INTENDED RETENTION OF RADIONUCLIDES FROM THE WASTE AIR OF REPROCESSING PLANTS

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The low emission rates of the nuclear power plants actually in operation are, besides other reasons, based on the fact that practically no defects of fuel elements occur. In reprocessing plants, during the dissolution all radioactive materials contained in the fuel are transferred either to the fuel-solution or to the dissolver-off gas (DOG).

The second column of table I shows the expected airborne emission rates of a reprocessing plant with an annual throughput of 1500 t of heavy metal, if no special retention facilities are installed. During chopping and leaching of the fuel elements, practically 100 % of the Kr 85 and more than 99 % of the C 14 (in the form of CO_2) are released into the DOG. More than 60 % of the tritium produced in the fuel is fixed in the fuel-rod cannings in the form of zirconiumhydrid. If the liquid effluents of tritium shall be kept low, the main release path way of tritium - including H 3 from the highly active waste (HAW) storage tanks - will be the waste air. Without any additional measures, only a small part of the I 129 is released into the DOG. This release raises up to more than 99 %, if a sufficient quantity of carrier gas is passed through the dissolver. Residual iodine remaining in the solution will be distributed in the whole process. Major sources of radionuclides bound on aerosol particles are the dissolution, the transport of process-fluids by airlifts or steamjets, the off gas of the process vessels (e.g. washers, pulsed columns, mixer settlers, centrifuges) and the gas produced by radiolysis. Assuming 10 mg of the process fluid being carried away with each m^3 of DOG and VOG, the emission rates without any additional retention facilities beside the off-gas condensers - which are installed in any case - will be about 37 TBq.

Table 1 shows the annual dose equivalents due to these emission rates assuming an emission height of 200 m in the northern part of the Federal Republic of Germany. The calculations are based on the data given in the guidelines of the Minister of the interior /1/. Only the emission of I 129 and aerosols results in annual doses which exceed the maximum permissible radiation exposure of the public in the Federal Republic of Germany, if we compare the effective dose with the limits of the total body. The maximum permissible annual dose equivalents in the radiation protection ordinance of the Federal Republic of Germany are 0.3 mSv for the total body, 1.8 mSv for bones and skin, and 0.9 mSv via the food chains for the thyroid. The doses due to H 3, C 14 and Kr 85 are about a factor of 25, 60 and 10, respectively, smaller than the limits. The doses due to globally distributed radionuclides are small, too. Assuming e.g. the reprocessing of fuel corresponding to a world wide installation of 1000 GW_e (which means about 1000 big power stations with light water reactors), the total emission of H 3 over a period of 50 years would result in a total body dose equivalent less than 10^{-5} mSv. Under the same conditions, the dose due to C 14 for the total body would be less than 0.001 mSv and the dose due to Kr 85 for the skin would be less than 0.01 mSv /2/. Mixing the total amount of I 129 with the surface water of the oceans would result in an annual dose equivalent for the thyroid due to globally distributed I 129 of about 10^{-4} mSv /2/.

For a first big reprocessing plant, which certainly will be necessary in Germany in this century, the following questions have to be answered: Should any retention facilities for H 3, C 14 and Kr 85 be installed; and which efforts should be made to retain I 129 and the aerosols? Normally, the permissible emission rates result from extensive discussions between the applicant, the authority, the experts, the radiation protection commission (SSK) and the public. In 1977 and 1983, the radiation protection commission made recommendations concerning the emission of radioactive materials from the now deferred "Entsorgungszentrum" /3/ and a smaller reprocessing plant /4/.

Meanwhile the ICRP recommended the use of a cost-benefit analysis to determine the retention levels for radioactive materials /5/. Following this method, it was

tried to find the optimum retention facilities. The tables 2 to 6 show the marginal cost-effectiveness values for the four radionuclides and the aerosols. The valuation of 1 man-Sv with 20 000 DM /6/ results in no retention of H 3 and Kr 85. 99 % of the C 14 and about 99.3 % of the Iodine 129 should be retained. Surprisingly, for the aerosol retention only washers and mist eliminators together with the off-gas condensers should be installed. However, safety considerations in the case of incidents and accidents make HEPA-filtration necessary in every off-gas system. The marginal cost effectiveness of the C 14-retention, for integration times of 500 as well as 10^6 years, is very small.

Due to the future reduction of the radiation exposure due to C 14 caused by the combustion of fossile fuel and due to the very small additional individual doses, the retention of C 14 seems to be unnecessary.

The question of tritium retention is strongly related to the site of the reprocessing plant. As the reprocessing plant planned in the Federal Republic of Germany will be situated far away from the coast, the emission rates with the waste water must be reduced with the aid of a H 3-scrubber. Following the German radiation protection ordinance, it is not allowed to emit the tritium retained by the scrubber by means of active measures.

The considerations made above are related to a big reprocessing plant with an annual throughput of 1500 t. At the moment, a smaller plant with an annual throughput of 350 t is under discussion in the Federal Republic of Germany /4/. The statements concerning the intended retention facilities are transferable to this smaller plant /7/.

/1/ Bundesminister des Innern:
Allgemeine Berechnungsgrundlagen für die Strahlenexposition bei radioaktiven Ableitungen mit der Abluft oder in Oberflächengewässer.
Gemeinsames Ministerialblatt 15.8.1979, p. 371 ff.

/2/ Bonka, H.:
Strahlenexposition durch radioaktive Emissionen aus kerntechnischen Anlagen im Normalbetrieb.
Verlag TÜV Rheinland (1982)

/3/ SSK, RSK:
Grundsätzliche sicherheitstechnische Realisierbarkeit des Entsorgungszentrums.
GRS, Köln (1977)

/4/ SSK:
Empfehlung der SSK zur Rückhaltung radioaktiver Stoffe bei einer Wiederaufarbeitungsanlage.
Bundesanzeiger 128 vom 14. Juli 1983

/5/ ICRP:
Publication 26.
Pergamon Press (1977)

/6/ Horn, H.G., et al.:
Kosten-Nutzen-Analyse zur Rückhaltung radioaktiver Stoffe in Kernkraftwerken und Wiederaufarbeitungsanlagen.
(publication in preparation)

/7/ Bonka, H., Horn, H.-G.:
Optimization of the Retention of Radioactive Material from the Airborne Effluents of Reprocessing Plants.
CEC-Seminar, Luxemburg, 8. und 9. 11. 1983

Table 1: Emission rates without additional retention facilities, individual dose equivalents and effective collective dose equivalents due to airborne emissions of a 1500 t/a reprocessing plant
Cooling time 1 a, composition of aerosols according to /6/

nuclide	annual emission without retention [TBq]	maximum annual dose equivalent [mSv]				total effective collective dose equivalent [man-Sv]		monetary valuation of the effective collective dose equivalent for α = 20 000 DM/man-Sv [DM]	
		effective	skin	thyroid	bone-surface	t = 500 a	t = 1 E6 a	t = 500 a	t = 1 E6 a
H 3	1.5 E4	0.012	0.012	0.012	0.012	55	55	1.1 E6	1.1 E6
C 14	26	0.005	0.005	0.002	0.003	410	3700	8.2 E6	7.4 E7
Kr 85	7.4 E5	0.015	0.16	0.013	0.013	290	290	5.8 E6	5.8 E6
J 129	2.2	1.4	<	41	<	1800	5700	3.6 E7	1.1 E8
aerosols	37	0.47	0.14	0.15	1.4	400	400	8 E6	8 E6

Table 2: Cost-benefit analysis for the retention of H 3

No.	retention process	retention efficiency [%]	annual costs for retention [DM/a]			total annual costs for retention and final disposal [DM/a]		marginal cost effectiveness $\frac{\Delta K}{\Delta S}$ [DM/man-Sv]	
			capital	operating	total	storage in geological formations	deep sea dumping	storage in geological formations	deep sea dumping
1	tritium scrubber and recycling	81	1 E5	1.6 E5	2.6 E5	2.7 E6	8.4 E6	61 000	1.9 E5
2	case 1 and separation from DOG	82	1.5 E5	5.1 E5	6.6 E5	3.1 E6	8.8 E6	7.3 E5	7.3 E5
3	case 1 and separation from VOG	84	1.5 E5	5.1 E5	6.6 E5	3.1 E6	8.8 E6	2.4 E5	2.4 E5
4	case 1 and separation from HAW-depot off-gas	95	3.2 E5	7.7 E5	1.1 E6	3.5 E6	9.2 E6	1 E5	1 E5

Table 3: Cost-benefit analysis for the retention of C 14

No.	with or without Kr 85 retention	retention-process	retention efficiency [%]	annual costs [DM/a]				marginal cost effectiveness $\Delta K/\Delta S$ [DM/man-Sv]	
				retention		final disposal	total		
				capital	operating	operating		t = 500 a	t = 1 E6 a
1	without	highly efficient scrubbing	99	4 E5	3.5 E5	0.6 E5	8.1 E5	2 000	220
2	with	simple scrubbing	81	4 E5	3.5 E5	0.6 E5	8.1 E5	2 500	280
3		highly efficient scrubbing	89	5 E5	3.5 E5	0.6 E5	9.1 E5	3 000	340
4		oxidation of CO and C_nH_m and highly efficient scrubbing	98	6 E5	1 E6	0.6 E5	1.7 E6	21 000	2 400

Table 4: Cost-benefit analysis for the retention of Kr 85

No.	retention and final disposal process	retention efficiency [%]	annual costs [DM/a]					cost effectiveness $\frac{\Delta K}{\Delta S}$ [DM/man-Sv]
			retention		final disposal		total	
			capital	operating	capital	operating		
1	low temperature rectification and above ground storage	96	2 E6	2 E6	5 E6	2 E6	1.1 E7	40 000
2	low temperature rectification and deap sea dumping	96	2 E6	2 E6	6 E5	2.5 E6	7.1 E6	25 000
3	acc. to 2, capital costs following an industrial estimation	96	5 E6	2 E6	6 E5	2.5 E6	1 E7	36 000

Table 5: Cost-benefit analysis for the retention of I 129

No.	retention process	retention efficiency [%]	annual costs [DM/a]				marginal cost effectiveness $\Delta K/\Delta S$ [DM/man-Sv]	
			retention		final disposal	total		
			capital	operating	operating		t = 500 a	t = 1 E6 a
1	retention from DOG	99.3	0.8 E6	1.2 E6	0.1 E6	2.1 E6	1200	370
2	retention from DOG and VOG from extraction stages	99.6	1.6 E6	1.3 E6	0.1 E6	3.0 E6	1.7 E5	5.3 E4
3	retention from DOG, VOG from extraction stages and VOG from waste systems	99.9	3.5 E6	1.4 E6	0.1 E6	5.0 E6	3.7 E5	1.2 E5

Table 6: Cost-benefit analysis for the retention of radionuclides bound on aerosol particles

No.	retention process	retention efficiency [%]		$\frac{S}{S_0}$	annual costs [DM/a]			total	marginal cost effectiveness $\frac{\Delta K}{\Delta S}$ [DM/man-Sv]
					retention		final disposal		
		β-aerosols	α-aerosols		capital	operating	operating		
0	condensor, washer and mist-eliminator in all off-gas systems (necessary in any case)	99	99	1	3.0 E6	0.5 E6	<	3.5 E6	88
1	measure 0 +prefilter and HEPA in DOG	99.4	99.3	0.6	4.0 E6	0.5 E6	5 E4	4.6 E6	6900
2	measure 1 +prefilter and 1 HEPA in VOG of waste vitrification	99.8	99.3	0.25	7.0 E6	1.2 E6	8 E 4	8.3 E6	26 000
3	measure 2 +prefilter and 1 HEPA in VOG of 1st extraction	99.9	99.9	0.1	9.0 E6	1.25 E6	9 E4	10.4 E6	35 000
4	measure 3 +prefilter and 1 HEPA in VOG of 2nd/3rd extraction	99.92	99.999	0.05	10 E6	1.3 E6	9 E4	11.4 E6	50 000
5	measure 0 +prefilter and 1 HEPA in all off-gas systems	99.999	99.999	0.001	12 E6	1.7 E6	1 E5	13.8 E6	120 000