Radiological Work Control Considerations for Alpha Contamination Risk Activities at CNE Cernavoda

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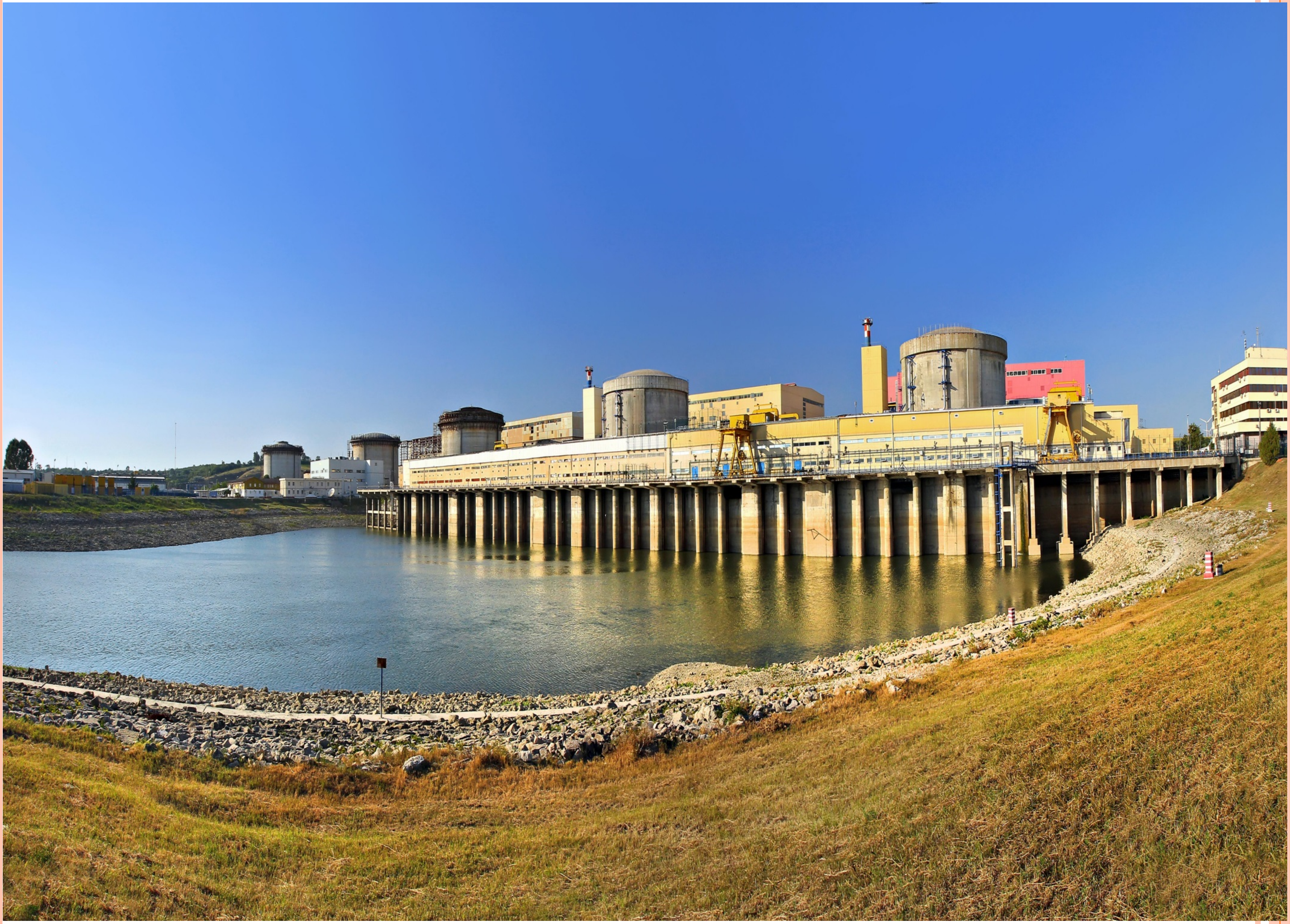

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INTRODUCTION

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- In case of CANDU reactor tritiated heavy water (DTO) is the major contributor to the internal dose of exposed workers –up to 40% of the total effective dose.
- Internal contamination with other radionuclides than tritium is infrequent, usually having a negligible contribution to occupational exposure.
- Significant unplanned internal exposures to TRU were reported during refurbishment of PHWR reactors, due to an inadequate radiological protection program, not able to recognize the potential for alpha contamination at the job site.

INTRODUCTION

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Under normal operating conditions, TRU are contained within the fuel rods and they are not a contributor to radioactive contamination.

The presence of alpha emitting radionuclides in working areas is related to fuel cladding defects, allowing the fission products to migrate into the primary heat transfer – PHT circuit.

Once in the reactor coolant, this material may be distributed throughout other areas creating accumulations of TRU which could have significant dose implications for personnel involved in work activities such as routine operations, maintenance, repair and refurbishment of equipment and systems.

ACTINIDES IN CANDU REACTORS

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The presence of TRU includes longer-lived radionuclides, such as: ^{238}Pu, ^{239}Pu/ ^{240}Pu, ^{241}Pu, ^{241}Am, ^{243}Cm/ ^{244}Cm.

Because alpha-emitting nuclides have high internal dose conversion factors, especially for the inhalation pathway, they result in significantly lower limits and action levels, compared to beta/gamma nuclides.

Alpha-emitting nuclides are generally more difficult to measure, and often must be inferred from the presence of surrogate radionuclides, or quantified using relatively expensive and time-consuming analytical methods.

RP personnel must consider quantifying the presence of alpha-emitting radionuclides, to ensure effective protection of workers and compliance with regulatory requirements.

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ACTINIDES IN CANDU REACTORS

The impact on protective measures depends on the abundance of these nuclides, and the frequency of occurrence in different areas of the plant.

The radioactivity in the Primary Heat Transport System – PHT system is generated by fission in the core fuel, and by activation of dissolved and suspended materials.

The majority of these activated materials are corrosion products.

The activity may be transported out of the reactor core in solution or as a suspended solid. Outside the reactor core the radionuclides may remain in the heavy water or may deposit on PHT system surfaces.

ACTINIDES IN CANDU REACTORS

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Changes to the radioisotopic composition and levels of contamination hazard are expected as a CANDU station age. These changes would be more pronounced with prolonged operation, during decommissioning activities.

Smear samples from boilers, service rooms and equipment, crud samples from the PHT System and pressure tube scrape samples, from both units have been characterized to assess potential internal contamination hazards.

The results confirmed Fueling Machine maintenance rooms and Spent Fuel Bay as the most alpha contaminated accessible locations in the plant.

MANAGEMENT OF DEFECTIVE FUEL

As the alpha emitting isotopes have an important contribution to the toxicity of radioactive contamination, the defective fuel is managed with special attention.

Defective fuel is identified by continuous monitoring of radioactivity in fuel channels and it is promptly discharged to spent fuel bay.

There are two systems working together, dedicated to the management of defective fuel:

Gross Fission Product (GFP) monitoring system and

Delayed Neutron (DN) system.

By applying this operation policy a reduced number of significant defective fuel was registered.

MANAGEMENT OF DEFECTIVE FUEL

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Gross Fission Product Monitoring System (GFP) is a computer controlled, high resolution digital spectrum analyzer (low energy germanium detector) that operates continuously, measuring selected fission products dissolved in the coolant.

GFP detect the presence of failed fuel, monitor the 131-I activity and monitor noble gas activity (eg. 133-Xe)

Delayed Neutron (DN) system, locates low power defects below GFP threshold.

DN Scan monitor is used to locate the particular channel that contains the defect. The location of failed fuel bundle is determined by measuring the amount of delayed neutron activity in coolant.

AREAS WITH POTENTIAL FOR ALPHA CONTAMINATION IN CERNAVODA NPP

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First step was the characterization of gross alpha activity levels in the plant areas where TRU may be present in order to assign a proper Area Action Level, based on EPRI guidance:

Level III Areas (low alpha contamination): the relative abundance of alpha contamination is minimal. Internal exposure from alpha emitters is not likely to exceed 10% of the total internal dose.

Action Levels are recommended to verify the low abundance of alpha emitters when high contamination or high airborne radioactivity is present.

β-global/α-global activity report: >15000.

AREAS WITH POTENTIAL FOR ALPHA CONTAMINATION IN CERNAVODA NPP

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Level II Areas (medium alpha contamination): the relative abundance of alpha contamination is significant. Alpha emitters are likely to contribute more than 10% of the internal dose.

Contamination survey action levels are intended to alert radiation safety personnel of the presence of alpha emitters. Some smears and air sampling are necessary to determine alpha contamination levels.

β-global/α-global activity report: >150 and <15000.

AREAS WITH POTENTIAL FOR ALPHA CONTAMINATION IN CERNAVODA NPP

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Level I Areas (high alpha contamination): the relative abundance of alpha contamination is elevated. Internal exposure from the alpha emitters is likely to exceed 90% of the total internal dose based on the inhalation retention model.

Most smears and all air samples should be counted for alpha contamination.

Use of Personal Air Samplers as internal dosimeters is recommended. Also, alpha frisking of personnel is recommended when the beta-gamma to alpha activity ratio is below 50-to-1.

β-global/α-global activity report: <150.

AREAS WITH POTENTIAL FOR ALPHA CONTAMINATION IN CERNAVODA NPP

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CNE Cernavoda started the characterization of potentially alpha contaminated areas in 2011. After each planned outage and each significant defective fuel discharge, contamination samples are measured to update alpha contamination status.

Table 1 presents some significant results for alpha, beta activities and alpha/beta ratios for the locations where alpha contamination was identified: spent fuel discharge bay (Unit#2 R-001 room), spent fuel bay, spent fuel discharge port and steam generator (Unit#1). The isotopic composition of these samples were determined by gamma ray spectrometry.

^{60}Co is present in all samples in wide spread proportions, between 4.1 and 7577 Bq, and resulting in scaling factors ^{60}Co / alpha between 5.9 and 814.

AREAS WITH POTENTIAL FOR ALPHA CONTAMINATION IN CERNAVODA NPP

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Sample description	Nuclide Activity (mBq)								Activity (Bq)		K1	K2
	Pu-239 /Pu-240	Pu-238	Am-241	Cm-243 /Cm-244	Cm-242	U-238	U-235	U-234	alpha global	beta global	(scaling factor beta/alfa)	(scaling factor Co-60/alfa)
Steam Generator 1 U#2-magnetite PHT side	356.4	42.9	1035	**2065.8**	24.6	<3	<4	10.6	3.4	471.5	**138.68**	**76.94**
Spent fuel discharge port U#1	178.4	78.5	115.4	**1519.6**	26.6	5.4	<3	12.8	2.4	548.7	**228.63**	**179.29**
Spent fuel bay water 2R-001	799.6	49.9	305.7	32.4	10	4.1	<2	3.8	1.652	926	**560.53**	**353.27**
Water – decontamination of equipment used at fuel channel inspection U#2	190	56.2	93.5	268.8	7.8	5.7	<2	3.9	0.55	86	**156.36**	**108.36**

Table 1 Beta and alpha gross activity and α-spectrometry in some samples from Cernavoda NPP

JOB CONTROL

Alpha contamination levels and locations are communicated to RC technicians to establish adequate protection controls during the jobs involving free radioactive contamination.

Areas and activities with significant risk of alpha contamination are identified and classified based on beta-gamma/alpha contamination ratio.

Alpha hazard classification is reviewed if the results of alpha and beta-gamma contamination monitoring indicate a possible modification of current level, or after special events susceptible to change the area level: some outage activities, defective fuel transfer to spent fuel bay.

JOB CONTROL

Specific Radiation Work Permits – RWPs are required if work is to be conducted in an Alpha Level II or I area.

Work controls should take into account the risk of exposure due to the work activity (e. g. aggressive surface destructive work – welding, cutting, polishing).

RWPs must establish specific monitoring requirements, and mitigation strategies: engineering controls as ventilated tents to confine contamination and HEPA filters to remove airborne alpha contamination, and respiratory protection.

Usually tritium and alpha hazards are simultaneously present in a CANDU plant. CNE Cernavoda has good experience in building tented structures for tritium control. Respiratory protection is mandatory when work is done in ventilated tents.

JOB CONTROL

Alpha contamination of airborne and surface is monitored before, during and after job completion.

- Friskers are used in the field to measure alpha contamination levels on equipment, in areas and on personnel.
- Continuous Air Monitors CAM (MGPi) are used to monitor airborne alpha activity nearby working areas.
- NT 200 radiometers are used to count lower levels of alpha contamination and to determine beta-gamma to alpha ratios on lower activity smears.

Stop Work Controls, Limits and Authorities are clearly established for alpha hazard jobs by a radiation exposure control process procedure.

INTERNAL DOSIMETRY PROGRAM FOR ACTINIDES

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As related to internal dosimetry, the radiation protection program includes the following elements: job specific / area scaling factor, estimates of intake and assessment of dose.

Biological retention and excretion models are provided by internal dosimetry software – IMBA or LUDEP 2.0.

In vivo whole body counting (WBC) for the detection of the major gamma emitters (e.g., Cs-137 and Co-60), that can be used as surrogate-nuclides, is applicable for the routine monitoring practices of TRU, depending on beta-gamma to alpha ratio.

^{60}Co is a better indicator of potential intake of TRU at the studied work areas. In the event that an intake of ^{60}Co is found by WBC, a follow-up faecal bioassay of actinides for dose assessment would be indicated.

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Instrumentation

FASTSCAN whole body counter - quickly and accurately monitor people for internal contamination of radionuclides with energies between 300 keV to 2000 keV.

Two large sodium iodine detectors [NaI(Tl)] providing a Lower Limit of Detection of 150 Bq for ^{60}Co with a count time of one minute for a person with normal ^{40}K internal activity. For a counting time of 3-5 minute, the detection limits are 50 Bq for ^{137}Cs and 60 Bq for ^{60}Co.

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Instrumentation

ACCUSCAN-II - identify and quantify radionuclides with energies between 100 keV and 2000 keV in complicated combinations.

Provides information on the location of the radioactive materials found in the body through its scanning mechanism and the system's ABACOS software.

Count time is the 3-5 minute range.

The detection limit for uncontaminated person (count time 30 minute) is 81 Bq for ^{137}Cs and 76 Bq for ^{60}Co.

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Estimates of Intake and Assessment of Dose

An estimate of the intake of gamma emitting radioactivity is determined from the whole body count measurements and applicable intake retention fractions:

$$I = \frac{A(t)}{IRF(t)}$$

I – estimate of intake in Bq

A(t) - the bioassay measurement obtained at time t in Bq

IRF(t) - intake retention fraction corresponding to the nuclide, solubility class, mode of intake, time after intake, and type of bioassay measurement.

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Estimates of Intake and Assessment of Dose

The committed effective dose (CED) from gamma emitters can be calculated using the estimates of the intake (I) and the Dose coefficients in the ICRP:

$$CED = e_{50} \times I \ (mSv)$$

e_{50} **is the Dose Coefficient – committed effective dose per unit acute intake calculated for 50 years, for adults in Sv/Bq.**

CED from alpha emitters will be calculated scaling the alpha-emitter intakes from the beta-gamma emitter intakes and calculating the CED from the intake of each radionuclide.

At this moment we have only the means for quantitative determinations of alpha nuclides, therefor the most conservative approach is to assume all alpha emitters are ^{241}Am.

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Scaling Factors

Since the ratio of beta-gamma to alpha activity is variable, a job specific / area scaling factor should be determined (see Table 1).

A "representative" air sample provides the most accurate measurement of the relative abundance of alpha and gamma emitters.

When specific job coverage air samples are not available, other air samples that are related to the same area and type of work may be used.

If no representative air samples are available, job specific loose surface contamination smears may be used

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Retention Models

The inhalation model predicts the retention of radioactive material assuming a particle size distribution having an activity aerodynamic diameter (AMAD) of 1-micron. For occupational exposure the default particle size is 5 µm AMAD.

The larger inhaled particles are rapidly cleared from the upper respiratory track, through the GI tract.

In order to determine as accurate as possible the biokinetic retention model – inhalation or ingestion - for the surrogate nuclide (^{60}Co) whole body counting must be performed daily after the intake.

The results will be compared with special monitoring predicted values (Bq per Bq intake) for inhalation and ingestion.

Retention Models

Transuranic alpha emitting nuclides are highly insoluble. Their retention is similar to other insoluble gamma emitters, e.g ^{58}Co and ^{60}Co which are well suited for determining retention fractions for alpha emitters because of their relative high abundance and solubility class.

As it was confirmed by calculation results based on ICRP models, ^{60}Co is a suitable "surrogate" nuclide for the evaluation of internal doses due to TRU alpha emitters for professionally exposed workers at CNE Cernavoda NPP.

Regardless of the beta-gamma to alpha ratio, all WBC results for ^{60}Co greater than MDA will be investigated. This approach ensures that all intakes are appropriately assessed.

CONCLUSIONS

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All the high alpha-radioactive samples contain significant quantities of ^{60}Co, which confirms its suitability as the surrogate nuclide for alpha internal dose evaluation.

^{243}Cm and ^{244}Cm were found having the highest contribution to alpha activity in the collected samples suggesting that the contamination source was a high burn-up defective fuel.

CNE Cernavoda contaminated areas are classified in present as Level II and Level I Areas (medium and high alpha contamination) and in case of an internal contamination the alpha emitters' exposure is likely to exceed 10% of the total internal dose.

CONCLUSIONS

Whole body counting represents an effective and inexpensive gamma bioassay tool that can be used initially to assess a gamma emitting intake. Whole body counters are capable of detecting small quantities of ^{137}Cs or ^{60}Co deposited in the lung or GI tract.

Due to its consistent ratio to gross alpha activity over time ^{60}Co is the best surrogate for estimating internal dose from alpha emitting contaminants.

Taking into consideration the limitations of our current program, the most conservative approach is to consider that every internal contamination with ^{60}Co, occurred in plant areas susceptible of alpha contamination, is accompanied by TRU intake, regardless the level of the ^{60}Co activity detected.

Thank you for your attention!

Questions?