COMPARISON OF CRITICAL ORGAN AND EFFECTIVE DOSE EQUIVALENTS

M. Baer, W. G. Hübschmann
Hauptabteilung Sicherheit, Kernforschungszentrum Karlsruhe GmbH.

1. OBJEKTIVES

The earlier method B of limiting stochastic irradiation defects, based on ICRP Publication 2, required the evaluation of organ and whole body dose equivalents and the comparison to the respective annual limits in order to determine the limiting 'critical organ'. In 1977 it is recommended in ICRP Publication 26 to replace this method by the evaluation and limitation of the Effective Dose Equivalent, method A.

In order to compare these two methods of dose equivalent limitation both methods are applied to the radionuclides and radionuclide mixtures listed in Tab. 1, which are assumed to be released continuously through a 100 m stack and to cause irradiation of the surrounding population.

RADIONUCLIDE	CHARACTERISTIC NORMALIZED NUCLIDE SPECTRUM IN PERCENT					EXPECTED CHEMICAL SPECIES RELEASED	ASSIGNED LUNG CLEARANCE CLASS
	PWR AEROSOLS	α-ACTIVE WASTE	LONG LIVED IODINE	NOBLE GAS FR2	NOBLE GAS REPROCESSING PLANT		
Co-58	25	-	-	-	-	OXIDES AND HYDROXIDES	Y
Co-60	35	-	-	-	-		Y
Sr-90	1	-	-	-	-	OXIDE	D
Cs-134	10	-	-	-	-	OXIDES AND HYDROXIDES	D
Cs-137	25	-	-	-	-		D
Ce-144	4	-	-	-	-		Y
Pu-238	-	44.7	-	-	-	OXIDES	Y
Pu-239	10^{-2}	2.8	-	-	-		Y
Pu-240	-	4.5	-	-	-		Y
Am-241	-	5.5	-	-	-		W
Am-242m	-	0.1	-	-	-		W
Am-243	-	0.3	-	-	-		W
Cm-242	-	3.9	-	-	-		W
Cm-244	-	38.2	-	-	-		W
I-131	-	-	∿100	-	-	ELEMENTAL	D
Ar-41	-	-	-	∿100	-	-	-
Kr-85	-	-	-	-	∿100	-	-
RELEASE RATE in Bq/a	$3.7\cdot10^{10}$	$3.7\cdot10^{9}$	$3.7\cdot10^{10}$	$3.7\cdot10^{15}$	$3.7\cdot10^{16}$		

TAB. 1: RADIONUCLIDE GROUP CHARACTERISTICS.

2. METHODS

Atmospheric dispersion and deposition of radionuclides on the ground as well as their transfer to the man via the various exposure pathways is calculated in both methods according to /1/.

Method A: The Committed Effective Dose Equivalent $H_{50,E}$ was evaluated corresponding to the following equation

$$H_{50,E}=\sum_T W_T \cdot \sum_T H^i_{Ex,T}+H^i_{50,T}$$

$H^i_{50,T}$ total committed dose equivalent in tissue (T) resulting from intake of radionuclide (i) (integration time: 50 years) in Sv

$H^i_{Ex,T}$ total dose equivalent in tissue (T) resulting from external irradiation of the radionuclide (i) in Sv (accumulation time of ground deposition: 50 years)

W_T weighting factor representing the ratio of the stochastic risk resulting from tissue (T) to the total risk when the whole body is irradiated uniformly, see Tab. 2.

Dose factors for intake of radionuclides have been taken from ICRP 30. The list of dose factors quoted in ICRP 30 has been completed in order to have a set of 20 organ dose factors per radionuclide for both inhalation and ingestion. Dose conversion factors published in reference /2/ have been used to determine dose factors for external γ-irradiation from the ground, taking into account radioactive decay chains. The limit of the effective dose equivalent is assumed to be the same as the whole body dose equivalent limit (300 µSv) specified in the German Radiation Protection Ordinance.

Method B: Dose factors for intake and external irradiation have been taken from reference/1/. Integration and accumulation times are the same as above. Dose equivalent limits refer to the German Radiation Protection Ordinance.

As ICRP 30 quotes dose factors for adults only, all dose calculations are restricted to adults, incl. the thyroid dose by iodine ingestion.

3. RESULTS

The dose equivalents calculated according to method A and B are summarized in Tab. 2. The five organs out of the remainder tissues, which are accounted for, are underlined.

4. CONCLUSIONS

1. The differences of organ dose equivalents in methods A and B are due to
   - improved metabolic data,
   - more detailed metabolic models.

2. Effective dose equivalents, related to the annual limit (method A) are smaller in the examples shown than the respective critical organ dose equivalents, related to their annual limit (method B).
   That means: method B was more conservative.

The difference ist most pronounced in the case of thyroid irradiation by incoporated iodine and of isolated skin irradiation, e. g. by Kr-85, due to the small W_T of the thyroid and the skin. The differences in external irradiation are due to the fact, that the self-shielding of the inner organs is taken into account in method A.

/1/ 'Allgemeine Berechnungsgrundlage für die Strahlenexposition bei radioaktiven Ableitungen mit der Abluft ...' GMBL, Ausgabe A, 30 369 (1979) and GMBL, Ausgabe A, 33 735 (1982)

/2/ D. C. Kocher:
"Dose Rate Conversion Factors for external Exposure to Photon and Electron Radiation from Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities", Health Phys. 38, 543 (1980)

EXPOSURE PATHWAY		INHALATION		INGESTION		γ-IRRADIATION FROM THE GROUND		INHALATION		INGESTION		γ+β-SUBMERSION			
MIXTURE		P W R - A E R O S O L						α-ACTIVE WASTE		J-131		Ar-41		Kr-85	
METHOD	W_T	A µSv	B µSv	A µSv	B µSv	A µSv	B µSv	A µSv	B µSv	A µSv	B µSv	A µSv	B µSv	A µSv	B µSv
GONADS	0.25	.02	-	4.1	-	3.5	-	5	-	.02	-	80	-	2.3	-
BREAST	0.15	.04	-	3.7	-	4.6	-		-	.05	-	85	-	5.1	-
RED BONE MARROW	0.12	.08	-	5.7	-	4.7	-	34	-	.04	-	72	-	1.9	-
LUNG	0.12	.74	.51	3.7	0.8	4.3	-	68	15	.05	-	72	-	1.9	-
THYROID	0.03	.04	-	3.7	-	3.8			-	213	230	90	-	2.5	-
BONE SURFACE	0.03	.43	-	7.6	-	5.1	-	422	-	.04	-	77	-	2.5	-
BONE		-	.93	-	28.8	-	-	-	406		-	-	-	-	-
GASTRO INTESTINAL TRACT		-	.03	-	5.5	-	-	-			4	-	-	-	-
SKIN	0.01	.02	-	2.9	-	5.5	-		-	.04	-	154	182	202	197
REMAINDER	0.3														
ADRENALS		.06	-	4.6	-	-	-		-	.03	-	68	-	1.9	-
BLADDER		.02	-	4.3	-	4.0	-		-	.02	-	-	-	-	-
STOMACH		.05	-	4.2	-	4.1	-		-	.14	-	66	-	1.8	-
SMALL INTESTINE		.03	-	4.7	-	3.5	-		-	.02	-	62	-	1.5	-
UPPER LARGE INTESTINE		.03	-	5.1	-	4.2	-		-	.02	-	72	-	1.8	-
LOWER LARGE INTESTINE		.03	-	6.2	-	3.3	-		-	.02	-	66	-	1.7	-
KIDNEYS		.04	.09	4.1	2.9	3.8	-		49	.02	-	72	-	1.9	-
LIVER		.14	.16	4.2	8.8	3.9	-	95	64	.02	-	68	-	1.8	-
PANCREAS		.06	-	4.0	-	3.8	-		-	.03	-	60	-	1.5	-
SPLEEN		.06	-	4.1	-	4.8	-		-	.03	-	66	-	1.7	-
THYMUS		.09	-	3.6	-	3.4	-		-	.14	-	76	-	2.0	-
UTERUS		.02	-	4.5	-	3.1	-		-	.02	-	60	-	1.5	-
EFFECTIVE DOSE EQUIVALENT		.15	-	4.6	-	4.2	-	32	-	6.4	-	78	-	4.5	-
WHOLE BODY DOSE EQUIVALENT		-	.05	-	5.8	-	6.8	-	12	-	0.4	-	137	-	3.2

CRITICAL ORGAN		LUNG		WHOLE BODY		WHOLE BODY		BONE		THYROID		WHOLE BODY		SKIN
ANNUAL DOSE LIMIT OF ADULTS IN µSv	300	900	300	300	300	300	300	1800	300	1800	300	300	300	1800
EFF.DOSE EQUIV. / ANNUAL DOSE LIMIT	.0005		.015		.014		.11		.02		.26		.015	
CRITICAL ORGAN DOSE EQUIVALENT / ANNUAL DOSE LIMIT		.00057		.019		.023		.23		.13		.46		.11

TAB. 2: DOSE EQUIVALENTS RELATED TO DOSE EQUIVALENT LIMITS.
Dose contributions smaller than 1 ‰ are omitted.