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Article

Contamination of seven workers with ^{241}Am

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ABSTRACT **Widespread contamination occurred in the building in which radiation waste was handled. An occurrence of internal contamination of workers was also suspected. Therefore, workers were measured *in vivo* and bioassay was performed too. Estimation of committed effective dose had to be based on results of excretion analysis as irremovable surface contamination occurred on the skin and hair of workers, thus influencing results of *in vivo* measurements. The results of bioassay of 7 workers are presented. Intakes and committed effective doses were calculated from excretion data using IMBA Professional Plus software. The best fits for the most of workers were obtained when combination of acute and chronic intakes was used. Acute intakes varied from 135 Bq to 1300 Bq, chronic intakes from 0.03 Bq/d to 0.3 Bq/d. Committed effective doses from 3 to 36 mSv were estimated for individual workers.**

Key Words: Am-241 / Internal contamination / Surface contamination / bioassay / intake

RÉSUMÉ **Contaminations de sept travailleurs par ^{241}Am.**

Une importante contamination s'est produite dans un bâtiment au sein duquel des opérations de traitement de déchets radioactifs avaient lieu. Une contamination interne des travailleurs étant suspectée, ces derniers ont bénéficié de mesures anthroporadiamétriques ainsi que d'analyses radiotoxicologiques des urines et des selles. Les doses efficaces engagées n'ont été évaluées qu'à partir des résultats de mesure de l'activité excrétée en raison d'une contamination externe résiduelle au niveau de la peau et des cheveux entachant d'erreurs les résultats de mesure de l'activité retenue. Les résultats des analyses radiotoxicologiques pratiquées chez 7 travailleurs sont présentés. Les incorporations ont été évaluées à partir des mesures urinaires et à partir des mesures fécales en utilisant du logiciel IMBA Professional Plus, donnant les meilleurs résultats quand des combinaisons des incorporations aigues et chroniques étaient présupposées. Les incorporations aigues entre 135 Bq et 1300 Bq et les incorporations chroniques entre 0,03 Bq/jour et 0,3 Bq/jour ont été évaluées. Les doses efficaces engagées consécutives à l'incorporation ont été estimées entre 3 et 36 mSv pour les travailleurs individuels.

1. Introduction

Since the early seventies, ^{241}Am has been used for many applications in the Czech Republic, especially for production of AmBe neutron sources, radionuclide sources for smoke detectors, radionuclide sources for the discharge arresters,

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standard sources for alpha and gamma spectrometry, etc. The original material was AmO_2 powder, imported from the former Soviet Union. The production of radionuclide sources included chemical treatment of original AmO_2 powder; for some purposes, the americium nitrate was the base. The production of sources for smoke detectors was performed by means of powder metallurgy. The briquettes from americium oxide were encapsulated by rolling into gold and silver foil and afterwards cut for the use as the radioactive sources in smoke detectors. Some of these operations were performed in hermetic boxes. At present time, these hermetic boxes have not been used any more and it was suspected that they could be a source of contamination in the laboratory, causing internal contamination of workers from time to time. Therefore, it was decided to remove the boxes and put them into radioactive waste. When dismantling and fragmenting the hermetic boxes for the cementation into waste drums, release of ^{241}Am into working environment occurred and suspicion of internal contamination of workers took place.

2. Materials and methods

2.1. Description of the event

The whole process of transportation of the boxes from the original place of use to the waste management facility and process of the fragmentation and cementation into drums took three weeks' time in June and July 2001. The owner of the boxes estimated the activity of ^{241}Am, remaining on the inner surfaces of the 3 boxes to be 150, 180 and 50 MBq, based on the measurement of the surface activity of inner and outer surfaces of the boxes. As to hinder the spread of radioactive material, the boxes were covered by fixating lacquer. Afterwards they were separated from each other, wrapped in plastic sheets and transported to the fragmentation unit of Radioactive Waste Department of the Nuclear Research Institute. During dismantling of the first two boxes, there were presumably no signals about the release of activity. However, during the dismantling of the third box, measurements of filters from the air activity measurement device from previous periods had been completed and showed that investigation level for the alpha activity (0.06 Bq/m^3) in air had been exceeded (1.7 Bq/m^3 on the filter from 10th July). Protective face masks of 4 workers were measured and significant activity of ^{241}Am was found on them, therefore a suspicion of internal contamination of workers had arisen. It was found that respirators (protective face masks from filtration material) and rubber gloves had been used repeatedly and stored in plastic bags between individual operations, therefore secondary contamination of them during the storage was possible (Report SÚJB, 2002). The work clothes were contaminated too and had been put into the radioactive waste without

distinguishing individual level of contamination. These clothes could have probably been a source of secondary internal contamination. On the basis of the first *in vivo* measurements some workers seemed to be qualified for treatment by DTPA infusions. Six workers were hospitalised and treated by two doses of 1g Ca –DTPA (Klener *et al.*, 2003), one of the workers (V.V.) preferred to take his holidays.

2.2. In vivo measurements of ^{241}Am activity

19 workers were measured for ^{241}Am by a whole body counter with HPGe detector and their heads and knees were measured with two special LEGe detectors. The LEGe detectors had been calibrated for measurements of content of ^{241}Am in skeleton as measurements of ^{241}Am in the skeleton were used for retrospective study, which has been under way in the National Radiation Protection Institute in Prague (Malátová *et al*., 2003a). A calibration for the ^{241}Am activity in lungs had been intended too and a phantom of lungs had been ordered from the IAEA, however, phantom reached the NRPI only a year after the described incident. Therefore, only *ad hoc* measurements, without previous calibration of the thorax were performed with the aim to estimate activity in lungs.

From the very beginning, there was a suspicion that significant activity on the skin all over the body was present, however, not measurable by the detection instruments (Digital Contamination Monitor LB 1210 E) for the surface alpha activity. The surface contamination was proven when ^{241}Am activity was detected in the sample of cut hair and on the bedclothes of one worker. Slow decline of the activity measured in the heads instead of expected increase according to the ICRP Publication 78 (ICRP, 1997) model as shown for one case in Figure 1, also proved skin contamination. Therefore, the results of measurements *in vivo* served only as a warning that internal contamination of an individual had occurred and that widespread contamination of the workplace probably existed.

2.3. Measurement of ^{241}Am in excretion

The workers, at whom measurable activity of ^{241}Am was found by *in vivo* counting, were instructed immediately to collect 24 hour samples of faeces and urine trough three consecutive days. Such approach was used as people with irremovable surface contamination had higher probability of internal contamination. For screening purposes the samples of excreta were first measured by semiconductor gamma spectrometry in native state. Native urine was poured into six cylindrical vessels of 200 ml content each, which were placed around the HPGe detector. The minimum detectable activity (MDA) for this geometry and time of measurement 2 hours was 2 to 3 Bq per sample, depending on efficiency

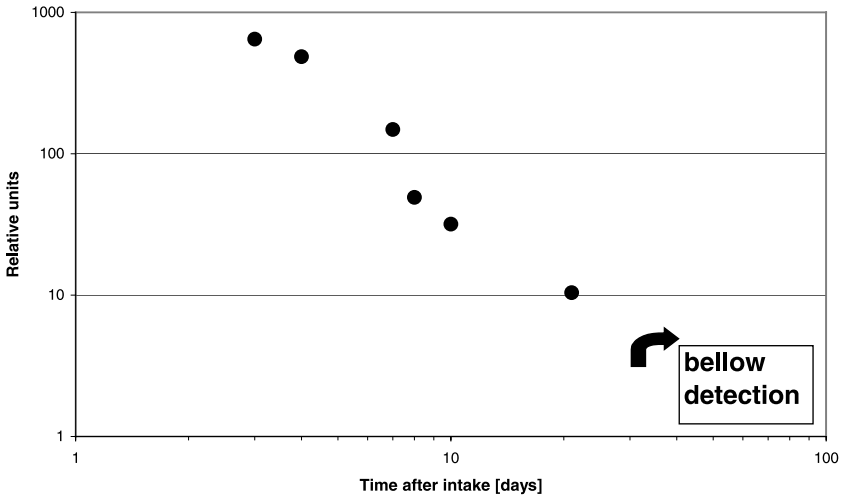


Figure 1 – ***Time course of the activity of ^{241}Am in head of case MS.***
Évolution de l'activité de ^{241}Am mesurée au niveau de la tête du travailleur MS.

of detector used. No measurable activity of ^{241}Am was found in any of the urine samples in native state, therefore radiochemical separation of Am followed by alpha spectrometry was used (Dulaiová *et al*., 2004) for determination of activity. As to obtain information about internal contamination as soon as possible, samples of faeces were measured first in the vessel in which they were brought, afterwards in a 200-ml vessel. Vessels were placed on the front of an HPGe detector for measurements. When activities of ^{241}Am per sample decreased below 3 Bq, samples of faeces were deep frozen, dried, ashed at the temperature below 450 °C and measured by gamma spectrometry using counting times at least 10 000 s. Ash was put either at the bottom of cylindrical vessel and placed on the cap of coaxial HPGe detector for measurement or in a small test tube, which was put in the well of the HPGe well type detector. When using the well detector and a long time of measurement (up to 3 days), minimum detectable activity was 0.01 Bq/sample. According to the amount of faeces ash, the whole ashed sample or only a part was used.

3. Results

3.1. Results of measurements

Results of *in vivo* measurements are not presented as they were seriously influenced by surface contamination and therefore had to be discarded. The

TABLE I

Excretion rates – case MS. Assumed date of the first intake: 9.7.2001.
Activités mésurées dans les urines et dans les selles au cours du temps – travailleur MS. La date supposée de la première incorporation : 9.7.2001.

Date of sampling	Time after the 1st intake [d]	Excretion in urine [Bq/d]		Excretion in faeces [Bq/d]	
07/12/2001	3	9.57E-02	± 1.30E-03	1.30E+02	± 5.70E-01
07/13/2001	4	6.18E-02	± 2.10E-03	1.20E+02	± 5.38E+00
07/14/2001	5	* 8.30E-02	± 1.24E-02	1.50E+00	± 8.00E-02
07/15/2001	6	*3.26E-01	± 1.56E-02	2.40E+01	± 2.05E+00
07/16/2001	7	* 3.85E-01	± 1.56E-02	3.00E-01	± 1.85E-02
07/17/2001	8	* 2.90E-01	± 1.00E-02	1.35E+00	± 8.45E-02
07/18/2001	9	1.69E-01	± 1.37E-02	3.00E-01	± 1.85E-02
07/19/2001	10	3.64E-01	± 2.25E-02	-	
07/20/2001	11	2.63E-01	± 1.78E-02	1.50E-01	± 1.30E-02
07/21/2001	12	2.04E-01	± 1.30E-02	5.00E-01	± 2.80E-02
07/22/2001	13	1.89E-01	± 1.21E-02	7.00E-01	± 6.60E-02
07/27/2001	18	4.16E-02	± 1.50E-03	2.00E-01	± 1.50E-02
07/28/2001	19	1.06E-01	± 5.80E-03	2.00E-01	± 1.00E-01
07/29/2001	20	1.09E-01	± 4.00E-03	9.00E-02	± 6.00E-03
08/18/2001	40	4.30E-02	± 3.20E-03	1.40E-01	± 9.00E-03
08/19/2001	41	2.90E-02	± 1.70E-03	4.00E-02	± 7.00E-03
10/23/2001	106	4.40E-03	± 0.40E-03	4.90E-01	± 3.60E-02
10/24/2001	107	6.30E-03	± 0.80E-03	4.90E-01	± 4.40E-02
10/25/2001	108	6.60E-03	± 0.50E-03	3.40E-01	± 3.00E-02
03/24/2002	258	1.10E-03	± 0.20E-03	7.50E-01	± 4.60E-02
03/25/2002	259	1.70E-03	± 0.70E-03	1.05E-01	± 1.00E-02
03/26/2002	260	0.90E-03	± 0.30E-03	2.52E-01	± 1.30E-02
01/10/2003	550	2.30E-03	± 0.10E-03	1.83E-01	± 1.80E-02
01/11/2003	551	-		1.30E-01	± 1.50E-02

DTPA administered on 14.7.2001 and 17.7.2001.
* - values not used for evaluation of intake.

suspicion that the substantial part of "the body activity" is a surface contamination has arisen immediately after the first few measurements. It, however, persisted after many showers. Massive surface contamination as well as the significant activity in samples of faeces led to investigation at the workplace.

Results of activity of ^{241}Am in faeces and urine of 7 workers are presented in Tables I to VII. They include not only activities, found in excretion in the short

TABLE II

Excretion rates – case VV. Assumed date of the first intake: 10.7.2001.
Activités mésurées dans les urines et dans les selles au cours du temps – travailleur VV. La date supposée de la première incorporation : 10.7.2001.

Date of sampling	Time after the 1st intake [d]	Excretion in urine [Bq/d]		Excretion in faeces [Bq/d]	
07/13/2001	3	4.30E-03	± 0.40E-03	4.50E+01	± 3.00E+00
07/14/2001	4	6.00E-03	± 0.50E-03	6.60E+01	± 4.00E+00
07/15/2001	5	1.90E-03	± 0.20E-03		-
07/16/2001	6	5.70E-03	± 1.00E-03		-
07/17/2001	7	9.70E-03	± 0.60E-03		-
07/19/2001	9		-	1.90E+01	± 2.00E+00
08/19/2001	40	1.50E-03	± 0.60E-03	1.30E+00	± 2.00E-01
08/20/2001	41	1.00E-03	± 0.70E-03		-
08/21/2001	42	1.70E-03	± 0.40E-03		-
10/31/2001	113	5.00E-03	± 0.50E-03	2.35E-01	± 2,00E-02
11/01/2001	114	5.00E-03	± 1.00E-03		-
11/02/2001	115	5.00E-03	± 0.50E-03		-
11/23/2001	136		-	6.00E-01	± 4.00E-02
11/24/2001	137		-	1.27E+00	± 9.60E-02
11/27/2001	140	6.00E-03	± 0.40E-03		-
11/28/2001	141	0.80E-03	± 0.10E-03		-
03/26/2002	259	1.20E-03	± 0.20E-03		-
03/27/2002	260		-	2.80E-01	± 2,00E-02
01/09/2003	548	6.50E-03	± 0.30E-03		-
01/10/2003	549	3.10E-03	± 0.20E-03	1.00E-01	± 1,00E-02
01/11/2003	550	5.40E-03	± 0.30E-03	1.80E-01	± 1,00E-02

time after the event, but also activities found in samples collected up to one and a half year after the incident. Values of activities in urine found shortly after the administration of Ca-DTPA, which are not suitable for the estimation of intake using standard biokinetic model, are denoted by asterisk.

The activities found on the face masks of the 4 workers are given in Table VIII.

3.2. Estimation of intakes and committed effective doses

The estimation of the dose was complicated due to surface skin contamination of workers, uncertainty of the time of the intakes, unknown way of intakes (ingestion *vs*. inhalation) and probably repeated smaller intakes. The knowledge of the

TABLE III

Excretion rates – case PV. Assumed date of the first intake: 9.7.2001.
Activités mésurées dans les urines et dans les selles au cours du temps – travailleur PV. La date supposée de la première incorporation : 9.7.2001.

Date of sampling	Time after the 1st intake [d]	Excretion in urine [Bq/d]		Excretion in faeces [Bq/d]	
07/13/2001	4	7.30E-03	± 1.10E-03	3.80E+01	± 2.25E+00
07/14/2001	5		-	1.38E+02	± 5.65E+00
07/17/2001	8	4.80E-03	± 0.70E-03	6.90E-01	± 4.30E-02
07/21/2001	12	* 3.97E-02	± 1.80E-03	7.00E-01	± 7.70E-02
07/22/2001	13	* 4.28E-02	± 1.70E-03		-
07/23/2001	14	* 9.90E-02	± 5.00E-03	2.00E-02	± 3.50E-03
07/24/2001	15	* 3.82E-02	± 1.50E-03	1.40E-01	± 2.40E-02
08/20/2001	42	4.3E-03	± 0.50E-03		-
08/21/2001	43	1.00E-02	± 1.20E-03	4.00E-02	± 5.00E-03
08/22/2001	44	6.00E-03	± 0.70E-03	7.60E-03	± 0.80E-03
11/02/2001	116	0.60E-03	± 0.10E-03	2.04E-01	± 1.20E-02
11/03/2001	117	0.70E-03	± 0.20E-03		-
11/04/2001	118	0.50E-03	± 0.20E-03	2.30E-03	± 2.40E-03

DTPA administered on 21.7.2001 and 22.7.2001.
* - values not used for evaluation of intake.

physico-chemical form of the contaminant was rather limited. In the hermetic boxes ^{241}Am in the form of AmO_2 was allegedly processed, however, presence of americium nitrate in the boxes in the past could not be excluded either. An influence of the fixating lacquer on the composition of the contaminant was also possible.

The ICRP 78 biokinetic model of ^{241}Am for the inhalation (ICRP, 1997), mostly with default parameters (aerosol of class M and AMAD 5 µm) was used for the estimation of the intakes and of the committed effective doses. It has to be based on measurements of ^{241}Am activity in the excretion only. Software IMBA Professional Plus, which uses maximum likelihood method for fitting experimental values by excretion curves, was used for the evaluation. The data sets from measurements of excreted activity with urine and with faeces were used simultaneously. Logarithmic–normal distribution of the experimental data was assumed. For activity excreted in urine total uncertainty 1.3, for activity in faeces total uncertainty 3 was supposed. The total uncertainty includes biological variability, sampling errors, counting errors etc. (Doerfel *et al*., 2005).

TABLE IV

Excretion rates – case KH. Assumed date of the first intake: 12.7.2001.
Activités mésurées dans les urines et dans les selles au cours du temps – travailleur KH. La date supposée de la première incorporation : 12.7.2001.

Date of sampling	Time after the 1st intake [d]	Excretion in urine [Bq/d]		Excretion in faeces [Bq/d]	
07/13/2001	1	2.10E-02	± 1.00E-03	-	
07/16/2001	4	9.30E-02	± 9.00E-03	-	
07/17/2001	5	1.30E-02	± 0.50E-03	1.50E+01	± 3.00E+00
07/18/2001	6	2.10E-02	± 1.50E-03	1.10E+01	± 1.00E+00
07/21/2001	9	* 4.92E-01	± 1.90E-02	1.50E+01	± 2.00E+00
07/22/2001	10	* 9.08E-01	± 3.80E-02	7.80E+00	± 1.00E+00
07/23/2001	11	* 2.76E-01	± 1.40E-02	6.20E-01	± 3.30E-02
07/24/2001	12	* 2.82E-01	± 1.30E-02	4.00E-01	± 3.50E-02
08/20/2001	39	6.30E-02	± 3.00E-03	5.00E-02	± 5.40E-03
08/21/2001	40	6.60E-02	± 2.40E-03	1.00E-02	± 5.00E-03
08/22/2001	41	6.30E-02	± 2.20E-03	8.00E-02	± 4.00E-03
10/22/2001	102	-		1.90E-01	± 1.70E-02
10/23/2001	103	1.10E-02	± 0.70E-03	-	
10/24/2001	104	1.00E-02	± 0.60E-03	1.70E-01	± 2.20E-02
10/25/2001	104	1.20E-02	± 0.70E-03	-	
03/22/2002	253	2.00E-03	± 0.40E-03	2.40E-01	± 3.20E-02
03/23/2002	254	2.00E-03	± 0.40E-03	7.40E-02	± 5.00E-03
03/24/2002	255	1.10E-03	± 0.40E-03	2.44E-02	± 1.70E-03
01/07/2003	544	3.10E-03	± 0.20E-03	4.40E-02	± 4.40E-03
01/08/2003	545	3.10E-03	± 0.30E-03	-	
01/09/2003	546	4.70E-03	± 0.20E-03	3.20E-02	± 2.00E-03

DTPA administered on 21.7.2001 and 22.7.2001.
* - values not used for evaluation of intake.

The best fits for the most workers were obtained when combination of acute and chronic intakes was used; in some cases, combination of intakes of class M and S seemed to be the best approximation. The time of the intake was chosen according to work diaries, and according to the investigation made after the incident. Generally, after the stay in the hospital the workers went on holidays and didn't return to the workplace until mid-August 2001. Therefore, the time interval 20-60 days was supposed as the time in which intake of ^{241}Am didn't occur.

The resulting intakes and committed effective doses CED are presented in Table IX. Excreted activities in urine after the application of DTPA were excluded

TABLE V

Excretion rates – case VS. Assumed date of the first intake: 15.7.2001.
Activités mésurées dans les urines et dans les selles au cours du temps – travailleur VS. La date supposée de la première incorporation : 15.7.2001.

Date of sampling	Time after the 1st intake [d]	Excretion in urine [Bq/d]		Excretion in faeces [Bq/d]	
07/16/2001	1	5.40E-02	± 4.00E-03	8.00E-02	± 8.00E-03
07/17/2001	2	5.60E-02	± 2.00E-03	1.50E+01	± 2.92E-01
07/18/2001	3	4.10E-02	± 3.00E-03	1.28E+01	± 1.54E+00
07/21/2001	6	* 1.56E-01	± 8.00E-03	1.23E+03	± 1.82E+00
07/22/2001	7	* 5.70E-02	± 3.00E-03	3.32E+00	± 3.16E-01
07/23/2001	8	* 8.80E-02	± 1.00E-03	5.13E-01	± 2.00E-02
07/24/2001	9	* 1.31E-01	± 2.00E-03	-	
08/17/2001	33	1.10E-02	± 1.00E-03	1.45E+00	± 7.20E-02
08/18/2001	34	9.00E-03	± 1.00E-03	2.10E-01	± 2.40E-02
08/19/2001	35	8.00E-03	± 1.60E-03	8.00E-02	± 7.00E-03
11/02/2001	110	2.00E-03	± 0.40E-03	1.20E-01	± 1.10E-02
11/03/2001	111	1.10E-03	± 0.30E-03	2.67E-01	± 1.60E-02
11/04/2001	112	1.30E-03	± 0.40E-03	7.20E-02	± 1.10E-02
03/23/2002	251	1.00E-03	± 0.40E-03	2.42E-02	± 1.60E-03
03/24/2002	252	0.60E-03	± 0.20E-03	6.40E-03	± 0.70E-03
03/25/2002	253	-		3.70E-03	± 0.70E-03
01/10/2003	544	0.60E-03	± 0.10E-03	-	
01/11/2003	545	0.30E-03	± 0.10E-03	-	
01/12/2003	546	0.40E-03	± 0.20E-03	4.30E-03	± 0.30E-03

DTPA administered on 21.7.2001 and 22.7.2001.
* - values not used for evaluation of intake

from the calculations of intakes, data with the excluded values are marked with asterisks in Tables I to VII. Time-course of ^{241}Am activity in the excretion together with the fitted model curves for the cases MS and VS are presented in Figures 2a to 2d. When calculating the intake of worker V.V., time of sampling of faeces 3.5 days was used as he informed us that he usually had two portions of faeces in a week.

4. Discussion

The workers were followed for about one and a half year after the first intake.

Difference in patterns of measured activity time-course in excreta between individuals could be explained by the fact that each of them performed different

TABLE VI

Excretion rates – case LZ. Assumed date of the first intake: 18.7.2001.
Activités mésurées dans les urines et dans les selles au cours du temps – travailleur LZ. La date supposée de la première incorporation : 18.7.2001.

Date of sampling	Time after the 1st intake [d]	Excretion in urine [Bq/d]		Excretion in faeces [Bq/d]	
07/21/2001	3	* 7.72E-01	± 2.40E-02	1.80E+01	± 4.00E+00
07/22/2001	4	* 1.08E+00	± 2.40E-02	1.80E+00	± 4.00E-01
07/23/2001	5	* 2.02E-01	± 5.60E-02	9.00E-01	± 3.00E-01
07/27/2001	9	1.36E-01	± 6.00E-03	-	
07/28/2001	10	1.26E-01	± 7.00E-03	2.00E-01	± 1.50E-02
07/29/2001	11	1.14E-01	± 5.00E-03	1.40E+00	± 3.17E-01
08/17/2001	30	1.82E-01	± 7.00E-03	6.00E-02	± 5.00E-03
08/18/2001	31	-		7.00E-02	± 8.00E-03
08/19/2001	32	2.50E-02	± 1.00E-03	4.00E-02	± 9.00E-03
09/21/2001	65	4.00E-03	± 0.50E-03	7.70E-01	± 5.40E-02
09/22/2001	66	4.00E-03	± 0.70E-03	6.00E-02	± 9.00E-03
09/23/2001	67	3.00E-03	± 0.80E-03	8.00E-02	± 6.00E-03
11/03/2001	108	3.00E-03	± 0.20E-03	1.40E-01	± 1.60E-02
11/04/2001	109	2.00E-03	± 0.30E-03	9.90E-02	± 7.00E-03
11/05/2001	110	2.00E-03	± 0.30E-03	7.30E-02	± 1.20E-02

DTPA administered on 21.7.2001 and 22.7.2001.
* - values not used for evaluation of intake.

tasks and also their personal attitude to radiation safety differed. Some of them personally fragmented contaminated hermetic boxes, whereas some of them worked at a distance from the very source of contamination. It is therefore possible that different people inhaled aerosol of different quality and in different time-pattern. Their contaminated work clothes put into the radioactive waste without distinguishing individual level of contamination had been a probable source of secondary internal contamination. As to the time of intake, it followed from the report describing the investigation of the incident that combination of acute and prolonged intakes was possible.

Additional information about the process of decontamination of workplace, which took place in the autumn 2001, led to the assumption that small chronic intakes were likely.

This assumption was supported by the fact that surface contamination of walls in the premises in which hermetic boxes were handled was confirmed by repeated smear samples. Lower surface contamination was confirmed even about one year

TABLE VII

Excretion rates – case FH. Assumed date of the first intake: 18.7.2001.

Activités mésurées dans les urines et dans les selles au cours du temps – travailleur FH. La date supposée de la première incorporation : 18.7.2001.

Date of sampling	Time after the 1st intake [d]	**Excretion in urine [Bq/d]**		**Excretion in faeces [Bq/d]**	
07/21/2001	3	* 8.26E-01	± 4.90E-02	2.12E+02	± 1.50E+01
07/22/2001	4	* 8.26E-01	± 4.90E-02	1.20E+01	± 9.00E-01
07/27/2001	9	6.07E-01	± 2.20E-02	1.20E+00	± 2.00E-01
07/28/2001	10	4.08E-01	± 2.20E-02	2.10E+00	± 3.00E-01
07/29/2001	11	4.33E-01	± 1.90E-02	7.00E-01	± 4.00E-02
08/18/2001	31	1.74E-01	± 1.20E-02		-
08/19/2001	32	1.13E-01	± 5.00E-03	2.95E+00	± 2.06E-01
08/20/2001	33	1.52E-01	± 6.00E-03	3.51E-01	± 2.80E-02
09/21/2001	65	2.50E-02	± 1.00E-03		-
09/22/2001	66	8.80E-02	± 8.00E-03	7.70E+00	± 3.86E-01
09/23/2001	67	4.50E-02	± 3.00E-03		-
10/26/2001	100	2.00E-02	± 1.00E-03	7.90E+00	± 5.60E-01
10/27/2001	101	1.80E-02	± 1.00E-03		-
10/28/2001	102	3.00E-02	± 2.00E-03	2.20E-01	± 1.30E-02
11/22/2001	127		-	4.75E+00	± 2.37E-01
11/26/2001	131	8.00E-03	± 1.00E-03	3.40E-01	± 6.50E-02
11/27/2001	132	8.00E-03	± 1.00E-03		-
11/28/2001	133	6.00E-03	± 0.50E-03		-
03/25/2002	250	3.00E-03	± 0.40E-03	1.12E+00	± 7.50E-02
03/26/2002	251	3.00E-03	± 0.80E-03		-
03/27/2002	252	3.00E-03	± 0.80E-03	2.53E+00	± 1.63E-01
05/17/2002	303	2.00E-03	± 0.40E-03	2.21E+00	± 1.30E-01
05/18/2002	304	2.00E-03	± 0.30E-03	2.99E+00	± 1.60E-01
05/19/2002	305	3.30E-03	± 0.50E-03	2.30E-01	± 4.00E-02
01/10/2003	541	1.70E-01	± 0.20E-03	3.73E-01	± 1.60E-02
01/11/2003	542	2.90E-03	± 0.30E-03		-
01/12/2003	543	5.10E-03	± 0.30E-03	1.95E-01	± 1.80E-02

DTPA administered on 21.7.2001 and 22.7.2001.

* - values not used for evaluation of intake.

TABLE VIII
Activity of ^{241}Am on face masks.
Activités de ^{241}Am mesurées sur des masques.

Worker *	Activity [Bq]
MS 1	2700
MS 2	560
PV	330
VV	14
KH	6

* the exact data when the face masks were worn were not given.

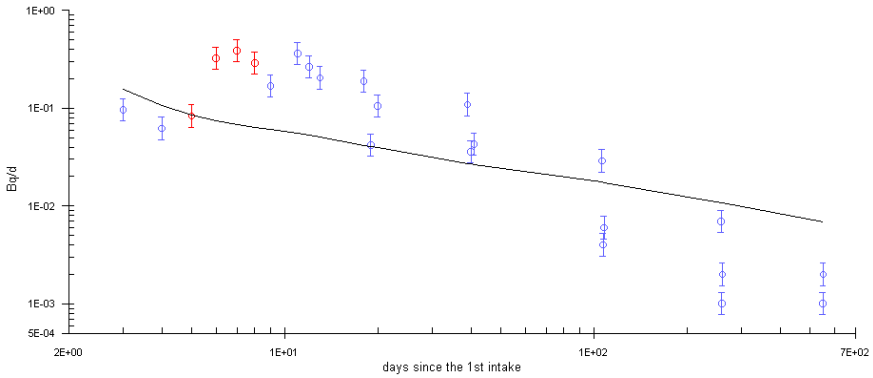
TABLE IX
Estimated intakes of ^{241}Am and committed effective doses.
Valeurs estimées des activités incorporées de ^{241}Am et des doses efficaces engagées.

Worker	1st intake			2nd intake			CED total [mSv]
	Date	Activity	Type	(days since the 1st intake)	Activity	Type	
MS	07/09/2001	1186 Bq	M	40-600	0.07 Bq/d	M	33
PV	07/09/2001	135 Bq	S	50-150	0.025 Bq/d	M	3.7
VV	07/10/2001-07/20/2001	179 Bq/d	S	40-600	0.34 Bq/d	M	20.7
KH	07/12/2001-07/18/2001	207 Bq/d	M	60-600	0.03 Bq/d	M	34.2
VS	07/15/2001	146 Bq	S	0-4	30.4 Bq/d	M	4.9
LZ	07/18/2001	584 Bq	M	20-100	0.03 Bq/d	M	16.2
FH	07/18/2001	1259 Bq	M	70-560	0.16 Bq/d	M	36.3

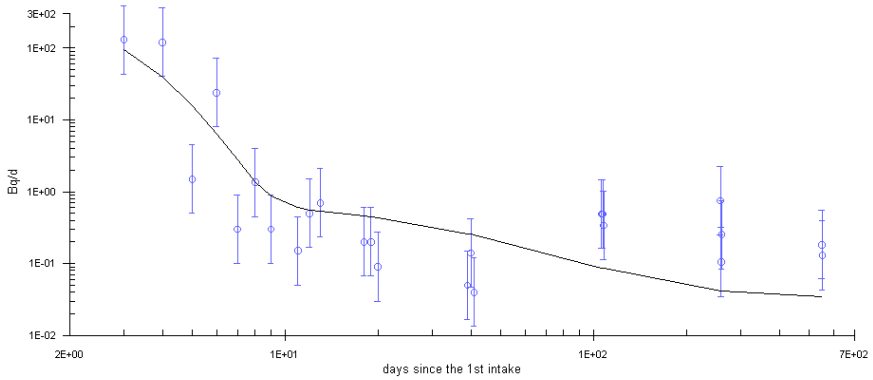
after the event, however, below guidance value given by the Czech Regulation on Radiation Protection (Regulation SÚJB, 2002).

Chronic intakes calculated for different workers for the periods 20 to 600 days after the first assumed intake were between 0.03 Bq/d and 0.3 Bq /d. Such intakes could lead to the annual committed effective dose from 0.2 mSv to 2 mSv.

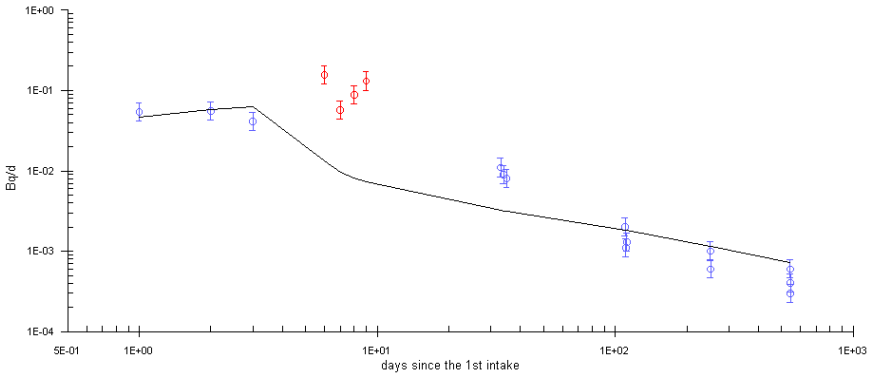
The efficiency of the DTPA treatment is not discussed here as there were not enough samples of urine for it, however, a brief evaluation was made in Malátová (2003b). Medical aspects of the case are discussed in (Pelclová and Fenclová, 2004). It is important to know that the other abbreviations for the contaminated workers


1E+00
1E-01
1E-02
1E-03
5E-04
Bq/d
2E+00
1E+01
1E+02
7E+02
days since the 1st intake

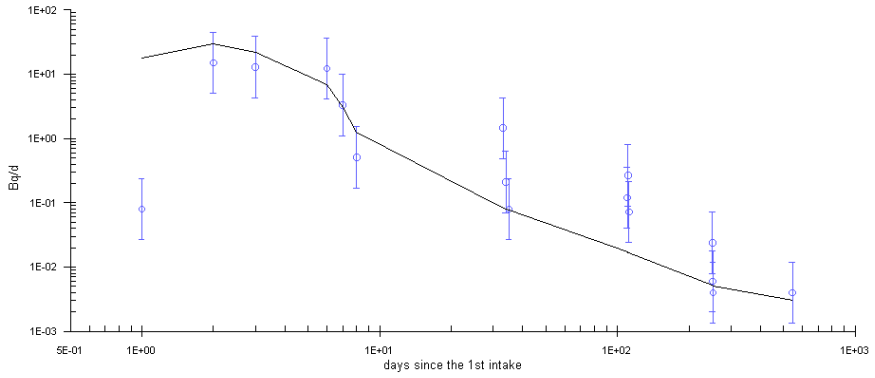
(a)


3E+02
1E+02
1E+01
1E+00
1E-01
1E-02
Bq/d
2E+00
1E+01
1E+02
7E+02
days since the 1st intake

(b)


1E+00
1E-01
1E-02
1E-03
1E-04
Bq/d
5E-01
1E+00
1E+01
1E+02
1E+03
days since the 1st intake

(c)



(d)

Figure 2 – ***(a) Observed excretion rates of ^{241}Am in urine and fitted curve by IMBA Professional Plus – case MS. (b) Observed excretion rates of ^{241}Am in faeces and fitted curve by IMBA Professional Plus – case MS. (c) Observed excretion rates of ^{241}Am in urine and fitted curve by IMBA Professional Plus – case VS. (d) Observed excretion rates of ^{241}Am in faeces and fitted curve by IMBA Professional Plus – case VS.***

(a) Comparaison des activités de ^{241}Am mesurées dans les urines à celles évaluées par le logiciel IMBA Professional Plus – travailleur MS. (b) Comparaison des activités de ^{241}Am mesurées dans les selles à celles évaluées par le logiciel IMBA Professional Plus – travailleur MS. (c) Comparaison des activités de ^{241}Am mesurées dans les urines à celles estimées par le logiciel IMBA Professional Plus – travailleur VS. (d) Comparaison des activités de ^{241}Am mesurées dans les selles à celles estimées par le logiciel IMBA Professional Plus – travailleur VS.

were used in this paper; number 1 was used for worker MS, 2 for PV, 3 for PH, 4 for VS, 5 for LZ and 6 for FH.

5. Conclusions

Widespread contamination with ^{241}Am occurred in the building in which radiation waste was handled. Also, internal contamination of seven workers was found leading to the committed effective doses from 3 to 36 mSv. Acute intakes varied from about 135 Bq to 1300 Bq. Afterwards, small chronic intakes were found at the whole group of workers.

Many radiation protection rules have been violated during the process of work; the most important feature being that neither workers nor even staff of dosimetric control were aware that small intakes of alpha emitting radionuclides could lead to significant committed effective doses and that such intakes are not measurable by *in vivo* technique.

It was proved again that decommissioning is the most common process in which internal contamination could occur. The cause for it is probably the long time period since the operation of facility had ceased, which could result in loss of direct knowledge (Investigation Team Report, 2000) or, when commercial company is hired, lack of comprehensive knowledge of the facility, what was the case here.

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REFERENCES

Doerfel H., Andrasi A., Bailey M. *et al*. (2005) General Guidelines for the Estimation of Committed Effective Dose from Incorporation Monitoring Data (Project IDEAS- EU Contract No. FIKR-CT 2001-00160).

Dulaiová H., Bečková V., Bučina I. (2004) Determination of Americium by Extraction Chromatography in Urine Samples, IRPA Regional Congress on Radiation Protection in Central Europe, Budapest, August.

ICRP Publication 78 (1997) Individual Monitoring for Internal Exposure of Workers, *Ann. ICRP* **27**(3/4).

Investigation Team Report (2000) Investigation of the source of potential internal radiological exposures involving eleven personnel in Building 771, Kaiser–Hill Company, Rocky Flat, March 15.

Klener V., Malátová I., Pelclová D. (2003) The contamination of workers with americium ^{241}Am during dismantling and disposing of glove boxes, *České pracovní lékařství* 4, 173-177.

Malátová I., Foltánová Š., Bečková V., Filgas R., Pospíšilová H., Hölgye Z. (2003a) Assessment of occupational doses from internal contamination with ^{241}Am, *Rad. Prot. Dosim.* **105**, 325-328.

Malátová I., Bečková V., Pospíšilová H. (2003b) Internal contamination with ^{241}Am during handling of radioactive waste, IRPA Regional Congress on Radiation Protection in Central Europe, September 22–26, Bratislava, Slovakia, Proceedings on CD Rom, ISBN 80-88806-43-7.

Pelclová D., Fenclová Z. (2004) Occupational contamination with americium and Ca-DTPA treatment, *Radiprotection* **39**, 383-388.

Regulation SÚJB (2002) Regulation SÚJB on Radiation Protection, 307/2002 Coll.

Report SÚJB (2002) Contamination of workers with ^{241}Am during waste processing operations. State Office for Nuclear Safety. Prague, Czech Republic.