RADIATION RISKS OF LARGE SCALE NUCLEAR ACCIDENTS - A CASE STUDY

John G. Kollas
Institute of Nuclear Technology - Radiation Protection
NRCPS "Democritos", Greek AEC
153 10 Aghia Paraskevi, Attiki, Greece

ABSTRACT

The object of this paper is the estimation of the radiological consequences of the latest 1000 MW Kozlodui reactor, a Soviet type PWR in Bulgaria, to the population of Greece. To estimate these consequences a series of severe accident scenarios are utilized. The results of the analysis indicate that under the conservative assumptions adopted, the radiological consequences of the most severe accidents considered would be non trivial. The magnitude of the potential effects from the accident scenarios analyzed is such that multinational emergency planning for nuclear installations may be required, even when nuclear power stations do not lie in proximity to national borders.

INTRODUCTION

The experience gained from the Chernobyl accident has shown that nuclear accidents may involve releases of radioactive materials to the environment, which extend to large distances. It is therefore appropriate to assess the radiological consequences to the population of Greece of a few representative severe nuclear accidents of the nuclear power station(NPS) at Kozlodui, Bulgaria, which is located closer to Greece than any other similar station. The Kozlodui site with 4 operating PWR units of 440 MW and 1 PWR unit of 1000 MW, is located near the northwestern borders of Bulgaria near the river Danube, at a distance of 225 km from the northern borders of Greece. In the present analysis attention is focussed on the larger unit, which in the improbable event of a severe accident would produce the most adverse effects.

The accident consequence calculations were performed using the CRAC.GAEC code, a version of code CRAC2[1,2]. The model describes the progression of the radioactive cloud released from the reactor building and predicts its interaction with and influence on the environment and man.

ACCIDENT RELEASES AND INPUT DATA

Reactor accident consequence calculations require the radionuclide inventory of the reactor under consideration. Since detailed data of VVER-1000 core inventories were not available, the simplifying assumption that they will be similar to the inventory of a standard PWR[3] multiplied by the ratio of the corresponding reactor thermal powers was made. The larger unit of 1000 MW has a thermal power of 3000 MW and a unit efficiency of 33.3%. The standard PWR inventory corresponds to an end-of-cycle equilibrium inventory of a 3412 MWt PWR, calculated with a burnup of 33000 MWd/MTU[3].

In order to delineate the upper bounds of the spectrum of consequences, the analysis is focussed on the consequences of four serious hypothetical PWR accidents, or release categories, namely the PWR-2, PWR-3, PWR-4, and PWR-5[4], which we assume that are also applicable to VVER-1000 reactors. Therefore the same release fractions applying to these accident categories are used for VVER-1000. The consequence assessment requires a large number of input data. Some of these data are taken identical to those of the reference case of the CRAC2 User's Guide document[1], while the rest are calculated specifically for the cases assessed.

The meteorological record used in the consequence model consists of 8760 hourly observations of wind speed, atmospheric stability and accumulated precipitation, and corresponds to a typical meteorological year of Athens. The associated wind rose is not taken into account, but a constant southward wind direction is assumed since the aim is to estimate the upper bound of the consequences, which obviously take their maximum values for Greece when the radioactive cloud is directed towards the centre of the country. In order to represent all possible weather conditions about 580 weather sequences are sampled from the meteorological record. The weather category sampling technique utilized[5] takes into account effectively the very low probability sequences, which have potentially high consequences. In addition we assume that no emergency measures are taken during the progress of an accident. For the estimation of latent health effects the BEIR method is used.

RISK AND LATENT HEALTH EFFECTS

The consequences resulting from Kozlodui's four hypothetical accidents would be due to early exposure, which includes direct irradiation by the passing cloud, exposure from inhaled radionuclides and exposure to deposited radionuclides, and to chronic exposure, which includes exposure to groundshine from contaminated ground, inhalation of resuspended radionuclides and ingestion of contaminated foods. The results are presented either as dose or cancer risk curves for exposed individuals versus distance from the Kozlodui site, or as complementary cumulative distribution functions (CCDFs) for latent health effects and collective exposure. The health effects considered include early deaths and early injuries, thyroid effects and latent cancer fatalities. Although the postulated releases would be very serious, the distance of 225 km of the northern border of Greece from the Kozlodui site prevents the manifestation of early deaths and early injuries among the Greek population. The effects that were manifested were only latent cancer fatalities and thyroid nodules as expected.

In Figs. 1-2 the variations of the mean and peak acute bone-marrow dose and the cancer risk from initial exposure versus distance from the reactor site are depicted for the four accident releases. Figs. 3-4 show the collective dose of the whole population of Greece as a CCDF and the latent health effects both resulting from the total exposure for all four cases analyzed. A summary of all latent health effects and the collective exposure is shown in Table 1.

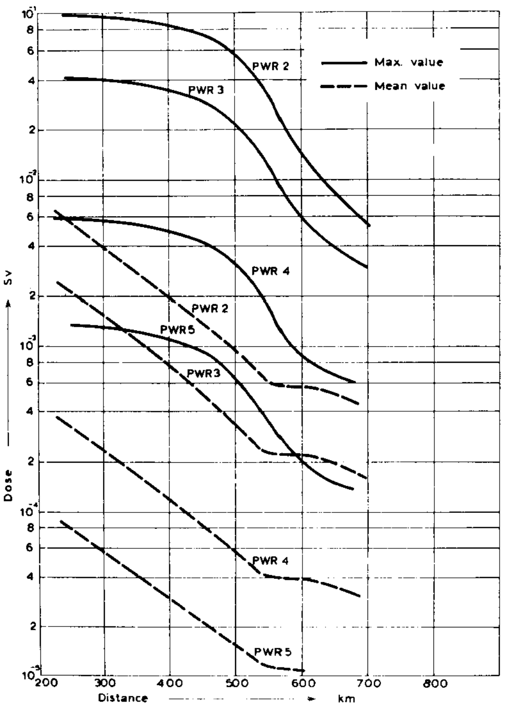

Fig. 1. Acute Bone Marrow Dose versus Distance from Kozlodui Site

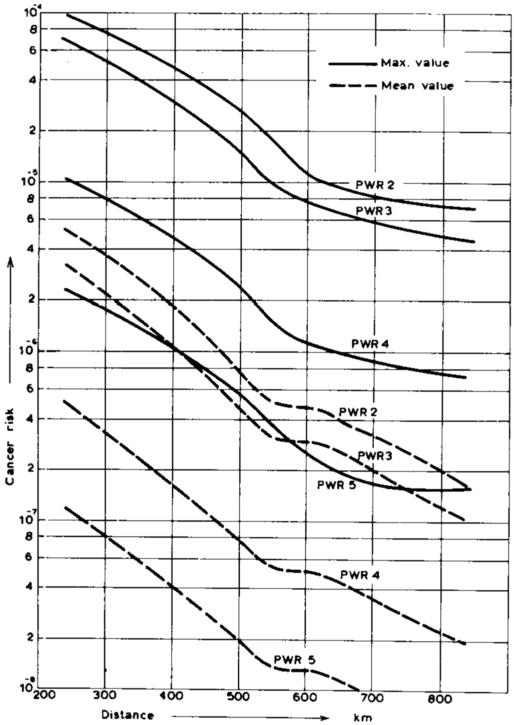

Fig. 2. Cancer Risk versus Distance from Kozlodui Site

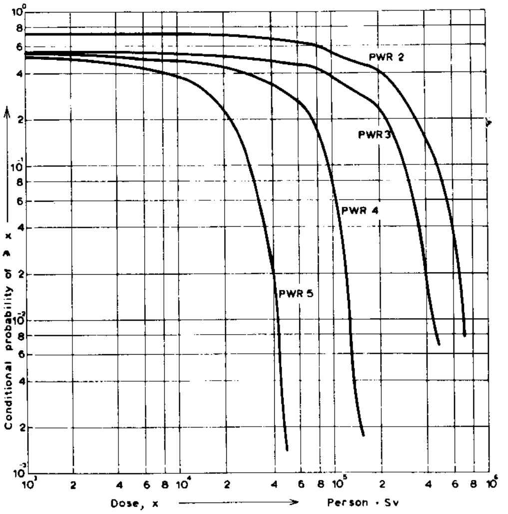

Fig. 3. Whole Body Collective Dose CCDF

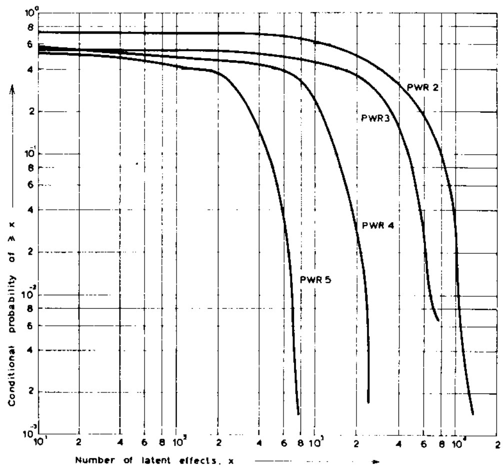

Fig. 4. Whole Body Latent Effects CCDF

Table 1. Summary of number of latent effects - Total exposure

Effect	Mean Values				Peak Values			
	PWR2	PWR3	PWR4	PWR5	PWR2	PWR3	PWR4	PWR5
Whole body	2830	1560	514	156	13200	7620	2460	780
Thyroid	2010	1000	391	199	11500	5960	1960	883
Leukemia	596	317	101	30.3	2850	1560	485	151
Lung	519	324	94.4	28.2	2410	1680	459	141
Breast	623	337	107	32.1	3030	1680	516	161
Bone	295	150	45.6	13.0	1410	747	221	64.4
GI tract	284	171	63.2	20.0	1180	782	300	99.2
Other	632	342	109	32.6	3070	1700	523	163
Whole Body Collective Exposure								
(10^3 person·Sv)	179	99.1	32.6	9.89	839	484	156	49.4

CONCLUSIONS

The results presented in this paper have been obtained under a series of conservative assumptions, such as wind blowing continuously southwards, most serious accident scenarios at the larger unit of the NPS etc., and are non-trivial. One must note however that if for example the wind direction was probabilistically treated, and less severe, more realistic scenarios were analyzed, the expected consequences (mean values), would be reduced by 2-3 orders of magnitude and then they would be minimal. Under the severe scenarios adopted and in the totality of 9746000 inhabitants of Greece some non-trivial effects would result during long periods after such accidents. The magnitude of the potential effects from the releases analyzed indicate that multinational emergency planning for nuclear installations, may be required even when nuclear power stations do not lie in proximity to national borders.

REFERENCES

1. L.T.Ritchie,et.al., Calculations of Reactor Accident Consequences, Version 2 (CRAC2):Computer Code User's Guide, NUREG/CR-2326, SAND 81-1994, Sandia National Laboratories, 1983.
2. L.T.Ritchie,et.al., CRAC2 Model Description, NUREG/CR-2552, SAND 82-0342, Sandia National Laboratories, 1984.
3. D.C.Aldrich,et.al., Technical Guidance for Siting Criteria Development, NUREG/CR-2239, SAND 81-1549, 1982.
4. Reactor Safety Study, App.VI:Calculations of Reactor Accident Consequences, U.S.N.R.C.,WASH-1400 , NUREG-75/014, 1975.
5. L.T.Ritchie,et.al., Weather Sequence Sampling for Risk Calculations, Trans. Am. Nucl. Soc., v.38, p.113-15, 1981.

ACKNOWLEDGEMENTS

This work was supported partially by the C.E.C. 1985-1989 Radiation Protection Programme.