OCCUPATIONAL EXPOSURE IN CANDU NUCLEAR POWER PLANT: INDIVIDUAL DOSIMETRY PROGRAM

AT CERNAVODA NPP

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INTRODUCTION

Cernavoda NPP has two CANDU 600 reactors in commercial operation, first since December 1996 and the second one since November 2007.

- For a CANDU 6 type reactor the major contributor (90%) to the external dose is gamma radiation.
- The major contributor to the internal dose of professionally exposed workers is the tritiated heavy water (DTO) – at least 40% of the total effective dose.
- The main purpose of design and implementation of the Individual Dosimetry Program is to measure, assign and record all the significant radiation doses received by an individual during activities performed at CNE Cernavoda NPP and ensure that all the exposure are kept ALARA.

INTRODUCTION

The results of personnel exposure to ionizing radiation are also used for:

- Estimation of real exposure of workers;
- Evaluation and development of operating / working procedures;
- Providing information about radiological conditions at the working places;
- Providing information allowing workers to know how, when and where they have been exposed, and to motivate them to reduce their exposures;
- Completing medical records.

INTRODUCTION

- We provide dosimetry services for measurement, evaluation and recording of all significant radiation doses received by workers and visitors at CNE Cernavoda,.
- For all the persons entering radiological controlled areas Health Physics Department provides individual, external and internal, dosimetric surveillance.
- Individual dose monitoring is provided by a licensed dosimetry service, approved by the Romanian regulatory body, at CNE Cernavoda.
- Radiation Protection Program for Cernavoda NPP is designed insomuch as legal dose limits, for atomic radiation worker and for public, will not be exceeded.

EXTERNAL RADIATION DOSES MONITORING AND EVALUATION

- At CNE Cernavoda NPP we consider as external hazards: X rays, gamma, beta and neutron radiation.
- For the major contributors (gamma and beta radiation) we provide routine individual monitoring for all the personnel working in radiological area.
- Neutrons can be considered as a minor contributor, with less than 10% contribution to the total collective dose.

EXTERNAL RADIATION DOSES MONITORING AND EVALUATION

A short look back

- Since 1995, when the fresh fuel was loaded into the reactor core at Unit 1, the dosimetry services were constantly improved.
- During Unit 1 new fuel loading activities in 1995 individual dosimetry surveillance was provided for 30 individuals using film dosimeters.
- Since “Radiation Island” was in effect, on February 26th, 1996, individual monitoring for external gamma and beta-gamma radiation exposure has been performed using thermo-luminescent dosimeters (TLDs).
- During Unit 2 new fuel loading activities in February 2007 individual dosimetry surveillance was provided for 255 individuals using thermo-luminescent dosimeters.

EXTERNAL RADIATION DOSES MONITORING AND EVALUATION

Whole Body Exposure to Gamma and Beta-Gamma Radiation

- **For all the persons entering radiological areas we provide routine, individual dosimetry surveillance.**
- **Individual dosimeters are thermo-luminescent type: three detectors made of $Li_2B_4O_7$ enriched with ^{7}Li and ^{11}B – neutrons insensitive, and the fourth made of $Li_2B_4O_7$ enriched with ^{6}Li and ^{10}B, very neutrons sensitive.**
- **Due to the fact that the first three elements are insensitive to neutrons, the deep gamma dose and shallow beta-gamma dose can be read out directly.**
- **The fourth element is used only to confirm the presence of neutron fields, as the response depends on the neutron energy spectrum and this is different in various location in the plant.**

EXTERNAL RADIATION DOSES MONITORING AND EVALUATION

Whole Body Exposure to Gamma and Beta-Gamma Radiation

The TLDs are read once a month (four or five weeks interval).

When entering in variable or heterogeneous gamma radiation fields, beside TLD, an electronic, direct reading, Personal Alarm Dosimeter (PAD) is used, providing:

- **immediate readout of gamma dose received,**
- **dose control by means of alarm set-points,**
- **back-up information for dose records if the TLD result is not available.**
- **dose accounting for specific jobs.**

EXTERNAL RADIATION DOSES MONITORING AND EVALUATION

Whole Body Exposure to Gamma and Beta-Gamma Radiation

At the end of a monitoring period the doses recorded by the TLDs are compared with those measured with PADs to check for any abnormal discrepancies between the two doses.

If such discrepancies exist investigations are conducted to determine the causes and the correct dose information.

The approved personnel dosimeter used by CNE Cernavoda NPP for official dose records is the TLD.

EXTERNAL RADIATION DOSES MONITORING AND EVALUATION

Whole Body Exposure to Neutrons

- **When entering / working in areas with significant neutron dose rates an integrating portable neutrons monitor is used both as field instrument to measure neutron fields and as a personal neutron dosimeter. This dose will be assigned to every person working in that location.**
- **The instrument used is a proportional counter for neutron.**
- **There is also an alternative method to evaluate the neutron doses that have not been reported, involving the use of the fourth element of the individual TLD ($^{6}Li_2\ ^{10}B_4O_7$), very sensitive to neutron fields.**

EXTERNAL RADIATION DOSES MONITORING AND EVALUATION

Exposure of the Extremities

- When contact beta-gamma dose rate exceed 10 times the dose rate at the level of the chest, thermo-luminescent extremities (hands or / and feet) dosimeters are used.
- The extremities dosimeters are also thermo-luminescent, made by natural Li2B4O7. They are used in pairs to measure the dose received by hands and / or feet.
- The extremities dosimeters are read in the Dosimetry Lab at the station, and the dose is recorded in the DOSERECORDS database.

INTERNAL DOSIMETRY PROGRAM

Cernavoda Nuclear Power Plant has a CANDU 6 type power reactor, which employs natural uranium as fuel and heavy water as a neutron moderator and as thermal agent.

The thermal neutron flux in the reactor core, by activation of deuterium, is the major producer of tritium.

The major contributor to the internal dose of professionally exposed workers is the tritiated heavy water (DTO), as vapors.

The minor contributors to the internal doses are:

- activation products as ^{95}Nb and ^{95}Zr (corrosion products from the Zircaloy in fuel sheath and pressure tubes) and 60Co (from other alloys in the systems in the active zone)
- fission products as ^{131}I, ^{133}I, ^{135}I and ^{137}Cs.

INTERNAL DOSIMETRY PROGRAM

Internal dosimetry for DTO

- Exposure to an atmosphere contaminated by tritiated water results in intake of that substance both by inhalation and by absorption through the intact skin, in a ratio assumed to be 2 to 1.
- Vapors of tritiated water are considered to be of SR-2 absorption class.
- The tritiated water is instantaneously absorbed into body fluids and uniformly distributed among all the soft tissues and is eliminated with a nominal half time of 10 days.
- A very small fraction is incorporated in non - exchangeable form and eliminated with a much longer half time.

INTERNAL DOSIMETRY PROGRAM

Internal dosimetry for DTO

- Professionally exposed workers are subject to a combination of acute and chronic tritium exposure and DTO dosimetry program is based on multiple sample results.
- Body DTO concentration is integrated over time and multiplied by the dose rate per unit concentration factor:

$$E = 5.8 \cdot 10^{-2} \sum_{i=0}^{k-1} [(C_{i+1} + C_i)/2] \cdot (t_{i+1} - t_i)$$

E - effective dose in mSv.

Tritium in urine concentrations Ci are given in MBq/L

Time is expressed in days.

INTERNAL DOSIMETRY PROGRAM

Internal dosimetry for DTO

- **The committed dose (mSv) associated with a ^{3}H concentration C (MBq/L) in case of an acute intake is computed as follows:**

$$E_{(50)} = 0.84 \cdot C$$

The dose factor 0.84 was computed by using tritium physical characteristics, anatomic and metabolic data for Reference Man.

INTERNAL DOSIMETRY PROGRAM

Internal dosimetry for DTO

- Bioassay monitoring for internal dosimetry of DTO is relatively simple involving the sampling of a single void urine sample.
- A monthly frequency of bioassay submission is used at for professionally exposed workers who are infrequently exposed or exposed to low tritium levels (urine concentration remains below 10 kBq/L).
- If the urine tritium concentration is greater than 10 kBq/L weekly sampling will be required.
- When concentration exceeds 1.2 MBq/L, the investigation level, daily sample submission is required.

INTERNAL DOSIMETRY PROGRAM

Internal dosimetry for DTO

- In case of acute exposures the most important error in dosimetry arises from the estimation of the time of intake. Therefore special monitoring is required when planned exposures to DTO are foreseen; the worker should submit additional samples before and after the task completion.
- When working conditions are unexpectedly changing and could produce abnormal exposures to DTO, all the personnel involved will submit additional samples.
- Dose assignments resulting from routinely measured weekly and monthly urinary levels of tritium oxide are based on the method of linear interpolation.

INTERNAL DOSIMETRY PROGRAM

Internal dosimetry for DTO

- In case of acute exposure dose-mitigating actions are recommended by the Occupational Medicine Specialist in consultation with Dosimetry Program responsible.
- The primary treatment for reducing internal dose from a tritiated water uptake is to accelerate the turnover of body water, by substantially increasing the fluid intake rate through oral or intravenous means, and/or using diuretics.
- Cernavoda NPP experience intakes indicated that a sustained drinking regime gave a clearance half-time of about 5 – 6 days compared with a 10 day normal clearance half-time.

INTERNAL DOSIMETRY PROGRAM

Internal dosimetry for minor contributors

- The minor contributors to the internal doses, radioactive contaminants in the air as gases and suspended particles (aerosols) and on the surfaces (as loose contamination) are:
- activation products as ^{95}Nb and ^{95}Zr (corrosion products from the Zircaloy in fuel sheath and pressure tubes) and ^{60}Co (from other alloys in the systems in the active zone)
- fission products as ^{131}I, ^{133}I, ^{135}I and ^{137}Cs.
- The most frequent internal contaminations are due to the presence of loose contamination with ^{95}Nb / ^{95}Zr, when primary heat transport system is opened.

INTERNAL DOSIMETRY PROGRAM

Internal dosimetry for minor contributors

- The fuel handling operators are monitored with Whole Body Counter four times a year.
- Nuclear operators, maintenance services workers, radiation control technicians, chemical lab technicians and NDE technicians are monitored once a year.
- Employees which are not involved very often in activities in contaminated areas are monitored every three years.
- New employees are monitored at the very beginning of activity in the radiological zone
- In case of a job with an important risk of internal contamination every worker involved is monitored at the Whole Body Counter prior the beginning of work and immediately after the end of that special activity.

MONITORING OF WORKPLACES

Routine monitoring of workplaces is intended to demonstrate that the working conditions allows continuing the activities and there have not been changes that compel modification of the operating procedures.

Routine program includes monitoring of:

- **beta, gamma and neutrons dose rates;**
- **tritium in air concentration;**
- **aerosols (alpha, beta, gamma);**
- **iodine in air concentration;**
- **surface contamination level.**

An electronic database containing information about all the radiological hazards is accessible for all the staff of the plant.

DOSE LIMITS

- The annual effective dose limit applicable at CNE Cernavoda is more restrictive (18 mSv) than legal limit (20 mSv).
- Dose Control Point (DCP) is an internal administrative limit, for control and limitation of occupational exposure to ionizing radiation. It represents half of the effective dose available until administrative limit of 18 mSv/year is reached.
- This limit cannot be exceeded (in single exposure) without Station Health Physicist approval.
- Target values are established annual for collective doses, for the entire plant and for compartments with major contribution to the plant collective dose.
- There are established dose targets for those tasks / jobs involving significant exposures of the workers.

DOSE RECORDING AND REPORTING SYSTEM

- **Cernavoda NPP provides recording and storage of atomic radiation workers' individual monitoring results as per national regulatory body requirements.**
- **Records are proving the conformity with regulatory body requirements, ALARA's efficiency and providing data regarding doses distribution, assessment of exposure tendencies, provide data for medical, legal and epidemiological purposes, and contribute to the development of monitoring program and procedures.**

DOSE RECORDING AND REPORTING SYSTEM

- Doses management is performed through a number of programs and a database (DOSERECORDS), for correct and complete dose recording. The system also keeps all the analytical results of dose measurements and non-dosimetric information (personal identification data).
- Since Unit #2 fuel load and first criticality efforts have been made for the integration of both units radiation protection programs and systems related to personnel dosimetric surveillance.
- DOSERECORDS was adapted to support and work with dose information from both units, allowing us to ensure that individual dose limits are not exceeded no matter an employee works in Unit #1, Unit #2 or both units.

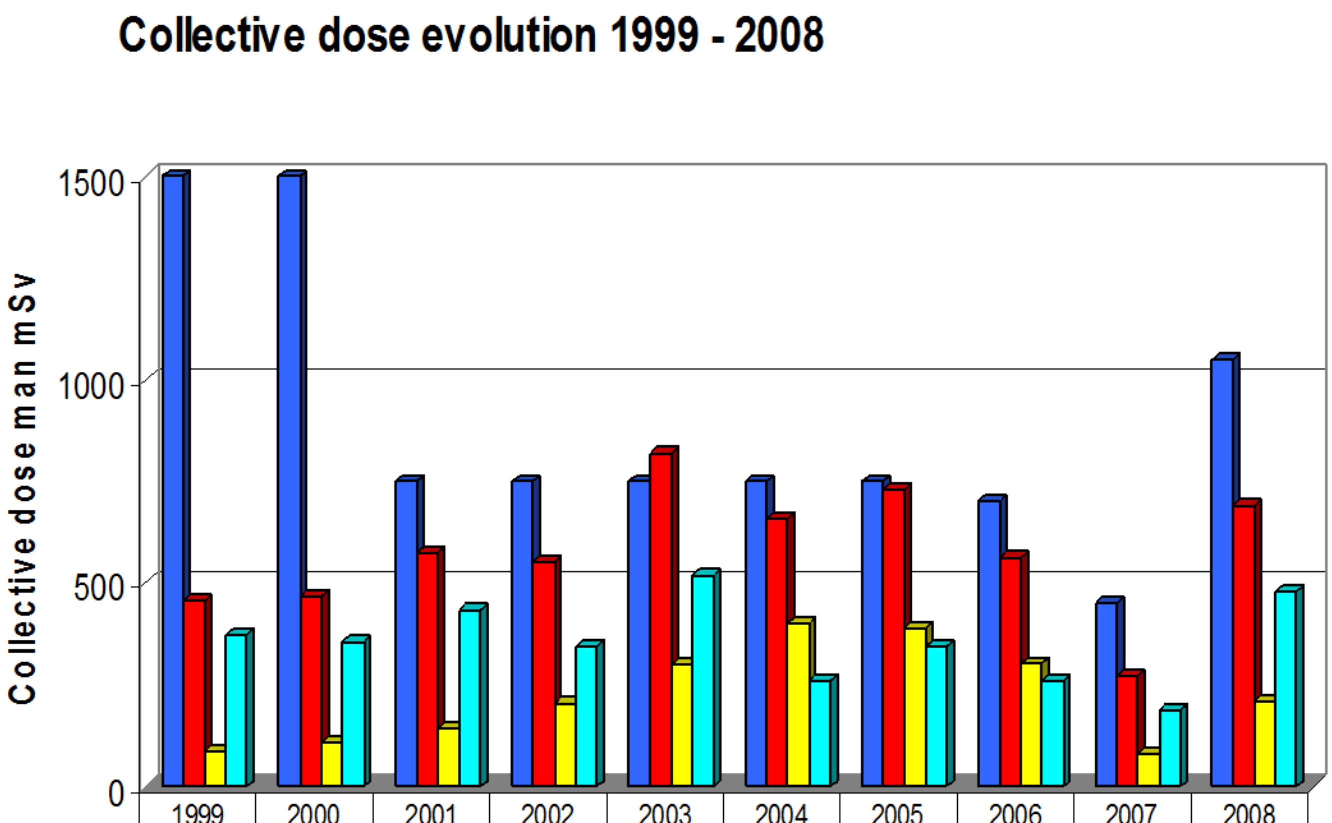
RESULTS OF THE IMPLEMENTATION OF RADIATION PROTECTION PROGRAM

- **The actual levels of individual and collective effective doses due to external and internal exposures reveal the effectiveness of implementation of the Radiation Safety Policies and Principles established by the management of the Cernavoda NPP.**
- **During 12 years of operation, most of the exposures (76%) were below the Recording Level and the majority of recordable doses (60%) were less then 1 mSv.**
- **Any legal or administrative individual dose limit has not been exceeded.**

RESULTS OF THE IMPLEMENTATION OF RADIATION PROTECTION PROGRAM

- The trends indicate that only for 2003 collective dose was over target due to planned outage extended duration and activities with major radiological impact.
- The increasing number of employees under dosimetric surveillance did not caused a comparative escalation of the collective doses and the number of exposed workers.
- The 688 man mSv for the year 2008 represents the collective dose for both Unit#1 and Unit#2 and with an extended planned outage in Unit#1.
- The actual levels of total effective doses reveal the effectiveness of implementation of the Radiation Safety Policies and Principles, based on the ALARA principles.

RESULTS OF THE IMPLEMENTATION OF RADIATION PROTECTION PROGRAM



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total effective dose target man mSv (collective)	1500	1500	750	750	750	750	750	700	450	1050
Total effective dose man mSv (collective)	456.53	466.2	574.86	550.48	818.28	656.71	731.59	561.06	270.83	688.64
Internal effective dose man mSv (collective)	85.42	110.81	141.42	206.43	298.02	398.26	389.3	302.27	83.34	209.3
External effective dose man mSv (collective)	371.11	355.39	433.44	344.04	520.27	258.45	342.29	258.79	187.49	479.34

Thank you for your attention!

Questions?