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IDENTIFICATION OF OCCUPATIONAL EXPOSURES TO NATURAL RADIATION SOURCES IN THE NETHERLANDS

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Abstract
In May 1996 the Council Directive 96/29/EURATOM came into force, laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation. Title VII of this directive addresses enhanced exposures due to natural radiation sources. In article 40 it is stated that „each member state shall ensure the identification by means of surveys or by any other appropriate means, of work activities which may be of concern".
By order of the Ministry of Social Affairs, KEMA/ECN has performed a study on the occupational exposures to natural radiation sources in Dutch industries. The study consisted of a literature search to identify the types of industries and occupations where ores, products or residues are processed with enhanced activities. For these industries specific work activities are identified, for which exposures are estimated based on scenarios with both normal (realistic) and unlikely assumptions.
The work activities are classified into five categories according to the dose levels 1, 6, 20 and 50 mSv/yr, ranging from minimum concern when doses, even under unlikely conditions, are below 1 mSv per year to high concern when doses, even under normal conditions, could be over 20 mSv per year.

Introduction
In May 1996 the Council of the European Union adopted the new Euratom Council Directive 96/29 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation [1]. This directive must be implemented by the member states in their legislation not later than 13 May 2000.
The Basic Safety Standards apply to all practices, which involve a risk from ionising radiation emanating from an artificial source or from a natural source in cases where natural radionuclides are processed in view of their radioactive properties. It also applies to work activities, which involve the presence of natural radiation sources, which cannot be disregarded from a radiation protection point of view.
Title VII of the directive specifically addresses enhanced exposures due to natural radiation sources. In article 40 it is stated that each member state shall ensure the identification by means of surveys or by any other appropriate means, of work activities which may be of concern, in particular:

a. work activities where worker sand, where appropriate, members of the public are exposed to thoron or radon daughters or gamma radiation or any other exposure in workplaces such as spas, caves, mines underground workplaces and aboveground workplaces in identified areas;
b. work activities involving operations with, and storage of, materials, not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of workers and, where appropriate, members of the public;
c. work activities which lead to the production of residues not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of members of the public and, where appropriate, workers;
d. aircraft operation.

This paper presents the Dutch fulfilment to the obligation of each member state to perform a survey in order to identify such work activities in their country.

Methodology

For this study in general the methodology of Penfold et. al was followed [2], which consist of the identification, based on data from literature, of industries in the Netherlands with a possible NORM problem and classifying work activities within these industries with the aid of exposure scenarios for both normal and unlikely conditions.

From data in literature a list of industries, of which it is know that naturally occurring radioactive materials (NORM) could pose a problem to workers as well as the environment, is generated. Industries of which less information is available but of which it is presumed that problems related to NORM could also be present, are added to the list.

Except exposure of aircraft personnel to cosmic radiation, most forms of exposure in the Netherlands to sources of natural radiation will be related to the processing of ores, products and residues with enhanced concentrations of natural radioactivity. From data in literature [2 – 6] it is known that such exposures may occur at various types of industry, the most important of which are:

- the phosphate industry
- the fertiliser industry
- the metal production industry
- the production of rare earth's
- the ceramic industry
- the production and use of thoriated materials
- the pigment industry
- the oil and gas production

Subsequently, based upon the exposure scenarios for normal and unlikely conditions, doses are calculated for selected work activities, which can lead to enhanced exposure to natural radiation. The work activities are then classified according to the following dose categories:

A. doses under normal conditions less than 0,1 mSv per year and for unlikely conditions less than 1 mSv per year;
B. doses under normal conditions between 0,1 and 1 mSv per year and for unlikely conditions between 1 and 6 mSv per year;
C. doses under normal conditions between 1 and 6 mSv per year and for unlikely conditions between 6 and 20 mSv per year;
D. doses under normal conditions between 6 and 20 mSv per year and for unlikely conditions between 20 and 50 mSv per year;
E. doses under normal conditions above 20 mSv per year and for unlikely conditions above 50 mSv per year.

Figure 1 gives a graphical representation of the classification scheme.

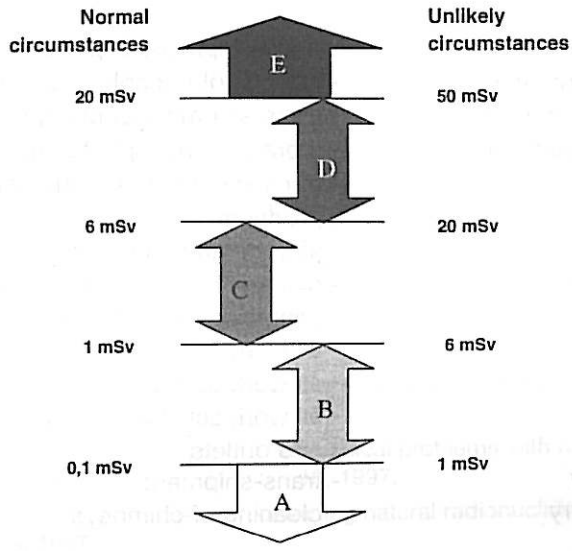

Figure 1: Classification of working activities based on doses received under normal and unlikely conditions.

Exposure scenarios
The effective annual doses for workers are calculated using exposure scenarios, which are specific for the concerning type of industry. The exposure scenarios are limited to external irradiation and internal contamination through the inhalation of dust. Internal contamination through ingestion of dust from dirty hands and/or skin doses are mostly of minor importance. The ingestion pathway, where applicable, is taken into account by means of an envelope scenario with an ingestion rate of 10 mg per working day or 1.25 mg per working hour, throughout the exposure duration.
Besides the industry specific parameters like activity concentration of the process materials, amount of material, annual throughput, specific exposure times, dust concentrations etc., general parameter values are used, where specific values are not known. These are for instance: size of the stock piles, which can vary from 1 m^3 to as much as several 10.000ths tons, inhaleable dust concentration (normal 1 to 5 mg/m^3; unlikely 10 or more mg/m^3), respiration rates (1,2 – 2 m^3/h; the latter value for heavy duties), exposure duration (in the Netherlands a maximum of 1800 hours per year is applicable) and particle size (AMAD), which in the absence of measured values is taken as 5 µm for normal and 1 µm for unlikely conditions. Furthermore it is assumed that all materials belong to absorption class S, which means that for most radionuclides the higher estimate of the dose conversion coefficients for inhalation is used.

For most industrial processes involving large quantities of naturally radioactive materials the following work activities can be discerned:
a. work activities during trans-shipment of raw material
b. work activities near an ore stock pile
c. work activities during the production process
d. work activities near stock piles of products
e. application of products
f. work activities during processing or near a stock pile of residues
g. maintenance or cleaning of contaminated installation parts

Results
Since at the moment of the preparation of this paper the process of establishing the industry specific exposure parameters for the dose calculations was still going on, the classification of work activities in the different dose categories is still tentative and can be subject to some changes. Nevertheless the overview presented below shows that most of the work activities involving materials with enhanced natural radioactivity fall in dose category A, which means an exposure under normal conditions of less than 0.1 mSv per year and under unlikely conditions of less than 1 mSv per year.

Category A: minimal exposure
Dose under normal conditions less than 0,1 mSv and under unlikely conditions less than 1 mSv per year:

■ Thermic phosphor production	- trans-shipment of phosphate ore
■ Thermic phosphor production	- storage of phosphate ore and slag's
■ Wet phosphoric acid production	- trans-shipment of phosphate ore, milling
■ Wet phosphoric acid production	- storage of phosphate ore
■ Fertiliser production	- trans shipment, storage of raw materials and products
■ Fertiliser application	- storage and strewing
■ Oil and gas production	- occupancy near stored tubing's (scales) and containers with sludge's
■ Energy production	- all work activities
■ Fly-ash industry	- all work activities
■ Cement industry	- all work activities, except maintenance of furnaces and outlets
■ Mineral sands industry	- trans-shipment
■ Coarse ceramic industry	- cleaning of chimneys
■ Cerium-oxide polish	

Category B: small exposure
Dose under normal conditions between 0,1 and 1 mSv and under unlikely conditions between 1 en 6 mSv per year:

- Thermic phosphor production - sintering plant
- Thermic phosphor production - phosphor production plant
- Fertiliser production - milling
- Cement industry - maintenance of furnaces and outlets
- Mineral sands industry - storage of raw material and milled products
- Fine ceramic industry - storage and application of ZrO_2
- Metal production
- Pigment production

Category C: significant exposure
Dose under normal conditions between 1 and 6 mSv and under unlikely conditions between 6 en 20 mSv per year:

- Thermic phosphor production - maintenance and cleansing of contaminated production installations
- Wet phosphoric acid production - maintenance on Ra-contaminated pipes and vessels
- Oil and gas production - maintenance of vessels and pipes
- Mineral sands industry - grinding process
- Metal scrap branch - Unaware exposure to NORM containing scrap metal
- Aircraft operation

Category D: high exposure
Dose under normal conditions between 6 and 20 mSv and under unlikely conditions between 20 en 50 mSv per year:

Category E: extreme exposure
Dose under normal conditions above 20 mSv and under unlikely conditions above 50 mSv per year:

Significant exposures can occur with maintenance and cleaning of contaminated vessel or pipes or other process equipment from the phosphate industry, the oil and gas industry and possibly also the chemical process industry where scales or precipitates are formed. Furthermore, unaware exposures to NORM containing components in the metal scrap branch and aircraft operation can lead to significant exposures with doses up to 10 mSv per year. Doses above 6 mSv per year under normal and above 20 mSv per year under unlikely conditions were not calculated, but cannot entirely be excluded since in some extreme conditions dose rates up to several tens of microsieverts per hour were observed.

References

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