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Incorporation monitoring during decommissioning – Am-241 problem in Gundremmingen

The decommissioning of the nuclear power station Gundremmingen unit A (KRB A) began in 1983 and should be finished in 2003. 153 people were included in the regular incorporation monitoring programme during the decommissioning between 1993 and 1998. The most important nuclide was Am-241 which has a contribution of 60% to the committed effective dose. The assessment of intake and dose were carried out in accordance to the German guidelines. The mean value for the effective dose was 1.5 mSv (geometric mean 0.67 mSv), calculated over all dose assessments. Intakes more than the ALI could not be detected from 1996 to 1998. Decontamination and decomposition of radioactively contaminated parts of the plant and handling of radioactive waste were found to be the activities with the highest risk of incorporation. Intensive regular cleaning and decontamination of the working places were established to avoid or to reduce incorporations. However, the most important requirement is to increase the workers sensitivity to the problems of incorporation of radioactive material by careful instructions related to their individual work. The strict realization of these measures have clearly reduced the risk of intake as can be seen from the results of the incorporation monitoring programme.

Inkorporationsüberwachung beim Rückbau – Am-241-Problem in Gundremmingen. Die Rückbaumaßnahmen für das Kernkraftwerk Gundremmingen Block A (KRB A)

begannen 1983, das Ende ist für 2003 vorgesehen. Im Rahmen der Rückbaumaßnahmen wurden in den Jahren 1993 bis 1998 insgesamt 153 Personen regelmäßig überwacht. Das Leitnuclid der Inkorporationsüberwachung war das Am-241, das allein über 60% zur effektiven Körperdosis beiträgt. Die Berechnungen der Aktivitätszufuhr und der Körperdosen wurden auf der Basis der in Deutschland gültigen Richtlinien durchgeführt. Der Mittelwert der berechneten effektiven Körperdosen betrug 1,5 mSv (geometrischer Mittelwert 0,67 mSv). Aktivitätszufuhren oberhalb des Grenzwertes der Jahresaktivitätszufuhr konnten nicht eindeutig nachgewiesen werden. Während der Überwachung stellten sich insbesondere die Dekontaminations- und Zerlegearbeiten sowie die Abfallbehandlung als Tätigkeiten mit besonders hohem Inkorporationsrisiko heraus. Zur Vermeidung bzw. Reduzierung von Inkorporationen wurden intensive regelmäßige arbeitsplatzbezogene Reinigungs- und Dekontaminationsmaßnahmen eingeführt. Die wichtigste Voraussetzung ist jedoch die Sensibilisierung der betroffenen Personen für die Inkorporationsproblematik durch eine intensive arbeitsplatzbezogene Unterweisung und die daraus resultierende Bereitschaft für eine effektive Umsetzung der getroffenen Maßnahmen. Durch die konsequente Umsetzung der genannten Maßnahmen konnte das Risiko einer Aktivitätszufuhr drastisch reduziert werden, was an den Ergebnissen des Überwachungsprogrammes deutlich erkennbar ist.

1 The KRB-A boiling water reactor history

The nuclear power station Gundremmingen unit A (KRB A) is located in Bavaria at the river Donau between Stuttgart and Munich. It was a boiling water reactor with an electrical output of 250 MW, which was under construction in 1962-66 as the first commercial nuclear power plant (NPP) in the Federal Republic of Germany. KRB A was operated from 1966 until January 1977. It was shut down in January 1977 due to a short circuit in the grid which caused substantial damage to the plant. In January 1980, it was decided to decommission and dismantle the plant. The planning phase of the decommissioning of unit A began in the same year, actual dismantling work started in 1983 and should be finished in the year 2003. Until 1998 more than 6200 tons of material were dismantled.

The decommissioning project was structured in 3 phases as shown in Table 1. It started 1983 with the removal of components and systems in the turbine house (phase I). Since 1990, the dismantling work have been extended to the primary

water system inside the reactor building (phase II). In 1992 the dismantling of the reactor pressure vessel (RPV) has started with the segmenting of the RPV-head and the steam dryer.

The EU Commission selected KRB A as a pilot dismantling project for its 1989-1993 RTD programme on the dis-

Table 1. Radioactivity and collective dose in the phases of decommissioning

Phase	System	Mass (Mg)	Activity (Bq)	Dose (Sv)
I	Steam and feedwater	4500	4E+10	1
II	Reactor water	700	1E+12	≈ 1.4
III	RPV and biological shield	600	2E+16	≈ 1.5

Table 2. Actual nuclide vector for dose calculation

Nuclide	Portion of activity [%]	Portion of ALI* [%]	Portion of effective dose [%]	Portion of organ dose (bone surface) [%]
Co-60	63.8	0.9	1.4	0.5
Cs-137	25.0	< 0.1	0.1	< 0.1
Eu-154	0.3	< 0.1	< 0.1	< 0.1
Pu-238	0.6	8.4	16.8	10.4
Pu-239/240	0.5	7.0	15.1	9.7
Pu-241	8.3	2.4	3.9	3.6
Am-241	1.4	78.5	60.3	73.0
Cm-243/244	0.1	2.8	2.4	2.8

* ALI = annual limit of intake

mantling of nuclear installations. The commission intends to promote the use of advanced techniques and the performance of collateral investigations, in order to enhance the development of useful knowledge and experience to serve in subsequent decommissioning tasks. In particular, the generation of specific data on costs, working hours, job dose as well as on the amount of generated secondary waste, is considered as an important objective of this pilot project.

More information about the NPP Gundremmingen, unit A is available from the internet under "www.krb.de".

2 The Am-241 problem

When starting the decommissioning the condition of the plant and the nuclide vector were not known in detail, as contaminated parts and units of the plant were amenable just in progress dismantling. The actual nuclide vector which is used for calculation of incorporated activity and total effective dose is shown in Table 2.

It was measured in 1997 from depositions from the exhaust air. It could easily be recognised, that the most important nuclide was Am-241 which has a contribution of around 1.4 % to the total activity but around 60 % to the committed effective dose. Therefore Am-241 was chosen as the leading nuclide for the incorporation monitoring programme. It seems to be not very useful to take one of the gamma emitters, for example Co-60, as leading nuclide for the monitoring programme. Unknown changes of the nuclide vector could not be detected and could cause great changes for the effective dose. Therefore a very intensive control of the

nuclide vector would be necessary to avoid this. The direct measurement of Am-241 seems to be the better way for the monitoring programme. As the ratio of Am-241 to plutonium and curium isotopes is well known the analysis of Am-241 delivers the main nuclides which covers around 95 % of the effective dose.

In this publication the problem of incorporation monitoring is mainly described from the point of view of the state office which has the function to control the operator of the plant and to carry out the dose assessment.

3 The monitoring programme

153 people were included in the regular incorporation monitoring programme during the decommissioning between 1993 and 1998.

At the beginning of the monitoring programme each worker was regularly examined at least by one urine sample and one body counter measurement per year. From 1993 to 1995, 169 urine samples were analysed and 274 body counter measurements were carried out. 108 workers were included in the regular incorporation monitoring programme during this time. While Am-241 could not be detected in the urine samples, it was found in only one case of the body counter measurements in 1995. Dose assessment results in an effective dose of approx. 21 mSv. As there were only one measurement of body activity and a few additional information available for the calculation, the dose assessment has great uncertainties.

As consequence of this incorporation the monitoring programme was changed in 1996. A reference group of 15 workers was chosen for the regular monitoring programme. The workers, who were assumed to have the highest risk for incorporation, had to take faeces samples in an interval of around 6 weeks. Am-241 could be detected in 76 % of the faeces samples. This high number of positive results has not been expected. The assessment of intakes and doses from the results was very difficult as there were nearly no information about the pathway of intake, the time of incorporation, the activity median aerodynamic diameter (AMAD) etc. Although the workers were requested to be more careful and some actions were taken to avoid incorporation the situation in 1997 was quite the same. When in August 1997 an excretion rate of nearly 600 mBq/day was measured in one faeces sample an excess of the ALI could not be excluded. Therefore the decision was made to start an additional decontamination programme which should avoid incorporations in the future. The result of the actions should be controlled by an intensive regular incorporation monitoring programme. 103 workers were involved in this programme and 572 faeces samples were analysed in 1998. 487 of the measurements were done in the laboratory of the Siemens AG (KWU) in Erlangen. The rest was analysed in the laboratory of the State Office for Environmental Protection in Kulmbach.

Table 3 gives an overview about the size of the incorporation monitoring programme from 1993 to 1998.

4 Results of the monitoring programme with faeces samples

From 1996 on, the monitoring programme was changed to faeces. 741 faeces samples were analysed and around 330 body counter measurements were additionally carried out until the end of 1998. Am-241 could be detected in 43 % of the faeces samples. 590 mBq/day was the highest excretion rate found. No positive result for Am-241 in faeces samples

Table 3. Size of the incorporation monitoring programme

Year	Workers	Investigations		
		urine samples	faeces samples	body counter measurements
1993	57	57	–	87
1994	63	63	–	89
1995	69	69	–	98
1996	15	–	66	102
1997	15	2	103	121
1998	103	–	572	103

Table 4. Overview about the results of the measurements of faeces samples

Year	All	< 1 mBq/day	1–10 mBq/day	10–100 mBq/day	> 100 mBq/day	arithm. mean [mBq]	geom. mean [mBq]
1996	66	16	20	24	6	45.4	16.0
1997	103	17	35	45	6	32.2	12.3
1998 reference group	178	96	61	21	0	10.2	6.2
1998 without reference group	394	267	105	21	1	7.7	5.3
1998 all workers	572	363	166	42	1	8.7	5.6

was obtained for 49 of the 110 workers who were included in this programme.

Table 4 gives an overview about the results of the measurements of the faeces samples from 1996 to 1998.

The incorporation monitoring for Am-241 with faeces samples is a very sensitive method to detect every type of incorporation independent of the path of intake. Therefore, this method is very useful for controlling the steps that are arranged in 1998 to avoid incorporations.

As a result of this programme, the number of faeces samples in which Am-241 could be detected decreased considerably. The same compliance could be made for the average and the maximum of the single values for Am-241 which also decreased significantly.

The reference group of workers in Table 4 shows two effects:

- The results for Am-241 in 1998 are much lower than in 1996 and 1997 which shows the effect of the decontamination programme.
- The mean values of the workers of the reference group are significantly higher than the mean values of the rest of the workers. The risk of incorporation for these people is especially high which depends on the work they have to do.

5 Assessment of intake and dose

The assessment of intake and dose was carried out in accordance to the German guidelines for incorporation monitoring [1, 2, 3]. However in many cases the strict procedure of the reference method of the guidelines was not very useful. Therefore some additional agreements were used for the dose assessment.

5.1 General rules

The results of the monitoring programme for Am-241 in faeces were used for the assessment of intakes. Effective doses were calculated from this value with consideration of the nuclide vector of Table 2.

The assessment of intakes and doses was done when Am-241 could be detected at least in one faeces sample of a worker. Intakes and effective doses were documented and for all cases an assessment was carried out even when the result was below the interpretation level (3% of the annual limit of intake).

Inhalation of aerosols with an AMAD of 1 µm was supposed to be the only path of intake of activity. The path of ingestion was not taken into account for the assessments, although there were some indications for the occurrence of this path.

5.2 Rules for intake assessment

Dose assessments started with the reference method of the German guidelines that means

- the only path of intake is inhalation
- AMAD of the aerosol is 1 µm
- time of intake is the middle of the investigation interval.

The result of the following investigation was used to control the assessment. A correction of the intake according to the result of the following sample was done by a shift of the possible date of intake. No further parameters for the calculation were changed. Samples in which no Am-241 could be detected were used to calculate the maximum of intake.

Table 5. Overview about the results of the dose assessments

Year	Number of workers	Number of dose assessments	Effective dose calculated over all dose assessments			
			arithmetic mean [mSv]	geometric mean [mSv]	lowest value [mSv]	highest value [mSv]
1996	15	13	1.3	0.9	0.2	5.8
1997	15	13	3.4	2.3	0.9	14.5
1998 reference group	12	12	1.0	0.6	0.1	2.8
1998 without reference group	91	46	0.6	0.4	0.01	4.6
1998 all workers	103	58	0.7	0.5	0.01	4.6

Table 6. Jobs with high risk of incorporation

Job	Protection measure
general dismantling of contaminated parts	foil tents, exhausting, masks
dismantling and packing of the secondary steam generators	foil tents, exhausting, masks
high pressure treatment of waste	foil tents, exhausting, masks
waste handling	masks
decontamination	exhausting, masks

If successive results of measurements are in correlation with one single date of incorporation, the intake of activity was calculated as mean value of the single results.

A chronic intake was assumed if it was not possible to bring a succession of results in reasonable correlation. The daily intake was calculated from the mean value of the measurements, the excretion rate in the middle of the period and the number of days of the investigation period.

Following results below the detection limit were used to prove the plausibility of the calculations. In accordance with the German guidelines the results were accepted if they did not vary by more than a factor of 3 from the measured values.

No positive result for Am-241 in faeces samples was obtained for 49 of the 110 workers who were included in this programme. No dose assessment was necessary for these cases.

In 31 of the overall 83 cases (37 %) the assessment resulted in an intake less than 3 % (interpretation level) of the annual limit of intake (ALI), in 48 further cases (58 %) the results of the intake assessment were between 3 and 30 % of the ALI. The investigation level of 30 % of the ALI was exceeded only in 4 cases (5 %). Intakes more than the ALI have not been detected from 1996 to 1998.

Committed effective doses of 21 mSv for 1995 and 15 mSv for 1997 were estimated as highest internal exposures. The mean value for the effective dose was 1.5 mSv (geometric mean 0.67 mSv), calculated over all dose assessments. Table 5 gives an overview about the results of the dose assessments.

6 Jobs with high incorporation risk and protection measures

During decommissioning the following jobs were correlated with a high possibility for incorporation.

In spite of the protection measures that were arranged incorporations could not be avoided as could be seen from the monitoring results of the years 1996 and 1997. The reason was the general contamination of the plant and the working places which causes incorporations when they were not expected. The cleaning and decontamination of tools and the taking off of the working clothes were two typical examples. Also the individual behaviour of the workers was one of the problems which could not be estimated.

During the programme in 1998 the following measures were taken to remove the alpha-contamination and to avoid incorporations.

- related to the workers:
intensive instruction related to the job and the potential risk

investigations of the personal behaviour and removal when necessary

- related to contaminations:
continuous cleaning and decontamination of the working places by defined workers
continuous investigation of the contamination of the plant especially in areas which were not working places
use of machines for cleaning the ways of traffic to avoid contamination
use of local and mobile exhausting to avoid radioactive aerosols
- related to protective clothes and general hygiene:
new protective clothes
use of one way shoes
use of one way masks when radioactive aerosols could not be excluded
special assistance for taking on and off of protective clothes and masks
optimising of decontamination and monitoring procedures when leaving the controlled area.

7 Conclusion

The decommissioning of a nuclear power plant is very exacting on the incorporation monitoring especially in areas with alpha contamination. As general air monitoring is not useful, monitoring systems for each individual worker have to be used. Incorporation monitoring with faeces samples is a very sensitive method to detect every type of intake and to control decontamination procedures. As the analysis of faeces samples is very expensive a monitoring programme has to be established to reduce work and costs. It is also very useful to have a guideline for the assessment of intake and dose so that these calculations can be carried out in a given way. During the decommissioning of KRB A decontamination and decomposition of radioactively contaminated parts of the plant and the handling of radioactive wastes are found to be the activities with the highest risk of incorporation. Since regular cleaning and decontamination of the working places was newly established or was done more intensively, incorporations were clearly reduced. However, the most important requirement is to increase the workers sensitivity to the problems of incorporation of radioactive material by careful instructions related to their individual work.

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References

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