RADIOACTIVE RELEASE IMPACT FROM KOZLODUY NUCLEAR POWER PLANT, BULGARIA INTO THE ENVIRONMENT

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ABSTRACT

The aim of this paper is to present a general overview of the radioactive releases impact generated by Kozloduy Nuclear Power Plant (KNPP), Bulgaria to the environment and public.
The liquid releases presented are known as the so called controlled water discharges, that are generated after reprocessing of the inevitable accumulated liquid radioactive waste in the plant operation process.
The radionuclides containing in the liquid releases are given in the paper as a result of systematic measuring.
Database for radiation doses evaluation on the public around Kozloduy NPP site is developed using IAEA LADTAP computerized program.
The computer code LADTAP represents realization of a model that evaluates the public dose as a result of NPP releases under normal operation conditions.
The results of this evaluation were the basic licensing document for a new liquid release limit.

INTRODUCTION

The Nuclear Power Plant electricity production is more reliable and cheaper than conventional Thermal Power Plant all over the world. But we should not forget the two big accidents: at Three Mile Island Nuclear Power Plant in the USA (1979) and Chernobyl NPP in Ukraine (1986) at the same time. Both of them struck a hard blow on the development of the nuclear energy industry.

Nevertheless they can not stop NPP's construction and their operation. This my opinion is confirmed by the Nuclear Power Status Around the World of IAEA which shows that 438 NPP units are in operation with total net of 349063 MWe and 31 units are under construction with total net of 351 327 MWE at 31 IAEA's member states. Besides this 31 units are under construction with total net of 27 756 MWe (1).

Nuclear share of electricity generation as of April 2001 in some countries is very big. For example France keeps first place with 76,4%, Lithuania is the second with 73,7%, Belgium – third with 56,8%. Bulgaria is sixth in the world with 45,0%, as it is shown in IAEA's Bulletin Vol. 43, No. 2, 2001.(1).

Republic of Bulgaria has got 6 units PWR VVER type reactors Russian design at Kozloduy NPP site. The different power units were commissioned stage by stage as follows:

- First stage, 1974-1975 – units 1 and 2, equipped with VVER 440 reactors, model B 230;
- Second stage, 1980-1982 – units 3 and 4 of the same type and parameters as those of units one and two, but provided with some more safety systems improvements;
- Third stage, 1987-1992 – units 5 and 6, constructed according to a completely different VVER 440 unit concept. Each unit is equipped with a new generation reactor, VVER 1000, model 320.

The power plant total installed capacity of 3760 MWE defines it as a huge nuclear facility in the world, which is of a significant national and regional importance.

The individual units power generation during the year 2000, is given in Table I (2).

Table I. Power generation by individual units

Unit	**Generated electricity for 1999 MWh**	**Total electricity production for 2000 MWh**	**Relative share for 2000 %**	**2000 generation compared to 1999 %**	**Generation Plan for 2000 MWh**	**Plan 2000 fulfillment %**
1	1 402 226	2 115 978	13.52	150.90	2 109 480	100.31
2	1 909 819	1 397 841	8.93	73.19	1 233 600	113.31
3	1 530 110	1 990 135	12.72	130.06	1 945 320	102.30
4	1 847 692	2 281 729	14.58	123.49	2 062 680	110.62
5	2 945 434	3 968 303	25.36	134.73	4 188 720	94.74
6	4 643 077	3 896 595	24.90	83.92	3 458 160	112.68
Units 1 – 4	6 689 847	7 785 583	49.75	116.38	7 351 080	105.91
Units 5 & 6	7 588 511	7 864 898	50.25	103.64	7 646 880	102.85
NPP	14 278 358	15 650 581	100	109.61	14 997 960	104.35

The safe and reliable KNPP operation is due to the enhanced radiation protection and safe management of radioactive waste.

Discharges from the plant are in the form of gaseous effluents and liquid releases.

The radiation effects of liquid releases into environment must be in the frame of IAEA recommendation specified in Table II (3), which are adopted by Republic of Bulgaria.

Table II. Accepted liquid release limits at KNPP

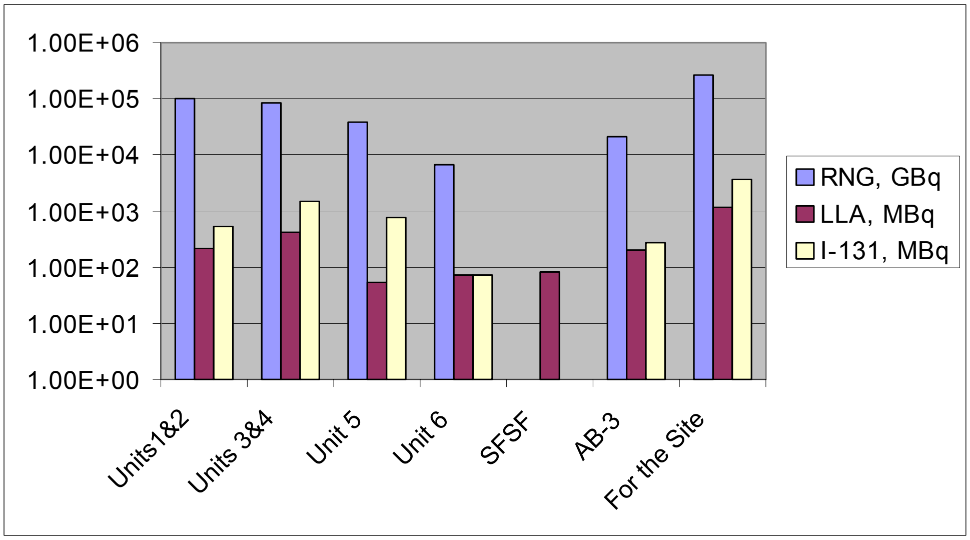
Dose	**Level**
Effective dose	1 mSv in a year. In special circumstances up to 5 mSv in a single year provided the average dose over five consecutive years does not exceed 1 mSv .
Equivalent dose to lens of the eye	15 mSv in a year
Equivalent dose to the skin	50 mSv in a year.

GAS-AEROSOL RELEASE IN THE ENVIRONMENT

The gaseous releases are monitored by two independent channels for each ventilation stack continuously. Control levels representing 10% of the permissible limit are established and are incorporated as an indicator for effective and safe power plant operation. The releases data is specified in Tables III, IV, V and VI (4)

Table III. Total Aerosol Releases Activity from Kozloduy NPP Ventilation Stacks

366 days	**Units** 1 & 2	**Units** 3 & 4	**Unit** 5	**Unit** 6	**AB-3***	**For the site**	
						total for the period	% of the permi-ssible limit
*RNG, GBq	96645	85437	38991	7706	22990	251769	1.0
**LLA, MBq	335	448	68	80	185	1186	0.2
I-131	551	1586	817	82	224	3260	0.6



*RNG – Radioactive Noble Gases
**LLA – Long Lived Aerosols
*** AB – Auxiliary Building

Table IV. Radioactive Noble Gases Release Emissions, GBq

Month	Units 1 & 2	Units 3 & 4	Unit 5	Unit 6	AB-3	For the site	
						total for the period	% of the permissible limit
I	10720	7370	5618	394	2302	26404	1.2
II	7870	7200	3499	942	1862	21373	1.0
III	9020	7280	3471	695	1729	22195	1.0
IV	8630	7020	4443	274	2102	22469	1.1
V	8130	7410	475	257	1744	19016	0.8
VI	6969	7304	495	326	1682	16776	0.8
VII	7220	7810	403	1099	1569	18101	0.8
VIII	7386	7323	2257	975	1581	19522	0.9
IX	7310	6880	4367	709	2229	21495	1.0
X	7000	6930	2793	1142	2024	19889	0.9
XI	9260	6100	4498	702	2001	22561	1.0
XII	7130	6810	6672	191	2165	22968	1.0

Table V. Long Lived Aerosols Emissions, MBq

Month	Units 1 & 2	Units 3 & 4	Unit 5	Unit 6	AB-3	For the site total for the period	For the site % of the permissible limit
I	34	87	4	3	11	143	0.2
II	28	13	5	4	11	66	0.1
III	37	40	6	5	10	105	0.2
IV	30	26	9	4	12	87	0.1
V	29	28	5	4	13	86	0.1
VI	27	32	4	4	15	88	0.1
VII	27	40	5	5	15	98	0.1
VIII	26	44	7	6	15	105	0.2
IX	26	37	11	8	17	104	0.2
X	23	40	4	24	26	124	0.2
XI	23	26	4	9	24	91	0.1
XII	25	35	4	4	16	89	0.1

Table VI. I-131 Emissions, MBq

Month	Units 1 & 2	Units 3 & 4	Unit 5	Unit 6	AB-3	For the site total for the period	For the site % of the permissible limit
I	74	72	15	4	11	176	0.4
II	39	97	7	4	10	157	0.4
III	47	100	6	6	8	167	0.4
IV	45	81	652	4	16	798	1.9
V	42	418	19	3	15	497	1.1
VI	37	161	13	2	22	235	0.5
VII	51	58	12	8	22	151	0.3
VIII	36	293	13	12	21	375	0.8
IX	40	143	47	11	23	264	0.6
X	41	67	15	13	23	159	0.4
XI	59	33	7	10	23	132	0.3
XII	40	63	11	5	30	149	0.3

The permissible limits for gas-aerosol releases total activity, referring to the KNPP site, are as follows:

- Permissible average value per day for radioactive noble gases (RNG) – 70 000 GBq;
- Permissible average value per day for long lived aerosols (LLA) – 2 000 MBq;
- Permissible average value per day for I - 131 – 1 400 MBq.

The total activity of the radioactive noble gases released in the environment is 251 769 GBq, which is 1% of the calculated permissible annual value; in terms of long lived aerosols it is 1 186 MBq, which is 0.2% of the calculated permissible annual value and for the I-131 – it is 3 260 MBq, which is 0.6% of the calculated permissible annual value. The individual stacks share is given in Table III.

The individual units operation is performed according to the approved Safety Criteria, Technical Specifications and Radiation Protection Instructions for power units 1 ÷ 6.

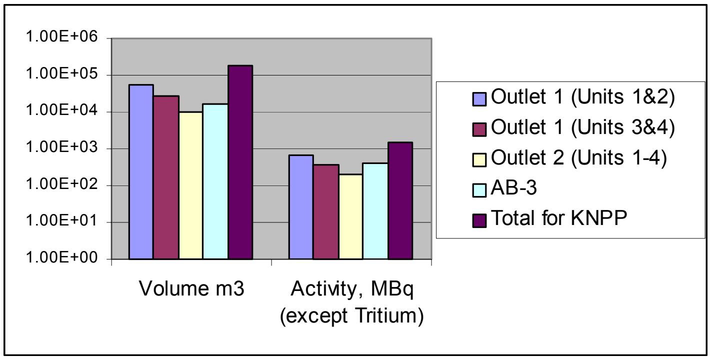
The individual gaseous emissions by months and ventilation stack are specified in Tables IV, V and VI.

LIQUID RELEASES INTO THE ENVIRONMENT

The total and specific activity of liquid waste releases in the Danube river by Kozloduy NPP in 2000 are lower than the permissible limits set by the Regulatory Body and agreed with the Health Ministry and Ministry of Environment. The measured values confirm the normal system and equipment for special water processing and purification functions in KNPP (Table VII).

Table VII. Radioactive Liquid Release in the Danube river

	Outlet 1 units 1 & 2	Outlet 1 units 3 & 4	Outlet 2 units 1 - 4	AB-3	Total for KNPP
Volume, m cub	55035	47160	8880	32368	143443
Activity, MBq (except Tritium)	855.233	592.808	98.718	484.51	2031.269



More details for the impact of liquid releases into the environment is given in the second part of the presentation.

RADIATION BACKGROUND

The dose rate activity (gamma background) in the monitored points on site, using "Berthold" portable devices, indicates that the radiation status within the KNPP fence area has no deviations from the specific natural values (Table VIII).

Table VIII. Gamma Background Registered by "KATRIN" System

Location	Minimum Value	Maximum Value
Entrance Gate 1 (units 1-4)/µSv/h	0.07	0.11
Entrance Gate 2 (units 5,6)/µSv/h	0.06	0.09

The monitoring is performed following an approved annual program.

RADIATION STATUS IN THE RESRTICTED CONTROL AREA (RCA)

Continuous radiation monitoring in the RCA is performed by the available automatic information systems for measurement of remote dose rate activity, specific volume activity in the premises and water in the process loops.

The process control systems by design are: "SYSTEMA 8004" – 500 channels for units 1 ÷ 4; "SEYVAL" system – 600 channels for units 5 & 6 and autonomous stationary radiometric devices.

The scope of monitoring, detector units, ranges and accuracy of measurement values, technical characteristics and all radiation monitoring equipment and systems components meet the instructions and regulatory document requirements.

A Radiation Protection Program and Prognosis Dose Budget are developed for each reactor unit outage campaign.

The plant operation practice shows that the set liquid releases activity limit by 1995 – 3.00E-10Ci/l (1,1Bq/l) is one of the reason to have accumulated bigger volume of RAW, as it is written in the project. This limit is very low comparing it to the limit used in other operating NPPs in Eastern and Western Europe.

WHAT IS NPP’S LIQUID RELEASE?

The moderator in primary circuits of the units contents nuclides that are product of the Uranium nuclear fission process, active corrosion elements and active natural moderator elements as well. Primary circuit of VVER is hermetically closed. But the nature of NPP technological process is such that it makes inevitable the release of some known nuclides, even in a very small quantities into environment.

At NPP operation there are two ways of nuclides to get into the environment: liquid controlled release in the cooling tank and aerosol releases through the ventilation stack. These nuclide releases are strictly controlled in order to avoid their concentration to exceed the maximum allowed limits for concentration of nuclides in water, air, soil, plants and animal products.

Radioactive liquids are produced in the process of decontamination of primary circuit equipment which are of high salt content but not in large volume.

While after decontamination of special protective clothing are produced radioactive liquids of low salt content and low radioactivity, the presence of detergents in large quantity makes difficult its processing. The total volume of those radioactive waters is about 30 000 m cub./year.

A technology for regeneration of ion exchange resins in special water cleaning system without primary circuit moderator cleaning system is accepted.

In the process of regeneration of ion-exchange resins highly radioactive liquid is generated having a very high salt content too.

All these radioactive liquids are evaporated and processed in order to obtain minimum quantity of radioactive waste for storage and disposal with the best economical and environment interest. The stream cools off after evaporation and the liquid phase is cleaned by carbon, ion exchange resins filter. This water, named as controlled liquid release, after the relevant control of the radiation level is discharged in the cooling reservoir (Danube river).

WHAT KIND OF RADIONUCLIDES ARE AVAILABLE IN THE LIQUID RELEASE?

The radionuclides in the liquid releases were found as a result of a systematic monitoring in the period 1990/1999 (5). They are most important in terms of public hygiene radiation. They are the following:H-3, Mn-54, Fe59-, Co-58, Co-60, Nb-95, Zr-95, Ru-103, Ag-110m, I-131, Cs-134, Cs-137. Dose exposure rate public evaluation was done using an average annual value of liquid release radioactivity in 1990 and 1991. The data of real radioactive releases were compared by projected values. In fact there is a slide shift of the real measured values of radioactivity of the controlled water discharges in the Danube river from those by the project (with one exception those of I-131). This demonstrates that if the evaluation of the public additional dose exposure from liquid releases is calculated on the base of the projected values this evaluation could not be sufficiently realistic. A group of 10 schoolboys which live in town of Oriahovo on the right bank of the Danube river in controlled zone of 30 km on the East of NPP were investigated. It should be pointed out that wind “rose” direction in the 100 km around

Kozloduy NPP is from West to East. Five years later the dose exposure of these schoolboys was investigated again. The radioactivity of the liquid releases in 1990,1991 and 1995 are shown in the following Table IX.

Table IX. Radioactivity of liquid releases into the environment for the specified years

	Radioactivity (Bq) in years		
Radionuclide	**1990**	**1991**	**1995**
Ag-110m	10,915E+07	5,735E+07	8,51E+07
Co-58	1.898E+07	2,449E+07	7,77E+07
Co-60	60,310 E+07	30,821E+07	20,35E+07
Cr-51	-	-	63,27E+07
Cs-134	52,540E+07	30,784E+07	19,61E+07
Cs-137	72,890E+07	54,02E+07	135,79E+07
Fe-59	0,9E+07	-	9,250E+07
I-131	7,548E+07	6,29E+07	7,03E+07
Mn-54	0,05E+07	0,818E+07	8,88E+07
Nb-95	3,563E+07	0,477E+07	0,477E+07
Ru-103	0,31E+07	-	5,92E+07
Zr-95	0,688E+07	-	5,55E+07
Sr-90	0,529E+07	0,222E+07	0,74E+07
Total	212,054E+07	131,616E+07	296,63E+07
H-3	0,105E+07	1,421E+07	0,498E+07

WHAT KIND OF PROBLEM IS IT?

Accordance to the requirements of regulations total radioactivity of controlled water discharges from NPP do not exceed 3.00E-10Ci/l (1.1 Bq/l) (5), by June the 1-st, 1995 as it was mentioned above. That means that the radioactive liquid releases by Kozloduy NPP in the Danube river have drinking water characteristics. To achieve this low limit it has to use a high processing depth of the liquid radioactive waters. At the same time this limit is rather higher in highly developed countries which operate the same type of reactors.

In Western Europe there is a principle adopted for setting the permissible limits and this principle is based on the understanding that public additional radiation doses should be kept as low as the economically grounded (substantiated), i.e. the principle ALARA (As Low As Reasonably Achievable) is adopted. Precisely this is not the main principle, not only in Bulgaria, and in all other former socialist countries, in the process of management decision making, in general in the field of nuclear energy operation and in particular the decisions concerning the release of controlled liquid discharges into environment.

At the same time there was no assessment of the possible additional radiation exposure received by the public around NPP as a result of the liquid releases.

Due to this reason, Kozloduy NPP requested IAEA through the Regulatory Body to help in terms of scientifically based evaluation of the additional radiation exposure that the public in the 30 km zone of the plant region is receiving through controlled water discharges.

DATABASE FOR RADIATION DOSES EVALUATION

A computer code LADTAP (6) was utilized and adopted by the IAEA assistance and IAEA experts D-r Djurica Tancosic from USA and D-r Anatoly Tsarenko from IAEA. The leader of Bulgarian team specialists from Kozloduy NPP, was Professor Ivelin Kuleff from Sofia University. The Danube river runs from West to East of NPP. The villages of the controlled zone which were investigated are located downstream KNPP.

The input data is stored in the format text file and include the necessary model data for reading the distribution of the radionuclides discharged with the controlled water in Danube river, through the food channel to every independent individual of public in the region. Those data can be classified, as follows:

- consumption of irrigated food products united in 4 groups: leaf vegetables,
- vegetable food (including the wheat), milk and meat;
- the usage of the water reservoir by the public for swimming, boating, the usage of the beaches, precision of commercial and hobby fishing;
- data about liquid radioactive waste according the type of radio nuclides content from all units for the relevant year;
- data about the cooling reservoir: discharge velocity of the hot channel in Danube river, hydrological data about the river – width and depth, average velocity, distance from the point of discharge of hot channel to the point of drinking water pumping;
- demographic data for NPP region.

To execute the evaluation was necessary to rather the following data:

- public number and its group distribution by their age in the 30 km controlled zone around the plant;
- location and discharge of drinking water sources;
- agriculture production: vegetables, vegetable foods, milk, meat as well as to define the production from irrigated fields;
- annual consumption of food products and its ration with the physiological defined norms of consumption.

RECENT INFORMATION FOR IMPLEMENTED NEW LIQUID RELEASES RADIOACTIVITY LIMIT AT KOZLODUY NPP

The total radioactivity and special activity of liquid releases from NPP into the Danube river and into environment in 1999 are lower than the maximum new permissible value, set by the Regulatory body after an approval by the Ministry of Health and Ministry of Environment (7).

Monthly radioactivity (MBq) of technological liquid releases into Hydrosphere excluding Tritium is shown in the following Table X.

Table X. Monthly radioactivity (MBq) of technological liquid releases into hydrosphere excluding Tritium

Month	Units 1-2 (AB-1)*	Units 3-4 (AB-2)	Special Laundry of Units 1-4	Units 5-6 (AB-3)	Total for the plant
January	39.999	195.181	6.993	22.74	264.913
February	89.005	160.544	5,661	4.53	259.74
March	107.937	72.701	4.662	4.13	189.43
April	76.3	0	7.326	22.54	106.166
May	93.763	0	6.993	45.146	145.902
June	62.936	0	6.327	5.36	74.623
July	63.208	50.935	5.994	5.64	125.777
August	71.85	135.513	5.328	7.7	220.391
September	43.693	66.353	5.328	6.81	122.184
October	22.544	66.329	5.994	4.94	99.717
November	22.662	64.973	7.326	8.34	103.301
December	43.278	78.227	7.659	31.92	161.084
Total	737.175	890.666	75.591	169.796	1873.228

The monthly and total Tritium activity released by discharged water in the river of Danube is given in the following Table XI.

Table XI. Monthly radioactivity (MBq) of technological liquid releases into Hydrosphere with Tritium

Month	Volume discharged [1/1000]	Specific activity [MBq/l]	Total activity [GBq]
January	9393	624.5	5866
February	1199	1072.6	1296
March	10509	1142.4	12005
April	9201	1040.9	9577
May	10995	867	9532
June	7791	674.8	5257
July	9969	456.9	4555
August	12837	434	5571
September	11535	342.1	3946
October	10152	384	3898
November	9493	261	2478
December	12621	348.6	4400
Total	115695	7648.8	68381

The annual permissible Tritium limit, by the Regulatory body, to be discharged with the technological liquid releases is 185 000 GBq, and the control level is 25 900 GBq.

GENERAL INVESTIGATION RESULTS

On the investigation base and on the base of the results of implementation the IAEA computer code it was estimated and lisenced a new liquid release volume radioactivity limit – 5.00E-08 Ci/l (1,85E+03 Bq/l without Tritium) and control level 1.00E-08 Ci/l (3,7.00E+02 Bq/l). The total annual radioactivity limit of 20 Ci (7,4.00E+11 Bq without Tritium) and control level 4 Ci (1,48.00E+09 Bq) are licensed by Regulatory Body. Total annual Tritium limit is accepted 5000 Ci (1,85.00E+14 Bq) and control level 700 Ci (2,59.00E+13 Bq). There is a quarterly limit set also.

CONCLUSIONS

Summarizing the Kozloduy NPP radiation protection indexes the following conclusions can be come up to:

- The gamma contamination dose rate activity on the site is in the normal range and is totally comparable to those from previous years.
- The year 2000 data compared to data from the past indicates absence of negative trend of change. For some of the indexes there is a trend observed for stable reduction, respectively to radiation status improvement.
- The released radioactivity from Kozloduy NPP through the effluents is in the range of 2% of the permissible limits and is totally comparable to those in NPPs in other countries.
- The year 2000 data compared to those from the past years and the data before the KNPP putting into operation in 1974, identifies absence of radiation status trends and changes beyond the acceptable risk limits.

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