COLLECTIVE DOSES DUE TO RADIOACTIVE EMISSIONS FROM NUCLEAR PLANTS

H. Bonka and H.-G. Horn

Lehrstuhl für Reaktortechnik, RWTH Aachen, F.R.G.

In publication No.26 (1) ICRP recommends the use of cost-benefit analysis for the optimization of the retention of radioactive materials in nuclear facilities. This Requires the evaluation of the collective effective dose equivalent commitment. While the collective doses can be evaluated generally for airborne effluents the collective dose for the water pathway is highly dependent on the river under consideration.

COLLECTIVE DOSES DUE TO AIRBORNE EFFLUENTS

Due to different numerical methods it is useful to separate the evaluation of collective doses into first pass exposure and global distribution. The annual average air-concentration for first pass exposure within a 5o km range can be evaluated using the Gaussian Plume model. For greater distances a homogenous distribution over a constant mixing layer is assumed (2). Comparing the calculation of collective doses with an homogenous 360 deg. distribution and much more complex metheorological statistics it becomes obvious that there is no significant difference. The emission height also is of negligible influence on the collective doses. The contribution to the collective doses by the direct vicinity of the plant - where the emission height is of influence - is small, as shown in tab. 1.

Parameter analysis have shown that there is little difference in the equivalent collective doses for all sites in the F.R.G.

The global distribution can be evaluated with multicompartment models (3,4,5), see fig. 2 for ^{14}C e.g..

For the calculation of the ingestion dose caused by ^{3}H, ^{14}C and ^{129}I via first pass exposure, it is sensible to use the specific activity model. The average air concentration of ^{127}I for the F.R.G, as well as for other countries is about 1o ng/m^3 (7). An upper limit of collective doses due to iodine, except for ^{129}I and aerosols, can be evaluated with the models and data given in (8), taking into accound mean consumption rates of food. Caused by the high number of people and the very small change of air concentration in far distances, the contribution to the collective doses via first pass exposure in these areas is much more important than that in the vicinity of the plant. For this reason it is not necessary to regard the local statistics of harvest, which would make

---

This work was sponsored by the Federal Minister of the Interior of the F.R.G. under the number St.Sch. 68oa

evaluations much more complicated.

^3H first pass exposure is a special problem. Being emitted as tritiated water, ^3H contributes to the radiation exposure via contamination of food and drinking water. The concentration of ^3H can be evaluated easily with a rainfall of approx. 4oo mm/yr which is the contribution of the oceans to the total rainfall of approx. 7oo mm/yr. When calculating with the total rainfall, evaporation has to be taken into account (9).

The collective effective dose commitment can be evaluated using the weighting-factors given in ICRP 26 (1). In this paper a total collective effective dose equivalent commitment S_T with additional consideration of the detriment after the 2nd generation (1) and the external β-radiation (1o) is defined.

Tab. 2 shows the total collective effective dose equivalent commitment S_T related to 1 Ci ^3H, ^{14}C, ^{85}Kr, ^{131}I, ^{129}I and aerosols for first pass exposure. For the aerosols a typical nuclide composition of the effluent of a reprocessing plant was used (11). The approx. distribution of ^3H collective doses for different countries is shown in tab. 3.

In addition, tab. 2 contains the total collective effective dose equivalent commitments due to globally distributed ^3H, ^{14}C, ^{85}Kr and ^{129}I as a function of integration time.

From the viewpoint of a cost-benefit analysis, the integration time occurs to be very problematic. As seen in fig. 2, the greatest contribution to S_T from ^{14}C and ^{129}I results from times longer than 5oo years. For the cost-benefit analysis, the integration time should be $1o^4$ to $1o^5$ years, taking into account a world population of $1o^{1o}$ people. Using economical methods, the cost of detriment should be discounted. Tab. 4 shows the discounted collective dose.

For the fist pass exposure different sites were analysed. Stack releases at sites like Windscale which are geographically extremely different from the north-east of Germany result in a decrease of collective doses of approx. 3o %.

COLLECTIVE DOSES VIA THE WATER PATHWAY

The collective dose due to liquid releases into rivers can be evaluated for actual sites only. The utilization of the river is of great importance here. Assuming a river with a mixing volume of 1ooo m^3/s, which is used by $1o^6$ persons as drinking water, the total collective effective dose equivalent commitment due to ^3H would be about o.oo1 man·rem/Ci. If the consumption of fish would be 1oo t/yr, S_T due to the most important radionuclides would be approx.: ^{6o}Co - o.oo1 man·rem/Ci, ^{9o}Sr-o.1 man·rem/Ci, ^{134}Cs - o.o5 man·rem/Ci, ^{137}Cs - o.o2 man·rem/Ci.

REFERENCES

1. ICRP Publication 26, Pergamon Press (1977)
2. Klug, W.: Staub-Reinhaltung Luft 29 (1969) p.143
3. Nydal, R.: Journal of geophysical research 73 (1968), p.3617
4. Walton, A. et al.: Journal of geophysical research 75 (197o), p.3o89
5. Geyh, M.A.: Zeitschrift für Geophysik 37 (1971),p.9o9
6. Bonka, H.: Wissenschaftl. Symposium über ^{3}H u. ^{14}C des Instituts für Strahlenhygiene des Bundesgesundheitsamtes, Berlin 14-16 Nov. 1979
7. Schüttelkopf, H.: KFK 262o (1978),p.159
8. Der Bundesminister des Innern, Gemeinsames Ministerialblatt ISSN o341-1435 (1979),p. 369
9. Bonka, H.: IAEA-SM-232/12, p.1o5
1o. ICRP: Stockholm Meeting June 1978
11. Bonka, H.: IAEA-SR-36/14

TABLE 1 : Percentage of the first pass ^{85}Kr collective dose to the population in different areas related to the first pass ^{85}Kr collective dose to the total world population.

Area	Population	Percentage of ^{85}Kr collective dose [%]
Radius 0-50 km F.R. of Germany	8. E5	4.5
Radius 0-100 km F.R. of Germany	3.2E6	9
Radius 50-100 km F.R. of Germany	2.4 E6	4.5
F.R. of Germany	6.2 E7	40
World	4. E9	100

TABLE 2 : Total collective effective dose equivalent commitment S_T by an emission of 1Ci via a stack in north east of the Federal Republic of Germany

* Typical nuclide composition of a reprocessing plant

Nuclide	Total collective effective dose equivalent commitment [man rem/Ci]					
	First pass exposure	Global distribution in dependance of integration time				
		70a	500a	10000a	10^6 a	∞
H 3	0.013	5.7E-4	5.7E-4	5.7 E-4	5.7E-4	5.7E-4
C 14	3	23	56	370	520	520
Kr 85	5.E-5	1.4E-3	1.4 E-3	1.4 E-3	1.4 E-3	1.4 E-3
I 131	5	0	0	0	0	0
I 129	3000	4.8	7.8	72	6.8 E 3	1.6 E 5
Aerosols (repr. plants)	100*	0	0	0	0	0

TABLE 3: Approximate contribution to the collective dose of the different countries over the first pass exposure for an emittent near Hannover ($S_{first\ pass}$ (^{3}H) ≈ 0.013 man-rem/Ci)

Country	Contribution	Country	Contribution
Austria	1	Luxemburg	0.1
Belgium	2	Netherlands	5
Czechoslovakia	4	Norway	0.3
Denmark	1	Poland	15
France	6	Sweden	2
German Democratic Republic	15	Union of Soviet Socialist Republics	5
Germany, Federal Republic of	30	United Kingdom	9

Tab.4: Change of the global collective effective dose equivalent commitment with discounting the cost of detriment by infinite integration time

Nuclide	$S_{T,i}$			
	i=0%	i=1%	i=2%	i=3%
H 3	5.7E-4	4.6E-4	3.7E-4	3.0E-4
C 14	520	22	13	9
Kr 85	1.4 E-3	1.1 E-3	8.5E-4	6.8E-4
I 129	1.6 E 5	2	1.3	1

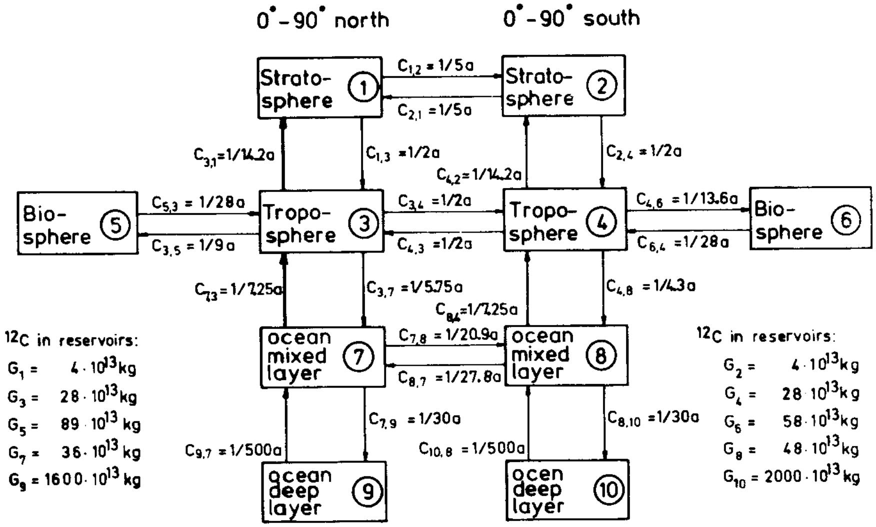

Fig.1: Compartment model for ^{14}C

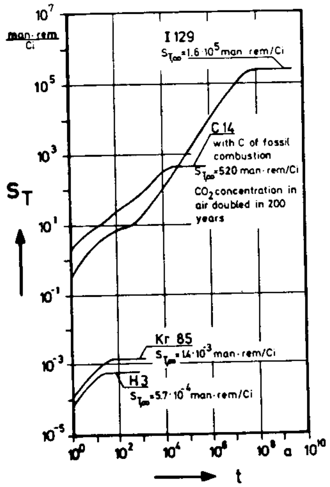

Fig. 2: Total collective effective dose equivalent commitment S_T from globally distributed radionuclides in dependence of integration time (world population 1.E10)