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OPERATIONAL CRITERIA FOR AUTHORIZING EMISSIONS OF RADIONUCLIDES FROM THE PROCESS INDUSTRY

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According to the EU-Directive, the member states of the European Union need to identify the work activities which involve the presence of natural radiation sources and lead to a significant increase in the exposure of members of the public, which cannot be disregarded from the radiation protection point of view. The process industry uses large amounts of raw materials like ore, marl or clay, which contain natural radionuclides. These radionuclides, present in the releases into air and water, impose a radiological risk to the population residing near an industrial site. A system of reporting and authorization for such emissions is now under development in the Netherlands. A work activity enters the system when the maximum individual dose or collective dose due to releases to air or water exceeds a certain value: the so-called basic dose criterion. In the system under development the process industry is classified into a limited set of reference situations. For each of these situations the dose criteria are then translated into operational emission criteria per radionuclide by calculating the emissions that result in a maximum individual dose of 10 μSv.a^{-1} and a collective dose of 1 manSv.a^{-1}. Besides describing the system, this paper will demonstrate the practical use of the system illustrated by a few examples of specific process industries in the Netherlands.

Introduction

The process industry is one of the work activities involving natural radiation sources leading to a significant increase in the exposure of the population and one which the member states of the European Union need to identify [1]. This industry uses large amounts of raw materials like ore, marl or clay, containing naturally occurring radionuclides, which are released into air and water, and impose a radiological risk to members of the population residing near an industrial site. We presented a review of the situation in the Netherlands at the first international symposium on radiological problems with natural radioactivity in the non-nuclear industry [2].

In the system of reporting and authorization under development in the Netherlands, the following basic dose criteria are used to identify the relevant work activities: a maximum individual dose criterion of 10 μSv.a^{-1} and a collective dose criterion of 1 manSv.a^{-1}. To check compliance with these criteria each industry should perform dose calculations. However, the competent authority, which provides the permits, needs simple criteria to determine whether a plant or or branch of industry either has to report the activity or take out a permit. Dose calculations are then necessary in a limited number of cases.

The purpose of this study is to investigate how the basic dose criteria can be translated into operational emission criteria. It is limited to emissions into air. Discharges to water are discussed elsewhere [3].

Methods

A work activity enters the system when the maximum individual dose or collective dose due to releases to air exceeds the basic dose criteria. In the system under development the process industry is first classified into a limited set of reference situations. Each reference situation is characterized by the height, the heat content of the emission and the particle size of the emissions (Table 1).

The following naturally occurring radionuclides are included: ^{210}Pb, ^{210}Pb, ^{222}Rn, ^{226}Ra, ^{228}Ra, ^{227}Ac, ^{228}Th, ^{230}Th, ^{232}Th, ^{231}Pa, ^{234}U, ^{235}U and ^{238}U. All of them are assumed to be bound to aerosols, except ^{222}Rn which is gaseous; emissions are assumed to be continuous and constant in time. The individual dose was calculated for a situation of individuals residing at the location where

the exposure is expected to be highest. The calculation method is described in more detail elsewhere [2].
The collective dose was calculated for the Dutch population, which consists of 15 million people. For high releases a considerable portion of the collective dose is received by individuals outside the Netherlands. The Netherlands was modelled as a number of concentric rings around the emission source. The population density in each ring was varied to study the effect of localizing the source in or near densely populated or rural areas.
The maximum individual and collective doses were calculated for each reference situation and radionuclide for an emission of 1 GBq.a^{-1}. Then two emission criteria per radionuclide were defined: the emissions that result in a maximum individual dose of 10 μSv.a^{-1} and a collective dose of 1 manSv.a^{-1}.
To test the suitability of emission criteria the emissions of ^{210}Po, ^{210}Pb and ^{222}Rn from the process industries in the Netherlands (specific situations, [2]) were compared with the emission criteria (reference situations).

***Table 1:* Emission characteristics for the eight reference situations.**

Reference situation *	Emission height (m)	Heat content (MW)	AMAD-distribution
L1a	2	0	coarse
L1b	2	0.1	coarse
L2a	10	0.1	medium
L2b	10	1	medium
L3a	30	1	medium
L3b	30	10	medium
L4a	150	10	fine
L4b	150	100	fine

* *Emissions at ground level (L1a and L1b) constitute dust particles that are blown about.*

Results and Discussion

The results of the emission criteria calculations are shown in Tables 2 and 3. The dose calculations for the L1 reference situations are highly uncertain because the dispersion model does not take into account the details of the source surroundings.
The selected emission criterion per reference situation and radionuclide is the lowest of the two values in the Tables 2 and 3. The difference between the L4b and the L1a situation after combining these tables is a factor of 400 to 2800, depending on the radionuclide; between the L4b and the L2a situations, the difference is a factor of 50 to 300.

***Table 2:* Emission criteria in GBq.a^{-1} per radionuclide per reference situation based on the maximum individual dose criterion of 10 μSv.a^{-1} for members of the public.**

	(L1a)	(L1b)	L2a	L2b	L3a	L3b	L4a	L4b
^{210}Pb	(7.0E-02)	(1.9E-01)	5.8E-01	5.2E+00	1.3E+01	1.2E+02	4.3E+02	7.8E+02
^{210}Po	(8.8E-02)	(2.3E-01)	7.2E-01	6.5E+00	1.6E+01	1.5E+02	5.3E+02	9.2E+02
^{222}Rn	(6.5E+01)	(1.9E+02)	5.9E+02	5.4E+03	1.4E+04	1.6E+05	7.4E+05	3.1E+06
^{226}Ra	(4.5E-02)	(1.3E-01)	3.8E-01	3.5E+00	8.8E+00	9.7E+01	4.2E+02	1.3E+03
^{228}Ra	(2.6E-02)	(7.4E-02)	2.2E-01	2.0E+00	5.2E+00	5.6E+01	2.3E+02	6.5E+02
^{227}Ac	(7.9E-04)	(2.2E-03)	6.7E-03	6.2E-02	1.6E-01	1.8E+00	8.3E+00	3.3E+01
^{228}Th	(1.1E-02)	(3.1E-02)	9.2E-02	8.5E-01	2.2E+00	2.5E+01	1.1E+02	4.7E+02
^{230}Th	(4.3E-03)	(1.2E-02)	3.7E-02	3.4E-01	8.7E-01	9.9E+00	4.6E+01	1.8E+02
^{232}Th	(3.9E-03)	(1.1E-02)	3.3E-02	3.1E-01	7.9E-01	9.0E+00	4.1E+01	1.7E+02
^{231}Pa	(3.1E-03)	(8.7E-03)	2.6E-02	2.4E-01	6.2E-01	7.0E+00	3.2E+01	1.3E+02
^{234}U	(4.6E-02)	(1.3E-01)	3.9E-01	3.6E+00	9.2E+00	1.0E+02	4.8E+02	1.9E+03
^{235}U	(4.9E-02)	(1.4E-01)	4.1E-01	3.8E+00	9.6E+00	1.1E+02	4.9E+02	1.7E+03
^{238}U	(5.4E-02)	(1.5E-01)	4.6E-01	4.2E+00	1.1E+01	1.2E+02	5.6E+02	2.2E+03

Table 3: **Emission criteria in GBq.a^{-1} per radionuclide per reference situation based on the collective dose criterion of 1 manSv.a^{-1} for members of the public; the source is located in a densely populated area.**

	(L1a)	(L1b)	L2a	L2b	L3a	L3b	L4a	L4b
^{210}Pb	(1.8E+00)	(3.0E+00)	3.8E+00	6.1E+00	7.2E+00	1.6E+01	2.4E+01	2.9E+01
^{210}Po	(2.3E+00)	(3.7E+00)	4.8E+00	7.6E+00	9.0E+00	2.0E+01	3.0E+01	3.6E+01
^{222}Rn	(1.7E+03)	(3.4E+03)	4.4E+03	8.0E+03	1.0E+04	3.9E+04	7.7E+04	1.8E+05
^{226}Ra	(1.3E+00)	(2.3E+00)	3.0E+00	5.3E+00	6.8E+00	2.2E+01	3.6E+01	5.8E+01
^{228}Ra	(7.3E-01)	(1.3E+00)	1.7E+00	3.0E+00	3.8E+00	1.2E+01	1.9E+01	2.9E+01
^{227}Ac	(2.3E-02)	(4.2E-02)	5.4E-02	1.0E-01	1.3E-01	5.2E-01	9.3E-01	2.0E+00
^{228}Th	(3.1E-01)	(5.8E-01)	7.5E-01	1.4E+00	1.9E+00	7.2E+00	1.3E+01	2.9E+01
^{230}Th	(1.2E-01)	(2.3E-01)	3.0E-01	5.7E-01	7.4E-01	2.9E+00	5.2E+00	1.1E+01
^{232}Th	(1.1E-01)	(2.1E-01)	2.7E-01	5.1E-01	6.7E-01	2.6E+00	4.7E+00	1.0E+01
^{231}Pa	(8.8E-02)	(1.6E-01)	2.1E-01	4.0E-01	5.2E-01	2.0E+00	3.5E+00	7.4E+00
^{234}U	(1.3E+00)	(2.4E+00)	3.2E+00	6.0E+00	7.8E+00	2.9E+01	5.2E+01	1.1E+02
^{235}U	(1.4E+00)	(2.6E+00)	3.4E+00	6.3E+00	8.2E+00	3.0E+01	5.5E+01	1.1E+02
^{238}U	(1.6E+00)	(2.9E+00)	3.7E+00	7.0E+00	9.1E+00	3.5E+01	6.3E+01	1.3E+02

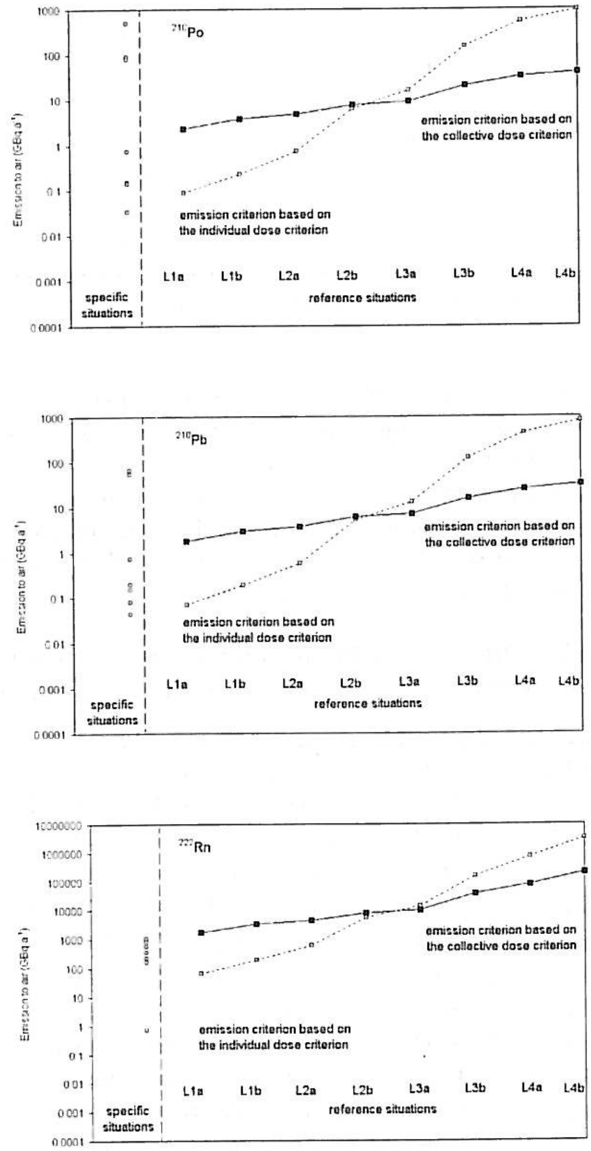

Figure 1: Comparison of emission criteria for ^{210}Po, ^{210}Pb and ^{222}Rn and specific emissions.

On the right-hand side of Figure 1, the emission criteria for ^{210}Po, ^{210}Pb and ^{222}Rn, based on the collective dose criterion, are compared with the emission criteria based on the individual dose criterion. The emission criterion based on the individual dose criterion changes most when the emission height increases. The difference in emission criteria among the various radionuclides, apart from ^{222}Rn, is rather limited. The reference situations can be divided into two groups: the situations with low emission heights for which the criterion based on the individual dose is the most restrictive and the situations with high emission heights for which the criterion based on the collective dose is the most restrictive. This separation in reference situations is the same for all radionuclides under study. However, the separation is not a universally valid result because the collective dose is calculated for the people in the Netherlands.

On the left-hand side of Figure 1, the actual ^{210}Po, ^{210}Pb and ^{222}Rn emissions for seven specific situations in the Netherlands are given (see also Table 4). These emissions vary between 0.03 and 1000 GBq.a^{-1}.

Figure 2 focusses on the case of ^{210}Po. When the most restrictive situation (L1a) is chosen, the comparison results in an emission criterion of 0.1 GBq.a^{-1}. Six of the industries given in Table 4 would exceed the emission criterion. When an average situation, such as L2b, is chosen the comparison results in an emission criterion of 10 GBq.a^{-1} and only the first three industries would exceed this criterion. When the appropriate reference situation, as given in Table 4, is chosen, the emission criteria for ^{210}Po would be exceeded by four industries.

The effects of varying population densities near the emission source proved to be almost negligible for the situations in which the emission criterion based on the collective dose criterion is the most restrictive one (L3a to L4b); in the case of ^{210}Po the emission criterion based on the collective dose criterion in the L3a-situation is a factor of 1.8 larger, i.e. less restrictive, when the source is located in a rural area as opposed to a densely populated area.

Table 4: **Estimates of the emissions of ^{210}Po, ^{210}Pb and ^{222}Rn by some of the process industries in the Netherlands [2].**

production / location	^{210}Po [GBq.a^{-1}]	^{210}Pb [GBq.a^{-1}]	^{222}Rn [GBq.a^{-1}]	reference situation
phosphorus, Vlissingen	490	66	560	L3a
iron and steel, IJmuiden	91	55	350	L4a
cement, Maastricht	78	0.20	160	L4a
mineral sands, Amsterdam	0.73	0.73	0.73	L1a
phosphoric acid, Vlaardingen	0.14	0.08	820	L3a
phosphoric acid, Pernis	0.15	0.15	1000	L3a
fertilizer, Amsterdam	0.034	0.044	220	L3a

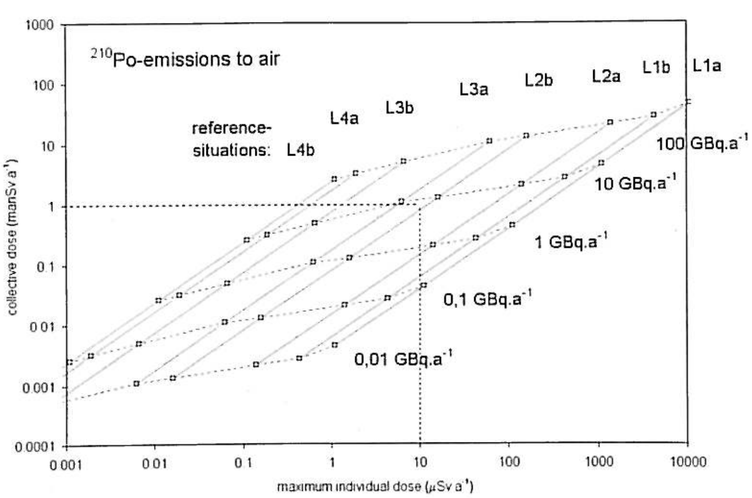

Figure 2: The maximum individual dose versus the collective dose for eight reference situations and five ^{210}Po emissions.

Conclusions

The system of emission criteria outlined in this paper can help in quickly identifying situations in which the basic dose criteria could be exceeded. The results can be used either to select one emission criterion per radionuclide for the complete process industry or to select a set of criteria for a number of reference situations.

References

[1] EU-Directive 96/29 Euratom of the Council of May 13, 1996 laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation. O.J. L 159 of 29.6.1996.

[2] M.J.M. Pruppers, R.O. Blaauboer, M.P.M. Janssen, S.T. van Tuinen, P. Stoop and H.P. Leenhouts. Radiological risks of non-nuclear industries in the Netherlands. Proc. Int. Symp. 'Radiological problems with natural radioactivity in the non-nuclear industry'. Amsterdam, September 8-10, 1997.

[3] R.O. Blaauboer, C.J.W. Twenhöfel and M.J.M. Pruppers. Study of emission and discharge criteria for granting Nuclear Power Act permits in the process industry, 1998. (in Dutch; in prep.)