Internal Contamination Incidents Occurred at Vanellos I Spanish Nuclear Power Plant during Dismantling Tasks

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Abstract

In year 1996 the Nuclear Power Plant Vandellos I started some dismantling tasks, one of these was the complete drainage of the spent fuel pools water and the removal of their content (tools, machines and elements used during operation with the spent fuel). During the 1996-97 period three incidents have occurred involving alpha internal contamination. This report describes each incident, the dosimetric assessment, in the third case the estimation was influenced by chelation therapy, and the lessons learned from an ALARA perspective.

Introduction

Vandellos I, a gas-graphite reactor operated from 1972 until 1989 when after a fire in the Turbine Hall it was definitely shutdown. In 1996 the utility started some dismantling tasks and the conditioning of radioactive waste. One of these tasks was the decontamination and drainage of the spent fuel pools comprising removal and dismantling of equipment, the decontamination of all the surfaces of the pools and the building. All the radioactive materials has been preconditioned and kept in dry storage in one of the decontaminated pools. The surface contamination level objectives for the pools were for loose contamination 4 Bq/cm^2 for _/_ and 0,4 Bq/cm^2 for _ , and 40 and 4 Bq/cm^2 for fixed contamination, respectively.

Initial conditions

The plant operated extracting the fuel continuously along with graphite sleeves. Both, fuel and graphite were driven to the pools where they were segregated and the fuel storage under water. The fuel was natural uranium with a magnesium cladding. The graphite sleeves were stored in a silo. During the operation of the reactor several incidents of fuel element cladding leakage were detected in the pools. Accordingly, the initial radiological survey monitoring was aware of the presence of alpha contamination but based on rough estimates rather than on measures.

The initial ventilation system was designed to maintain overpressure relative to the outside of the building and consequently the system needed modification.

Tasks planning

Before draining the pools water it was needed to proceed on the following way:

- Remove the graphite mud staying at the pools bottom by vacuum cleaning and filtering. Since the pools had never been cleaned before a great deal of material stayed at the bottom. Avoiding clouding the water was a priority. The radiation area levels were low as the pools were filled up with water.
- Extract the high radiant elements from the bottom. Activated material, like fragments of steel wires were remotely raised and placed in shielded containers.
- Remove, strip away, cut (when it was necessary), and decontaminate all the components installed inside the pool. Afterwards, the material was wrapped with a plastic covering and stored in a decontaminated pool. This pool would eventually be sealed with a concrete slab.
- A piping system was installed around pools to spray the stainless steel liner to wash down the contamination as the water level was lowered.
- An automatic brushing system swept the pool walls to decontaminate.

Initially, at the beginning of 1996, workers involved were wearing particle filter masks, as a preventive measure since alpha contamination were under 1 DAC, which was monitored by a particle filter and later measured in laboratory.

Description of the events related to these accidents

Case 1

On February of 1996 a significant raise of the airborne contamination was monitored up to 73 DAC, mainly due to Am^{241}. A tent enclosure provided with ventilation (SAS) was placed in the working area in order to decontaminate and to cut the elements extracted from the pools. A big size steel structure was lifted out of the pool and because of the size it could not be placed inside the tent so it was left without any mean to prevent the spreading of contamination. Then this structure was decontaminated with acetone. This was the cause of the airborne increase. The workers involved in this works were wearing particle filter masks.

Since an internal contamination was suspected, the Approved Internal Dosimetry Service of the CIEMAT (officially licensed by the CSN) established an internal monitoring programme for the workers involved in these tasks (a total of 13 workers). This programme consisted of the following actions:

· The workers were sent for whole-body counting.

· Phoswich detector was used for the investigation of pulmonary contamination with actinides.

· Urine samples were taken to carry out a bioassay measurement by radiochemical alpha spectrometry, to determinate the activity.

a. Methods for assessing intakes of radionucleides, and doses estimation from monitoring data

The initial dose assessment related to the internal contamination of the workers was made taking account the following parameters:

· <u>*Incorporate radionuclide:*</u> Am^{241}.
· <u>*Route of intake:*</u> Inhalation.
· <u>*Type of intake*</u>: Acute on the 28th of February of 1996.
· <u>*Solubility Class:*</u> W
· <u>*Biokinetics models:*</u>
- ICRP 30 Respiratory Tract Model for Standard Man
- ICRP 54 Compartment Model adapted to fit the Jones´ excretion function by the dosimetric code GENMOD-PC.

· <u>*AMAD:*</u> 1µm (the default value used in Publication 30).

b. Results

Intake and dose assessment for these assumptions are presented in Table 1.

Table 1: Doses assessment for each worker involved in the incident.

	Workers								
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Intake (Bq)	150	170	100	137	100	100	100	100	100
% ALI	75	85	50	68	50	50	50	50	50
Commited effective dose equivalent He,50 (msv)	18	20	12	16	12	12	12	12	12
Dose equivalent to lung Ht,50 (msv)	330	374	220	301	220	220	220	220	220

Four workers of the total of 13 workers involved in the incident did not showed internal contamination.

c. Actions taken from an operational radiological protection point of view

This incident revealed an insufficient planning and that contamination has a high degree of dissemination, this fact was enhanced by the lack of airtighness of the building and the initial ventilation design, so the airborne contamination can not be easily predicted.

After this event all the personnel entering the building wore aerosol–particle filter face masks, and those performing cutting and decontamination tasks inside enclosure tent were provided with supplied-air hoods.

Portable continuous airborne contamination measurement devices provided with visual and acoustic alarm were placed in the pools building.

As more material was removed from inside the pool and water level was reduced, the airborne contamination increased. Therefore, the use of supplied-air hoods was extended to all the workers entering the building. Task would be if airborne concentrations exceeded 10 DAC or the under pressure was lost in the building.

In addition to the superficial contamination monitoring on leaving the controlled area, workers were instructed to take nose swab to confirm the absence of alpha contamination. If traces of alpha contamination were measured or a positive nasal swab was detected an investigation process was started.

Case 2

On August of 1996, a positive nasal swab was detected with an Am^{241} contamination.

This event took place when a Radiological Protection agent was assisting to others workers taking their clothes off on exiting the controlled area.

a. Methods for assessing intakes of radionuclides, and doses estimation from monitoring data

The Internal Dosimetry Service of the CIEMAT established the dosimetric control programme for this worker.

This programme consisted of determining the activity of the isotopes of Pu^{238}, $Pu^{239+240}$, Am^{241} in the urinary excretion through urine samples that were taken to carry out bioassay measurements by radiochemical alpha spectrometry.

The initial dose assessment related to the internal contamination of this worker was made taking account the following assumptions:

- Incorporate radionuclide: Am^{241}
- Route of intake: Inhalation.
- Type of intake: Acute on the 30th of August of 1996.
- Solubility Class: W
- Biokinetics models:
  - ICRP 30 Respiratory Tract Model for Standard Man

- ICRP 54 Compartment Model adapted to fit the Jones´ excretion function by the dosimetric code GENMOD-PC.
· <u>AMAD:</u> 1µm (the default value used in Publication 30).

b. Results

Intake and dose assessment for these assumptions are presented in Table 2.

Table 2: Dose assessment for the worker implied in this incident due to Am^{241}

	Final Results
Intake (Bq)	50
% ALI	25
Committed Effective Dose Equivalent He,50 (mSv)	6
Dose Equivalent to Lung Ht,50 (mSv)	110

d. Actions taken from an operational radiological protection point of view

Since this event happened it was required all the Radiological Protection Agents wore respiratory protection when helping people to take off their clothes before leaving the controlled area.

Case 3

On 26th of March of 1997 a worker carried out a task consisting of the removal of the contaminated plastic cover of a probe without respiratory protection.

The worker presented a positive nasal swab taken on a routine basis at the end of a work period.

The Radiological Protection staff of the Nuclear Power plant took the following actions:

· Identify the potential source of contamination.
· Repeat nasal swab to this worker the following day (27/04/97). It gave a negative value.
· Monitoring of the whole body for gamma ray emitters by using a whole body counter provided with INa (Tl) detectors. There was any value above the register level.
· The worker was sent to the Medical Service of the nuclear power plant (NPP).
· The Medical Service administrated a chelate for the removal of radionucleides, DTPA (diethylenetriaminepentaacetic). It was chosen calcium salt form (Ca-DTPA). The total dose delivered was 0,5 gr. (2,5ml) and it was given by aerosol inhalation. The aerosol inhalation was done with 0,5gr Ca-DTPA diluted in normal saline placed in nebulizer.

a. Methods for assessing intakes of radionucleides, and doses estimation from monitoring data

The starting point was a contamination case with a mixture of transuranics (Pu^{238}, $Pu^{239+240}$, and Am^{241}), in which the worker involved in the event was subjected to DTPA therapy .

Taking into account these facts the Dosimetry Service of the CIEMAT designed a monitoring programme based on urine samples at weekly and fortnightly intervals. Due to the quelation therapy the urinary excretion rate increases significantly for periods up to one hundred days the monitoring programme lasted for four months.

The technique selected to carry out the analysis of urine samples was alpha spectrometry.

A total number of 12 urine samples were collected, the samples correspond to a 24 hours excretion, and the excretion rates were normalised to the real excretion of the worker according to the creatinine content.

The initial dose assessment related to the internal contamination of this worker was made taking account the following assumptions:

· <u>Incorporate radionuclide:</u> Am^{241}, Pu^{238}, $Pu^{239+240}$
· <u>Route of intake:</u> Inhalation.

- *Type of intake*: Acute on the 26th of March of 1996.
- *Solubility Class:* W
- *Biokinetics models:*
  - ICRP 30 Respiratory Tract Model for Standard Man
  - ICRP 54 Compartment Model adapted to fit the Jones´ excretion function by the dosimetric code GENMOD-PC.
- *AMAD:* 1µm (the default value used in Publication 30).

The calculation of assessment doses were carried out with the urinary excretion experimental data obtained from the days 96 to 117 after the incident.

The perturbation of the urinary excretion pattern caused by chelation therapy will usually subside within about 100 days following the chelation treatment. Thus, the easiest way to evaluate the intake following the chelation therapy was to model the urinary excretion data collected after the 100 day cut-off using standard biokinetics models recommended by ICRP.

b. *Results*

Intake and dose assessment for these assumptions are presented in Table 3

Table 3: Dose assessment for the worker involved in this incident.

	Am^{241}	**$Pu^{239+240}$**	**Pu^{238}**
Intake (Bq)	209	37	20
% ALI	104	19	7
Committed Effective Dose Equivalent (Msv)	25	4	2
Dose Equivalent to Bone Surface (mSv)	460	78	38

To sum up the final assessment of doses was the next:

- Committed whole body effective dose equivalent was 31mSv (62% LAD).
- Dose equivalent to bone surface was 576mSv (115% LAD).

c. Comparison of dosimetric assessment made applying ICRP 30 model and ICRP 66 model.

The dose assessment carried out in the above paragraph was made applying the human respiratory tract model given in ICRP Publication 30. This is the scientific basis for internal dosimetry of the current Spanish legislation (Royal Decree 53/1992).

The European Directive 96/29/EURATOM has based their regulations in the field of radiation protection on ICRP recommendations in particular concerning occupational exposure and exposure limits. It is obvious that Spain as member country of the European Community must comply with this Directive, being at this very moment transposing these regulation into Spanish legislation.

The forthcoming radiological protection standards of this Directive are based on the new recommendations for radiation protection, including basic concepts and guidelines for radiation protection published in 1991 by ICRP in publication 60 and the state of the art for biokinetic models recommended by the International Commission for Radiological Protection. The Human Respiratory Tract Model given in ICRP Publication 66 replace the one of ICRP 30, being much more complex (33 comparments, 19 parameters) than the former one.

At this position has been considered interesting to compare the internal doses calculated by both respiratory tract models.

The calculate of internal doses by ICRP 66 was made using the Lung Dose Evaluation Programme (LUDEP) developed by NRPB.

Internal doses assessment regarded to ICRP 66 model have been carried out under the following assumptions:

- *Solubility Class*: M
- *Biokinetic models*:

- ICRP 66 Respiratory Tract Model for Standard Man,
- ICRP 54 Excretion functions.Jones and Durbin Model both implemented in the dosimetric code LUDEP.

· *AMAD*: 1µm
· *Tissue Weighting factors* : ICRP 26

The calculations have been made using the ICPR66 model for the Am^{241} which its the radioisotope with a majority contribution on the dose in comparison with the Pu^{238}, Pu^{239}. The results obtained using the aforementioned criteria were the next:

Table 4: Comparison of results of dose assessment carried out using ICRP 30 and ICRP66 metabolic models

	Am^{241} ICRP 30 JONES MODEL	Am^{241} ICRP 66 JONES MODEL	Am^{241} ICRP 66 DURBIN MODEL
Intake (Bq)	209	288	262
Committed Effective Dose Equivalent (mSv)	25	26	24
Dose Equivalent to bone surface (mSv)	460	464	422

d. Actions taken from an operational radiological protection point of view

Regarding this incident attention must be focused mainly on the cause of it was an operational error of the worker involved in the incident by carrying out in a mistaken way a task considered as simple. An important reason for occurring this incident was, (as the worker explained after happening the incident), due to the moving limitations of the respiratory protection equipment.

A later analysis of this incident made evident different actions carried out by the Radiological Protection Service and Medical Service of the NPP which could be improved, such as:

· There were no written records of the actions carried out by the Radiological Protection Service in the first days after detecting the potential internal contamination, neither there were written information about the data provided by the Radiological Protection Service to the Medical Service for the treatment of this worker.

· Neither the Radiological Protection Service staff nor the Medical Service staff collected an urinary excretion sample of the worker involved in the incident before giving him the chelation therapy. Due chelation therapy is considered most effective when it is begun immediately after exposure no-one thought in the possibility of collecting a urine sample.

So after detecting this aspects it was recommended to improve the following points:

· Training and operational practices for the workers involved in tasks carried out in this controlled area.
· Operational proceedings and working guidance.

Conclusions

The conclusions which can be drawn from this article can be approached mainly from two points of view; the dosimetric standpoint and from the operational radiological protection perspective.

In the case of operational radiological protection the most important aspects which emerge from this article as lesson to be learned are the following:

· The alpha to beta ratio has changed. Alpha contaminants are now the critical source this made us to bear in mind these questions:

1. Actinides are highly toxic and a mere 200Bq represents the 50mSv legal annual dose limit.
2. The presence of airborne actinides requires the use of air assisted respiratory protection equipment.
3. The undressing process can ba a real internal contamination path if not carried out properly

4. All personnel, especially the Radiological Protection Agents must be aware of these facts to modify their behaviour in the prevention of contamination. When the respiratory protection is necessary and only as well as a delicate technique to take all clothes off.

· The total collective dose of this work during the 1996-97 period is 234 mSv·person, of which 56% is due to the committed effective dose because of these incidents. The internal dose management is a key element to achieve the ALARA goals. Therefore the following points must be considered:

- ***„Alpha awareness“.*** All the parties (management and operation personnel) must be aware of the risk and consequences of the alpha contamination.
- ***Detailed assessment of radiological risks.*** In the earliest stages of planning a strategy must be addressed considering the eventual destination of wastes; waste conditioning, secondary wastes production, and the doses (internal and external) involved in these tasks, balancing these factors with ALARA criteria.
- ***Interdisciplinary ALARA teams*** should thoroughly plan operations, as well as a carefully follow-up of jobs with prompt and adequate feedback of deviations.
- ***Detailed working procedures*** specially those with greater potential in spreading contamination. Those techniques directed to fix the loose contamination.
- ***Respiratory equipment use and undressing protective clothes instructions and practice.***
- ***Plans for anticipated incidents.*** All the reasonable incidents that may occur should be consider in order to planning proper remedial actions.
- ***Training.*** All the above mentioned items must be included in specific training courses.

Concerning the dosimetric assessment we can conclude the following aspects:

· Nasal swab samples may be used to detect or confirm inhalation of radionucleides and should be taken as soon as possible following a suspected intake.
· When a routine monitoring result indicates that a predetermined level has been exceed a pre-planned programme or further monitoring will be instigated for the purpose of assessing the magnitude of the exposure. Delays on the starting of this programme could cause problems because the analytical techniques used for calculating the intake present specific detection limits for each radionuclide.
· If an incident involving possible intake of actinides occurs, follow up urine samples are requested.
· The perturbation of the urinary excretion pattern caused by chelation therapy will usually subside within about 100 days following the chelation. The easiest way to evaluate an intake following chelation therapy is to model the urinary excretion data collected after the 100 day cut-off using standard biokinetic models.
· The comparison between the values estimated of committed effective dose equivalent due to Am^{241} assessed taking into account the metabolism model recommended by ICRP 30 and the metabolism model recommended by ICPR 66 point out that:

1. The dose estimated by using the model recommended by ICRP 66 and the excretion functions of the Durbin model is a factor 1,25 over the dose calculated by means of ICRP 30 model with the Durbin´s excretion functions.

2. The dose estimated by using the model recommended by ICRP 66 and the excretion functions of the Jones model is a factor 1,37 over the dose calculated by means of ICRP 30 model with the Jones´ excretion functions.

References

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