*Journal of Environmental Protection and Ecology* 2, No 2, 309–313 (2001)

*Environmental radioactivity*

# ENVIRONMENTAL IMPACT OF BULGARIAN NPP "KOZLODUY"

A. TZENKOVA*, J. IVANCHEVA, D. SYRAKOV, PL. VIDENOV

*National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences, 66 Tzarigradsko Shousse Blvd., 1784 Sofia, Bulgaria*
*E-mail: ani.tzenkova@meteo.bg*

**Abstract.** The aim of this work is to calculate ground fields of the concentration of the main radioactive pollutants (long-living aerosols, radioactive noble gases and radioactive $I^{131}$) emitted by the Nuclear Power Plant (NPP) "Kozloduy" as well as their deposition fields. For this purpose, four versions of a Gaussian plume model are used. The results show that the level of pollution created by NPP "Kozloduy" is farther below the sanitary-hygienic requirements.

*Keywords*: air pollution, dispersion models, long-living aerosols (LLA).

## AIMS AND BACKGROUND

The Kozloduy Nuclear Power Plant (NPP) produces about 1/3 of the electric energy Bulgaria needs. It is one of the main obstacles for the country's acquisition into the European Community. These facts necessitated the elaboration of a comprehensive estimation of the NPP impact on the environment. In the present work some of the obtained results are presented.

## EXPERIMENTAL

*The model.* Four versions of a Gaussian plume model were used for calculating the average fields of the concentration and the deposition of radioactive pollutants. They differ in nature of described pollutant (gas versus aerosol) and of meteorological input (time series of instantaneous measurements versus climatic meteo data – wind roses, precipitation, etc.).

The model is based on the well-known Gaussian formulae[1,2], realized on rectangular grid. The main features of the PLUM-model are as follows:

- Pasquil stability classes are used to account for the atmospheric stability;
- Briggs formulae for sigmas are used for rural and urban conditions;
- plum rise formulae of Briggs are used when information about gas temperature, flow speed and stack diameter is available;
- the wind speed is extrapolated from measurement height to the stack height by power law, exponent depending on stability;

* For correspondence.



309

- time sampling corrections of sigmas account for meandering effects;
- the wash out cases are treated by multiplying all the concentration field by seasonally depending decreasing factor;
- the calm conditions are treated as average plumes in all the directions, using proper stability class and wind speed of 0.5 m/s;
- the aerosol specific processes are described using a parameterization scheme suggested by Syrakov and Galperin[3].

*Emissions.* Under normal conditions of operation, the blocks of the Kozloduy NPP emit three types of pollutants: long-living aerosols (LLA), radioactive noble gases (RNG), and radioactive iodine (RI). Three subtasks were calculated: 1) for the years 1997 and 1998; 2) for the interval 1994-1996; 3) for the interval 1987-1989. The input meteorological information for the years 1997 and 1998 was the data recorded by the automatic meteorological station included in the NPP monitoring system. The Oriahovo climatic station recorded the data used for the interval 1994-1996. The data for the interval 1987-1989 were taken from the climatic handbooks for Bulgaria.

The emission data are shown in Table 1. From it, it is quite evident that the emissions from blocks 1 to 4 are much greater compared to the emissions from blocks 5 and 6.

**Table 1.** Emission of radioactive pollutants from the Kozloduy NPP

| Year | Blocks 1 and 2 | Blocks 3 and 4 | Block 5 | Block 6 | CK 3 |
|---|---|---|---|---|---|
| | | long-living aerosols (LLA) (MBq) | | | |
| 1988 | | 310.8 | | – | – |
| 1989 | 1321.0 | 740.0 | 1221.0 | – | – |
| 1994 | 566.0 | 945.0 | 150.8 | 60.9 | 253.5 |
| 1995 | 689.0 | 402.0 | 129.2 | 83.5 | 130.8 |
| 1996 | 1144.3 | 466.3 | 76.3 | 56.6 | 132.4 |
| 1997 | 1071.0 | 481.0 | 100.0 | 59.0 | 128.0 |
| 1998 | 405.0 | 488.0 | 71.4 | 60.0 | 142.6 |
| | | radioactive noble gases (RNG) (GBq) | | | |
| 1988 | | 605357 | | – | – |
| 1989 | 124801 | 114108 | 526806 | – | – |
| 1994 | 95651 | 129602 | 16494 | 7013 | 17146 |
| 1995 | 46400 | 164640 | 29982 | 5453 | 22602 |
| 1996 | 117230 | 222510 | 15781 | 5989 | 29040 |
| 1997 | 86510 | 79080 | 10613 | 4974 | 22283 |
| 1998 | 101330 | 92950 | 14991 | 5236 | 18997 |
| | | radioactive $^{131}$iodine (MBq) | | | |
| 1988 | | 7580.0 | | – | – |
| 1989 | 1073.0 | 1665.0 | 1369.0 | – | – |
| 1994 | 752.0 | 801.0 | 158.0 | 126.3 | 301.6 |
| 1995 | 411.0 | 413.0 | 182.8 | 108.8 | 355.3 |
| 1996 | 526.2 | 1055.7 | 86.8 | 81.5 | 210.8 |
| 1997 | 1439.0 | 828.0 | 223.0 | 81.0 | 166.0 |
| 1998 | 5500.7 | 4336.6 | 127.6 | 22.2 | 7.2 |



310

## RESULTS

The obtained results reveal that in 1997, the average annual field of concentration of LLA in the atmosphere reaches a maximum of 1.05 $\mu Bq/m^3$. During the two years, on average, nearly the whole 30 km area stays within the limit of 0.10 $\mu Bq/m^3$ (Figs 1, 3). The maximum values of the diurnal deposition are accordingly 1100 $\mu Bq/m^2$ for 1998, and 3400 $\mu Bq/m^2$ for 1997. The deposition in 30 km zone stays within the limit of 34 $\mu Bq/m^2$ for 1997, and 10 $\mu Bq/m^2$ for 1998 (Figs 2,4).

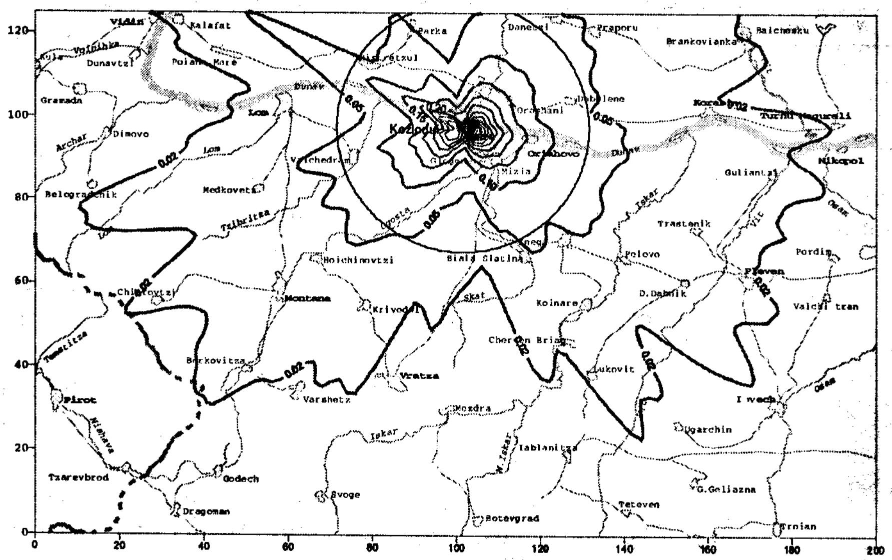



**Fig. 1.** The mean annual field of concentration of LLA – 1998 ($\mu Bq/m^3$)

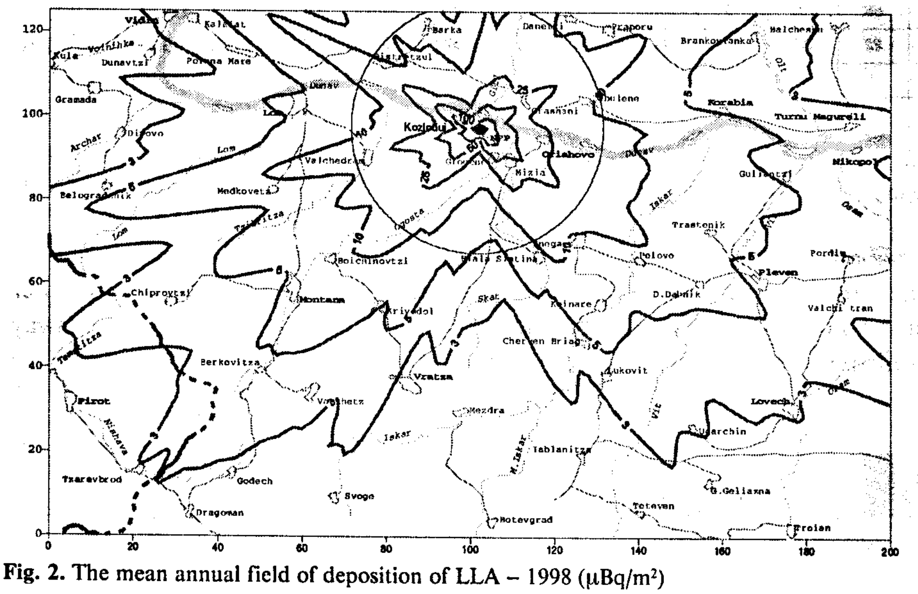
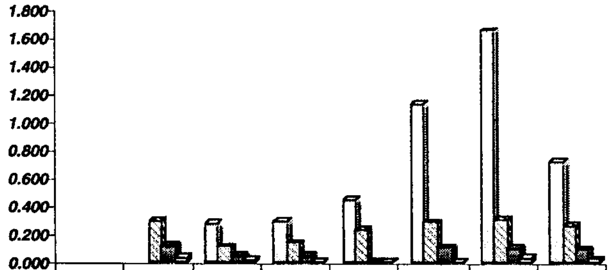



**Fig. 2.** The mean annual field of deposition of LLA – 1998 ($\mu Bq/m^2$)

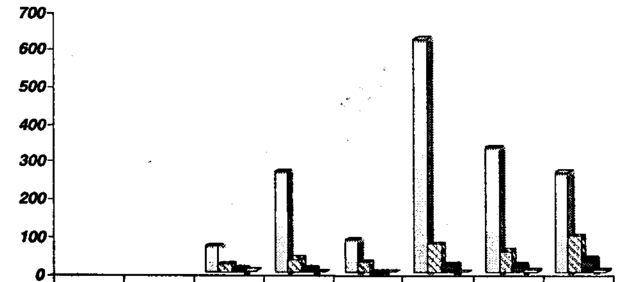


311




| | N | NE | E | SE | S | SW | W | NW |
|---|---|---|---|---|---|---|---|---|
| 3 | 0.314 | 0.608 | 0.267 | 0.288 | 0.443 | 1.130 | 1.650 | 0.712 |
| 12 | 0.107 | 0.288 | 0.105 | 0.138 | 0.229 | 0.278 | 0.303 | 0.253 |
| 30 | 0.040 | 0.113 | 0.042 | 0.047 | 0.000 | 0.106 | 0.098 | 0.093 |
| 90 | 0.012 | 0.032 | 0.013 | 0.000 | 0.000 | 0.000 | 0.025 | 0.023 |

**Fig.3.** The annual distribution of the concentration of LLA – 1997 (μBq/m³)




| | N | NE | E | SE | S | SW | W | NW |
|---|---|---|---|---|---|---|---|---|
| 3 | 86 | 131 | 70 | 268 | 86 | 622 | 331 | 264 |
| 12 | 22 | 38 | 22 | 33 | 26 | 74 | 57 | 96 |
| 30 | 8 | 12 | 8 | 10 | 0 | 22 | 20 | 34 |
| 90 | 2 | 4 | 2 | 0 | 0 | 0 | 6 | 5 |

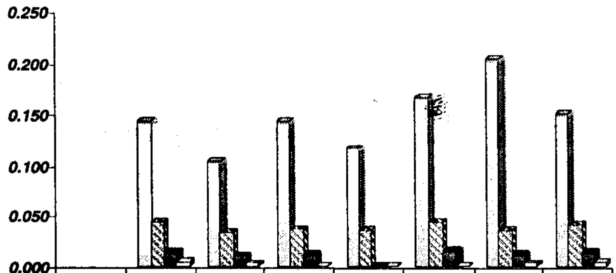
**Fig. 4.** The annual distribution of the deposition of LLA – 1997 (μBq/m²)

The maximum pollution with RNG for the years 1997 and 1998 in the region of the NPP is about 0.2 μBq/m³. Twelve km away from the source, the maximum concentrations of RNG for 1997 are about 0.04 μBq/m³, and 30 km away from the NPP they are within the range 0.000-0.015 μBq/m³ (Fig. 5). Three km away from the source, in the west direction, is the highest concentration of iodine – 4.46 μBq/m³, while the lowest one – 1.27 μBq/m³, is in the north direction.

For the years 1997 and 1998, the average seasonal fields of the concentration of LLAs were also calculated. Winter appeared to be the season with lowest concentrations, the maxima being accordingly 0.5 μBq/m³ for 1997, and 0.8 μBq/m³ for 1998. Higher values were recorded during the transitional seasons, the maximum in fall for both years being about 2.0 μBq/m³, and in the spring of 1997 – 3.0 μBq/m³. During all years studied, the maximum values recorded in the roundabouts of the NPP were lower than the maximum concentrations allowed. The level of pollution farther away complied with the sanitary-hygienic requirements.



312




| | N | NE | E | SE | S | SW | W | NW |
|---|---|---|---|---|---|---|---|---|
| 3 | 0.060 | 0.143 | 0.104 | 0.142 | 0.116 | 0.166 | 0.203 | 0.150 |
| 12 | 0.018 | 0.043 | 0.033 | 0.036 | 0.035 | 0.042 | 0.035 | 0.041 |
| 30 | 0.006 | 0.014 | 0.011 | 0.011 | 0.000 | 0.015 | 0.012 | 0.014 |
| 90 | 0.001 | 0.003 | 0.003 | 0.000 | 0.000 | 0.000 | 0.003 | 0.003 |

**Fig. 5.** The annual distribution of RNG concentration – 1997 (μBq/m³)

## CONCLUSIONS

As a result of the model study it was ascertained that the operation of the "Kozloduy" Nuclear Power Plant does not result in the formation of radioactive pollutants with concentration greater than allowed by the sanitary-hygienic norms. The obtained results are comparable to the data from the background monitoring of the country's radioactive air pollution. The radiation loading of the population, calculated based on the above concentrations, falls within the prescribed sanitary-hygienic limits.

## REFERENCES


1. Users Guide for the ISC2 Dispersion Models. US Environmental Protection Agency, 1992.
2. G. A. BRIGGS: Plume Rise Predictions. In: Lectures on Air Pollution and Environmental Impact Analysis. American Meteorological Society, Boston, Massachusetts, 1975.
3. D. SYRAKOV, M. GALPERIN: A Model for Airborne Poly-dispersive Particle Transport and Deposition. Proc. of 22nd NATO/CCMS International Technical Meeting on Air Pollution Modelling and Its Application, 2-6 June 1997, Clermont-Ferrand, France, 1997, 111-118.


*Received 24 November 2000*
*Revised 5 February 2001*



313