the mentioned isotopes.

Iodine-134 is, due to short half-life (it can hardly get trough cladding by diffusion), a good indicator of primary cycle contamination by uranium. Its concentration is used as a correction of activity for other isotopes due to contamination of the cycle.

The ratio of cesium isotopes is an indicator of the damaged fuel region. Both isotopes depend on burnout and their share in the fuel grows with higher exposure of fuel to thermal neutron flux.

Table 2.2.5: Comparison of characteristic values of isotopes Concentrations for the 7th, 8th and 9th cycle

ISOTOPE	7th CYCLE (1989) ACTIVITY (GBq/m3)	8th CYCLE (1990) ACTIVITY (GBq/m3)	9th CYCLE (1991) ACTIVITY (GBq/m3)
I - 131	0.08	0.025	0.014
I - 133	0.55	0.34	0.096
I - 134	2.22	1.22	0.34
Xe- 133	32.3	7.4	10.0
Xe- 135	2.96	0.89	1.26
Xe- 138	0.93	0.52	0.15
Kr - 85	1.11	0.26	0.35
Kr - 87	0.48	0.19	0.13
Kr - 88	1.11	0.32	0.41

Table 2.2.5 shows that the values of the 8th cycle are better than for the 7th cycle. One can derive from this that the fuel quality for the 7th cycle was very good, that the dispersed uranium of former cycles, which pollutes the coolant, prevails and that the leakage of fuel is under the detection limit. Table 2.2.5 also shows that the pollution of the coolant did not increase during the 9th cycle.

2.2.1.3 Radioactive Emissions to the Environment

The limiting values of radioactive emissions into environment are stipulated by the licence to start operations of the Krško NPP No. 31-04/83-5 issued on February 6, 1984 by the Republic Energy Inspection Authority. The emissions of radioactive waste into the Sava River are at the level of few percentage of limiting values of the licence for all radionuclides, except for tritium for which the annual emitted activity exceeds the half of the limiting value stated in the licence. The same is valid for air emissions

for the Krško NPP. The limiting values for tritium are considerably lower from those stipulated or enforced in licences issued for nuclear power plants in other European countries.
The relevant administrative authorities are regularly informed about the emissions in regular and special reports by Krško NPP. Regular reports are made on a monthly and yearly basis. Special reports are mostly relevant to planned emissions from containment before its venting. The Krško NPP daily informs relevant administration bodies in regular operation reports about the type and activity of emissions of radioactive waste into the Sava river.

Figures 2.2.5 and 2.2.6 show released tritium activity and released liquid activity during past years.

Figure 2.2.5: Released liquid activity (Krško NPP)

Figure 2.2.6: Released tritium activity (Krško NPP)

2.2.1.4 Doses Received by Personnel

The average exposure to irradiation of the personnel in the power plant is low and does not exceed 1/20 of the prescribed limiting value for professionals. The received doses are higher during refueling and maintenance operations than during the normal operation. The dose limits for nuclear power plant and contractor workers were obeyed, and the received doses were even below the latest ICRP recommendations as well.

Table 2.2.6 shows the distribution of effective equivalent doses of personnel that worked in 1991 within the fence of the Krško NPP from 1981 to 1991. Beside power plant personnel, subcontractors are also included in the table. The table shows that 8 persons have received the annual effective equivalent dose above 5 millisieverts (mSv).
The collective effective equivalent dose of the plant personnel was 0.2451 manSv. For other people including the personnel of main contractor the equivalent dose in 1991 was 0.0686 manSv. The annual collective effective equivalent dose per unit of electrical power generated was 0.56 manSv/GWyear (UNSCEAR 1988 sets the average for west European power plants at 4 man Sv/GW year). Table 2.2.7 shows collective effective equivalent doses of irradiation at Krško NPP in 1991 relevant to activities and Table 2.2.8 shows collective and average doses in 1991.

Table 2.2.6: Distribution of effective equivalent doses for all workers at Krško NPP during years 1981 and 1991

Range of doses mSv/year Year	0-1	1-5	5-10	10-15	15-20	20-25	Total
1981	475	45	0	0	0	0	520
1982	275	313	9	13	10	2	622
1983	462	206	53	45	34	31	831
1984	375	205	15	3	2	0	600
1985	517	277	79	17	2	0	892
1986	524	301	79	3	4	1	912
1987	486	242	65	16	6	1	816
1988	506	298	60	21	3	1	889
1989	443	200	66	19	3	0	731
1990	390	265	92	38	5	2	792
1991	257	89	8	0	0	0	354

Table 2.2.7: Collective effective equivalent doses of irradiation at Krško in 1991

Activity	Doses (manSv)		
	Krško per.	Subcon.	All
regular maintenance	0.2101	0.0686	0.2787
processing of radioact. waste	0.0349	-	0.0349
Total	0.2450	0.0686	0.3136

Krško per. - Krško personnel
Subcon. - Subcontractors

Figure 2.2.7: Collective effective equivalent doses (NPP Krško)

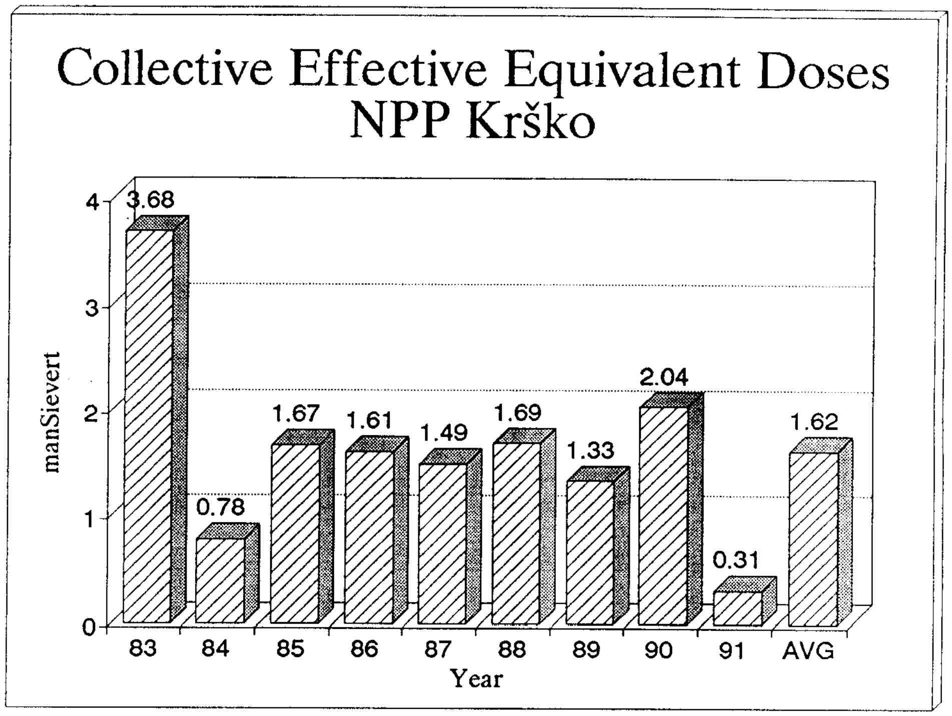
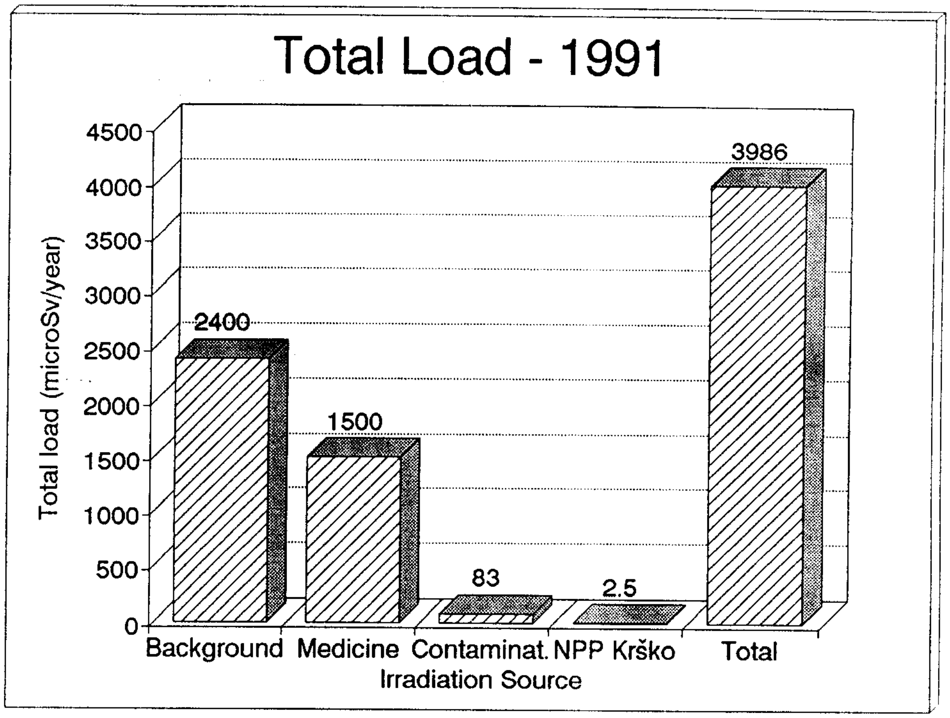


Table 2.2.8: Collective and average doses in 1991

Employees	Coll. doses (manSv)	No. of empl.	Average Dose (mSv)
Krško NPP	0.2450	278	0.9
Subcon.	0.0686	104	0.6
Total	0.3136	382	0.8

Subcon. - Subcontractors

Figure 2.2.8: Total load in the year 1991



2.2.1.5 Radioactive Waste

All radioactive waste is packed in the power plant in 200 liter barrels: low radioactive compressible waste without additional protection, other more active waste with additional protection which consists of concrete cylindrical liner inside the barrel.

In ten years of power plant operation 1648 m3 of waste in barrels have accumulated if protective concrete is included. Average specific activity in barrels is 21 GBq/m3.

Table 2.2.9: Radioactive waste in Krško NPP according to the type and activity at 31/12/1991

Type of waste	Number of barrels	Activity (GBq)	Volume (m3)	Specific Act. (GBq/m3)
SR	831	24740	166	149
CW	585	446	117	4
EB	6011	7656	1202	6
F	86	1774	17	104
O	111	20	22	1
SC	617	531	123	4
Total	8241	35167	1648	21

Type of waste:

SR - spent resin
CW - compressible waste
EB - evaporator bottom
F - filters
O - other waste
SC - super compacted waste

In the year 1991 the Krško NPP stored 279 standard barrels with concentrated evaporator bottom with total activity of 197 GBq and 94 standard barrels with compressible waste with total activity of 49.6 GBq.

2.2.1.6 Spent Nuclear Fuel

In the power plant spent fuel elements are stored in the spent fuel pool which has enough space for 17 refuelings and for the entire reactor core (121 fuel elements) as a permanent available reserve, if for what so ever reason, it was necessary to empty the reactor core. The capacity of the spent fuel pool is therefore sufficient for storage of used fuel elements at least until the year 2000.

There was no refueling in the year 1991.

2.2.1.7 Personnel Training

Peaceful use of nuclear energy requires highly trained personnel which is required also by regulations. Not only the level of education is stipulated by regulations but also programs of initial and permanent training as well as the system of checking of the skills of personnel for specific jobs and tasks as well. This is stipulated by internal regulations,federal and republic regulations (Official Gazette SFRY, No.86/87; Off. Gaz. of SRS No. 9/81) for Krško Senior Reactor operators, managers and department for protection against irradiation.

Krško NPP has its own training department which takes care of annual training programs. As in Slovenia there is no simulator of nuclear power plant, Krško training department organizes obligatory annual courses on a simulator abroad, mostly in the USA. All personnel that require the permit of operator or senior reactor operator were on refreshment courses in 1991 on a simulator of ZION NPP in the USA (47 participants from the Krško NPP). Each group had 7 day exercises, 28 hours in the classroom and 28 on the simulator. These people participated also at permanent training in spring and autumn according to the program which contains beside regular refreshment courses also studying of experiences from nuclear power plants in other countries and specialized topics like nuclear safety.

A course on Technology of Power Reactors and Systems and Operation of Krško NPP organized by Milan Čopič Educational Center for Nuclear Technology in Ljubljana was attended by 13 workers of the Krško NPP.

Three courses took place in the Krško NPP in the year 1991.

-April 17-19 : Zavod za istraživanje i razvoj sigurnosti organized a course on Explosive Detection attended by 10 workers from NPP.

-May 13-15 : Technical Management Services organized a course on Effective Contamination Control Programs attended by 14 workers from NPP.

-June 26-28 : Analysis and Measurement Services Corporation organized a course on On Line Measurement of Response Time and Calibration of RTD's and Pressure Transmitters in NPP.

2.3.1 TRIGA RESEARCH REACTOR

Jožef Stefan Institute's TRIGA Mark II research reactor at Podgorica in Ljubljana with power of 250 kW has been operating for more then 20 years. The reactor produces radioactive isotopes, mostly short-lived used in medicine, science and industry, deals in neutrons and gamma research, activation analyses, irradiation of materials for manufacturing of semiconductors and training of personnel.
In accordance with regulations all the necessary services for protection against irradiation, storage of radioactive waste and records and storage of nuclear fuel are organized in the reactor center.

2.3.1.1 Operational experiences

In 1991 Triga Mark II research reactor operated only from November 4. to December 20 because of reconstruction and generated 21.55 MWh of heat. Performance tests after reconstruction took place at this time. One refueling was made (55 new fuel elements). At the end of 1991 after tests there were 87 fuel elements in the core (27 new fuel elements and 60 old ones).
In the storage of Reactor center Podgorica there are 40 new fuel elements, one spent fuel element is in reactor building (in the protected barrel) other spent fuel elements are in a fuel storage building.

There were no damaged fuel elements.

a) Personnel: The following workers are in charge of reactor operation: head operator of reactor, five operators and service for protection against ionizing radiation.

b) Effective Equivalent Doses of Irradiation at Reactor Center Podgorica.

Reactor operators (9) have received effective equivalent doses of irradiation of gamma from 0.179 to 1.49 mSv.
Neutron doses were between 0.5 and 1.0 mSv.
Gamma doses included background dose (0.765 mSv/year)

c) List of performed improvements on the reactor building

- crane reconstruction
- protection of doors and windows at reactor building and nearby rooms
- addition of new door to the operating room
- emergency evacuation lights were installed

2.3.1.2 Interim Storage of Radioactive Waste in the Reactor Center Podgorica

Interim storage for solid low and medium radioactive waste for users in Slovenia (except for Krško NPP and Žirovski Vrh Uranium Mine) is functioning from 1987 on.

In 1991 the following activities have been going on:

- receiving and recording of additional radioactive waste,
- regular weekly supervision of the storage (visual and radiologic supervision).

There are three types of radioactive waste in the storage:

- closed barrels with contaminated objects (paper, plastics, glassware, etc.) and materials with induced activity due to irradiation in TRIGA reactor,

- other waste - bigger contaminated or active objects which due to their size cannot be stored in barrels and are therefore stored separately,

- closed sources - unusable closed sources of irradiation which are, as a rule, stored in original protected containers.

Quantity and activity of different types of radioactive waste are given in table 2.2.10. Previous state and changes in 1991 are also given. In 1991 the number of barrels has increased by 14, number of closed sources by 17, number of special waste 13.

Table 2.2.10: Radioactive Waste in the Transition Storage in the Reactor Center Podgorica at 31.12.1991 (cumulative)

Type	State	Isotopes *	Activity (GBq)
Barrels	125	Co-60, Cs-137, Eu-152, Ra-226	3-20
Special	63	Co-60, Ra-226, Am-241	10
Closed	75	Co-60, Sr-90	1100

* - isotopes providing the majority of activity are quoted only

3. RELEASED RADIOACTIVITY IN THE VICINITY OF NUCLEAR INSTALLATION

In Slovenia radioactivity of environment is being measured on the entire territory of the republic within the scope of so called Republic Program according to Regulations on locations, Methods and Time Schedule for Testing of Contamination with Radioactive Substances (Off. Gaz. SFRY No. 40/86).

Radioactivity in the vicinity of nuclear installations is regulated by Regulations on mode, scope and time schedule of systematic testing of contamination with radioactive materials in the vicinity of nuclear facilities (Off. Gaz. SFRY No. 51/86)

3.1 KRŠKO NUCLEAR POWER PLANT

All detectable and quantitatively evaluated loading of environment due to emissions of Krško NPP were under administratively allowed limiting values. Evaluated loading of persons and critical groups of population made as on the basis of evaluated emission values as on the basis of data of annual emissions of the Krško NPP by a computer model provides in 1991 values for the effective doses that are smaller than 10 microSv/year or smaller than 0.5% of annual dose received in average by a man in normally loaded environment by natural and artificial sources.

3.2 REACTOR CENTER AT PODGORICA

Because of reconstruction the Reactor Center at Podgorica was operating only a short time in 1991.
Monitoring of radioactive releases in 1991 is made on the basis of Program of regulation of radioactivity in the environment of the Reactor Center at Podgorica.

One can derive from the measured data (emissions) that two the most important effects on the environment were the following:

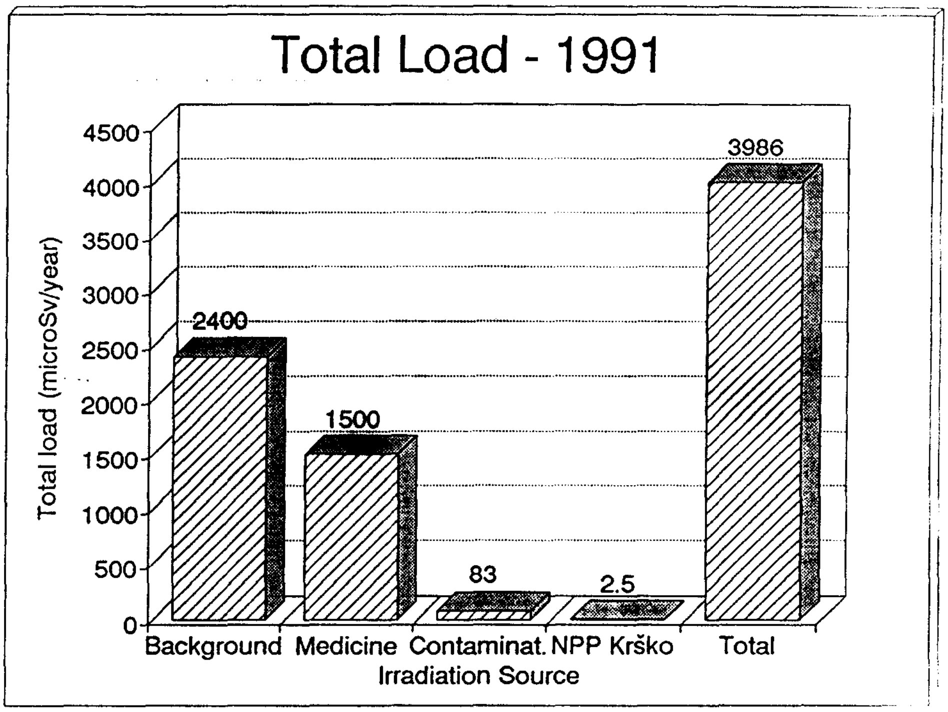
- discharge of Ar-41 into the atmosphere (ventilation system of reactor hall)

- discharge of radioactive substances in the Sava River with liquid waste from Department for Nuclear Chemistry.

Estimated year Effective Equivalent dose per person due to Ar-41 in the air is 40 nanoSv. (1991)
Estimated year Effective Equivalent dose per person due to discharge of radioactive substances in the Sava river is 0.9 microSv.

The dose was estimated on the basis of emission values, models of dispersion in the environment and dosimetric factors.
Figure 2.2.8 shows total load in the year 1991.

Figure 2.2.8: Total load in the year 1991



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