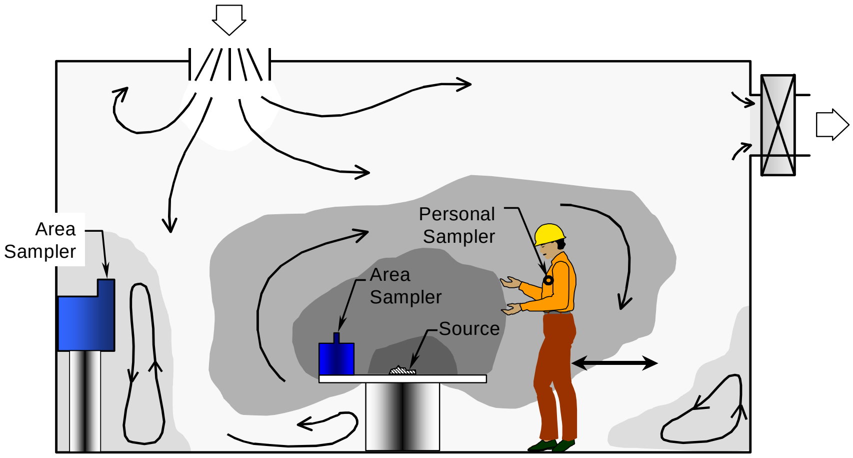
Strategies and Methods for Optimisation of Protection against Internal Exposures of Workers from Industrial Natural Sources (SMOPIE)

ANNEXES to the FINAL REPORT of the SMOPIE Project carried out under contract N° FIGM-CT2001-00176 by order of the European Commission



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Annex 1

Work Package 1

EU NORM Industries
Review of number of exposed workers and magnitude of internal doses

A1.1 INTRODUCTION

The objectives of Work Package 1 (WP1) of the SMOPIE project are to provide information on the numbers of industrial workers exposed to naturally occurring radioactive materials (NORM) and the magnitude of the internal radiation exposures received. In collecting such information, the initial intention was to draw upon the national dose registration/record systems in the countries of the principle contractors. In addition to this, other potential sources of information have been identified by the SMOPIE participants, as follows:

- European studies and projects relating (in some way) to internal radiation exposures; ESOREX, ESOREX-EAST, EURADOS, OMINEX, BIODOS and EULEP;
- work done in relation to the implementation of Title VII, Article 40 of Council Directive 96/29/EURATOM (Basic Safety Standards). This includes
  - EC guidance on identifying NORM industries with the potential for significant occupational exposures;
  - national studies carried out in response to Title VII and the above guidance; and
  - the draft EC report on the evaluation of the implementation of Title VII.

Other information was specifically sought and provided for the SMOPIE project by the principal contractors. Of these information sources, the SMOPIE industrial partners and other NORM industry representatives, were especially valuable.

A1.2 NATIONAL DOSE REGISTRATION AND RECORD SYSTEMS

A1.2.1 Netherlands (NDRIS)

The Dutch dose registration system (NDRIS) not only registers data on external exposures but also reports committed doses from internal contamination. The register contains a total number of 42 reported doses from internal contamination in the years 1993 - 2001. They range from 0.1 to 0.5 mSv and pertain without exception to doses from practices, i.e. using artificial sources. Doses received in work activities with NORM have not been reported.

Dose record keeping for workers from at least one NORM work activity (thermal phosphorus production) is being considered but has not yet been implemented.

A1.2.2 UK (CIDI)

NORM workers are not "classified" and statutory dose records are not required. There is, therefore, no data on NORM exposures (other than underground radon exposures) on the UK Central Index of Dose Information (CIDI). Instead, each employer has his own risk assessment, in which likely doses should be estimated, but not necessarily directly assessed. These estimates are recorded in internal documents rather than a central system. The results of the individual risk assessments are discussed further in Section A1.5.2.

A1.2.3 France

The French dose registration system does not provide information on internal exposures of workers in NORM industries. There are some data on measured doses in the rare earth processing industry. These are discussed later in section A1.5.1.

A1.2.4 EU (ESOREX)

ESOREX, the European Study of Occupational Exposure has reviewed the systems used to register occupational radiation exposure, the numbers of occupationally exposed persons in the EU and the dose distribution for the year 1995. The first part of the study, indicated as ESOREX WEST, covering the years 1997/1999, comprised the 15 countries of the European Union, Iceland, Norway and Switzerland. The draft final report on ESOREX WEST and has been submitted to the European Commission [1] but have not been published yet.

Five different work sectors were considered: medicine, general industry, education, research, safety inspection and natural radioactivity. However, the exposure data for general industry pertains solely to practices using artificial sources. The natural radioactivity sector comprises underground mining (coal, non-coal and uranium) and civil aviation. Consequently, reported doses pertain to exposures to radon and cosmic radiation, respectively. From a review of the ESOREX WEST draft final report, it is evident that the dose registration systems evaluated in the study do not provide useful inputs to Work Package 1 of SMOPIE[1].

A1.2.5 Eastern Europe (ESOREX EAST)

ESOREX WEST was extended with 10 central and eastern European countries (ESOREX EAST). The aims of the ESOREX EAST study were the same as for ESOREX WEST. The draft final report on ESOREX EAST has been submitted to the European Commission [1] but has not been published yet. From a review of the information collected so far, it is concluded that this study does not provide useful inputs to Work Package 1 of SMOPIE.

A1.2.6 Conclusion on information from national dose registers

From the information presently available, it is concluded that national dose registration systems do not provide useful information on either the number of workers exposed to NORM or the internal exposures received. Organisations (including the EC) that rely on the national dose registration systems for this type of information will have no indication of either the scale or the magnitude of NORM exposures.

A1.3 EUROPEAN STUDIES AND PROJECTS ON INTERNAL DOSIMETRY[2]

A1.3.1 EURADOS

The European Radiation Dosimetry Group (EURADOS) was conceived in 1981 to advance the scientific understanding and technical development of dosimetry in radiation protection, radiobiology, radiation therapy and medical diagnosis, by encouraging collaboration between European laboratories**.** Working Group 2 of EURADOS considers “Harmonisation of individual monitoring in Europe” in respect of both external and internal exposures. The first meeting was held in Oxford, September 2002 and was chaired by a representative of NRG, a principal contractor in SMOPIE. From discussions, it would appear that no information relevant to the SMOPIE project can be expected from EURADOS.

A1.3.2 OMINEX

OMINEX (Optimisation of Monitoring for Internal Exposure) is an international project, part-funded by the European Commission and co-ordinated by NRPB, a principal contractor in SMOPIE. OMINEX aims to provide advice and guidance on the design and implementation of internal dose monitoring programmes in the workplace for routine and incident monitoring.

Routine monitoring is an area of common interest between OMINEX and SMOPIE. Although OMINEX is mainly focussed on nuclear practices, the first phase of its work (evaluation of arrangements for internal monitoring) is intended to also cover non-nuclear industries. OMINEX has sent questionnaires to such industries, but information relevant to SMOPIE has not yet become available.

[1] Note: ESOREX continues: the Steering Committee met in June 2002 and it was confirmed that no new information of relevance to SMOPIE has since become available. In August 2003 the European Commission has issued an invitation to tender for ESOREX 2005.

A1.3.3 BIODOS

The project BIODOS (Biokinetics and Dosimetry of internal contamination) is co-ordinated by IPSN and NRPB participates. The overall objective is to improve the scientific basis of biokinetic models and to provide new or improved models that describe the behaviour of radionuclides in the human body. As such, the output from BIODOS may be relevant to the overall scope of SMOPIE, but not specifically to Work Package 1 being discussed here.

A1.3.4 RBDATA-EULEP

The Radionuclides biokinetics database (EULEP) and EULEP Working Party 5 also address the biokinetics and dosimetry of internal contamination. The aim is to improve the reliability of assessments of intakes of radionuclides and of the resulting doses delivered to workers and/or the public. The emphasis is on the actinides (uranium, plutonium) and fission products encountered in (nuclear) practices. The project is not likely to provide useful input to SMOPIE.

A1.3.5 Conclusions on European studies

A range of EC sponsored studies have been identified and reviewed to determine whether information relevant to SMOPIE is available, or is likely to become available in the future. Although some of these may have some relevance to the general scope of SMOPIE, none provide the information (numbers of exposed NORM workers, and doses received) required for SMOPIE Work Package 1.

A1.4 INFORMATION FROM THE IMPLEMENTATION OF EURATOM 96/29, TITLE VII

A1.4.1 Introduction

Title VII of the European Council Directive 96/29EURATOM (Basic Safety Standards)[3] requires that Member States identify NORM work activities that may lead to significant radiation exposures of workers and/or members of the public. The Commission subsequently issued guidance to assist in the implementation of Title VII in reports Radiation Protection 95 and 107.

A number of national studies have been carried out in response to Title VII. They contain information on industrial processes involving NORM and on potential occupational radiation exposures in these industries. In addition, EC projects on the implementation of Title VII by Member States and by applicant countries also provide some information of relevance to the SMOPIE project.

A1.4.2 Radiation Protection 95 and 107

Guidance to assist implementation of Title VII of the European BSS concerning natural radiation sources was published by the EC as Radiation Protection 95 [4]: "Reference levels for workplaces processing materials with enhanced levels of naturally occurring radioactive materials". The guidance was based on a study carried out by NRPB and CEPN published as Radiation Protection 107 [5]. For SMOPIE, annual individual doses to workers from inhalation of NORM have been estimated, using the RP107 methodology and data, for various industries and processing steps. A summary is given in Appendix RP107. This provides information on the types of NORM industry and work activity that potentially involve significant internal exposures from inhalation, i.e.:

- rare earth extraction - exposure to dust from stockpiles, and from radium bearing scales;
- titanium dioxide industry - exposure to dust from radium bearing scales;
- zircon sand processing - exposure to dust from stockpiles; and
- ferro-niobium processing - exposure to dust from stockpiles, and exposure to wastes and slag.

With regard to SMOPIE Work Package 1, there is no information on whether such industries and work activities are undertaken within Member States and on what scale. Furthermore, there is no information on *actual* exposures, nor on the number of workers involved.

A1.4.3 EU - The Title VII project

Identification of NORM industries that either discharge NORM into the environment, or produce NORM residues, is part of the EU research project B4300/2001/326105/MAR/C4 (known as the Title VII project) [6]. The information currently available from this project that may be of some relevance to SMOPIE is shown in Appendix EUVII/TENORMHARM.

Like RP107 above, this information is also restricted to the types of NORM industry that should be considered, rather than numbers of workers and doses received. However, the information does at least give an indication of the actual presence of these NORM industries across EU Member States. Not included, however, are industries with negligible NORM discharges or residues, such as mineral sand milling. As indicated in RP107, such industries may involve significant occupational exposures from internal radiation and, therefore, be of direct relevance to SMOPIE Work Package 1.

A1.4.4 EU Project TENORMHARM

This project focuses on the adoption and harmonisation of regulations and mitigation methods for NORM/TENORM[2] between candidate countries to meet the requirements of the EU Directive 96/29. Belgium and Germany are the two Member States involved.

The project includes an overview of work activities and sources that may cause significant radiation risks - a summary of the currently available information provided by the co-ordinators of TENORMHARM is given in Appendix EUVII/TENORMHARM. As with the Title VII project referred to above, the information is limited to the distribution of certain types of industry that produces NORM wastes. An assessment of the exposures of workers in NORM industries is also planned (Deliverable 2 from TENORMHARM), but was not available at the time of this report.

A1.4.5 National reviews – Germany

In 1997, the German Commission on Radiological Protection issued a "Statement on the Radiation Exposure at Working Places by Natural Radionuclides" [7] in response to Title VII, Article 40 of the European Directive 96/29/EURATOM.

The report provides an English translation of the results of the study. Information on the range of NORM work activities categories according to annual dose ranges is reproduced in Appendix Germany. The German study also provides an estimate of the number of exposed workers in each NORM industry and dose band. These results are reproduced in Table A1.1.

[2] TENORM refers to Technologically Enhanced NORM, i.e. from industrial processes that have produced an artificial enhancement of some or all NORM radionuclides. For example, the term NORM is used to describe materials such as mineral sands used in industry, etc. These materials may have above-average activity concentrations, but these are the same as in the natural state. If the industrial process results in materials (waste, byproducts, scales) with higher activity concentrations, these materials are TENORM. The term NORM is used throughout this report and may be taken to include TENORM as appropriate.

Table A1.1. Estimated number of occupationally exposed workers in German NORM industries [7]

NORM work activity	Number of workers with annual doses[1] in range (estimated values)	
	1 to 6 mSv	> 6 to 20 mSv
Phosphate fertiliser - Trade	1000	---
Phosphate fertiliser - Application	2000	---
Th welding electrodes - Production	100	---
Th welding electrodes - Use	45000	5000
Gas mantles exchange	200	---
Zircon sands - Moulding casts	100	---
Pyrochlor ore processing	30	---
Scrap recycling	10	---
Copper slag processing	10	---
Total	**48450**	**5000**

[1]"Dose" refers to the sum of effective and committed effective doses. In most cases, the committed effective dose due to inhalation of dust is a significant part of the total dose.

From Table A1.1, there are estimated to be approximately 53,500 exposed NORM workers in Germany, of which 50,000 are associated with the use of thoriated electrodes.

The German Radiation Protection Ordinance (Strahlenschutzverordnung) of July 2001 [8] provides a list of additional work activities to be considered, where NORM process residues have the potential for exposures exceeding 1 mSv per year. The list includes:

- sludge and sediment from the recovery of oil and gas;
- unconditioned phosphoric plasters, sludge from their preparation, dust and slag from the processing of raw phosphate (phosphorite);
- waste rock, sludge, sand, slag and dust from the extraction and processing of bauxite, columbite, pyrochlore, microlite, euxenite, copper shale, tin, rare earths and uranium ores; and
- dust and sludges arising from the off-gas scrubbing in metal smelting.

The number of exposed workers involved in the above industries is not, however, estimated, nor is the magnitude of internal exposures.

A1.4.6 National reviews - Netherlands

In The Netherlands, two studies were carried out in response to Article 40 of Title VII. The second one published in June 2001 [9] comprised an update of the first study published in

May 1999 [10]. The study followed the same general approach as in RP107 described earlier, however account was taken of site-specific data and radiation protection measures where possible to produce more realistic dose estimates. The results relevant to SMOPIE Work Package 1 are reproduced in Table A1.2. It should be noted that estimated doses are substantially lower than those predicted by RP107 using generic exposure parameters.

The large differences between the dose estimates for normal and unfavourable conditions illustrate the sensitivity to scenario parameters. Whether the unfavourable scenario conditions occur in practice is generally not known. However, the potential for significant exposures is present in many industrial activities, especially where the radiological risks are unrecognised.

As in RP 107, the Dutch study does not provide estimates of the number of potentially exposed workers in the different work activities considered.

Table A1.2. Summary of the results of the Dutch study in response to Title VII: NORM industries, work activities and estimated doses [9, 10].

Type of industry	Work activity	Annual dose[1] Normal conditions (mSv)	Annual dose[1] Unfavourable conditions (mSv)
Cat. C: dose under normal conditions between 1 and 6 mSv per year *or* under unfavourable conditions between 6 and 20 mSv per year			
Aviation	Flights > 8 km	2 – 5	> 6
TIG welding	TIG welding	0.3	14
Thermal phosphor production	Decontamination	0.2	10
Oil and gas production	Revision at specialised companies	0.15	9.3
Cat. B: dose under normal conditions between 0.1 and 1 mSv per year *or* under unfavourable conditions between 1 and 6 mSv per year			
Mineral sands industry	Milling and processing	0.8	4.5
Thermal phosphorus production[2]	Phosphorus plant	0.8	2.7
Electricity production	Maintenance of boiler walls	0.005	2.1
Slag wool[2]	Dismantling of installations	0.09	2.0
Steel production	Sinter plant	0.08	2.0
Thermal phosphorus production[2]	Sinter plant	0.4	1.7
Metal recycling	Ra-scale bearing components	0.07	1.7
Catalyst production	Maintenance of installations	0.02	1.6
Metal recycling	Cutting E&P components	0.04	1.4
Mineral sands industry	Storage of zircon sands	0.2	1.2
Fertiliser production	Maintenance of installations	0.02	1.2
TIG welding	Grinding of welding electrodes	0.15	1.1
TiO_2 pigment production	Dust from MeOH waste	0.05	1.1
Cement production	Maintenance of clinker ovens	0.04	1.1
Road construction	Application of phosphor slag	0.3	0.8
Fertiliser production	Storage of phosphate ores	0.2	0.9
Zinc production	Storage of cobalt waste	0.11	0.9
Mineral sands industry	Storage of milled products	0.16	0.8
Fertiliser production	Storage of fertiliser	0.12	0.7
Slag wool	Normal occupancy	0.11	0.6
Glass ovens (ZAC)	Normal occupancy	0.13	0.2

[1]"Dose" refers to the sum of effective and committed effective doses. In most cases, the committed effective dose due to inhalation of dust is a significant part of the total dose.
[2] Thermal phosphorus production is exclusively a Dutch operation within the EU. Similarly, the historical use of tin slag insulation wool also seems to be almost unique to the Netherlands.

A1.4.7. Conclusions on work done in relation to Title VII

The above studies and reports associated with the implementation of Title VII identify an extensive list of NORM materials, industries and work activities that could give rise to significant occupational radiation exposures. It should however be noted that:

- Occupational exposures derived from generic exposure scenarios such as in RP107 are deliberately pessimistic, and should not be taken to represent actual exposures. The use of more site-specific parameters in the RP107 methodology should, however, enable more realistic (and representative) doses to be estimated, as in the Dutch study;
- NORM exposure data based on actual workplace monitoring is very scarce; and
- Information on the number of exposed workers is also very scarce: only the German study provides an estimate of the number of exposed workers in each industry.

A1.5 OTHER SOURCES OF INFORMATION

During the project, the need for additional information to complete Work Package 1 became clear. Consequently, the following information was collated specifically for the SMOPIE project by the principal contractors.

A1.5.1 FRANCE –Work Package 1 input from CEPN

Appendix France prepared by CEPN, provides a summary of the available data on the total number of workers in the main French NORM industries, and any information on exposures from inhalation. A summary of the information relevant to SMOPIE Work Package 1 is presented below in table A1.3.

Table A1.3. Summary of data for Work Package 1 for the main French NORM industries

Type of NORM industry	Number of workers[1]	Available data on doses from inhalation
Steel – primary production	(37 000)	-
Iron and steel foundries	(20 000)	-
Non ferrous metals	(22 000)	-
Phosphoric acid and fertilisers	(6 600)	-
Refractory ceramics	(4 200)	-
Titanium oxide pigments	(1000)	Estimated: can exceed 1 mSv/y
Rare Earth extraction	130 monitored workers	Measured: Average 1.5 mSv/y Maximum >20 mSv/y
Zirconium industry	-	Estimated: 1 - 7 mSv/y for some workers
Metal smelting	-	Estimated: can exceed 1 mSv/y
Optical industry (glass polishing)	-	Estimated: can exceed 1 mSv/y

[1]The values on brackets are the *total* number of persons employed in the industry in France. The number of *exposed* workers is expected to be a very small fraction of this number.

Table A1.3 does not include all work activities involving NORM. For example, welding with thoriated rods is not included. It appears that it is presently not possible to provide substantiated figures for the number of exposed workers in the French NORM industries. The exception is the rare earth extraction industry in which about 130 workers are monitored because of the potential for exposures (in some cases exceeding 20 mSv per year) from inhalation of dust.

A1.5.2 United Kingdom – Work Package 1 input from NRPB and UKHMSA

NRPB conducted a survey of UK NORM industries through the industrial partner UK Heavy Mineral Sands Association. The results are given in Table A1.4.

Unlike the French data, the survey aimed to determine the number of "exposed persons", which include all workers involved with the handling of NORM who *could* potentially receive a dose (from all exposure pathways) above 1 mSv per year. In many cases, exposures are expected to be lower than this due to a combination of engineering controls, good working practices and personal protective equipment. Any additional information provided on the number of workers receiving significant doses has been summarised in the comments column in Table A1.4.

There is some information on doses received by workers – this is obtained from the NRPB RPA service, and is based directly on workplace measurements. However, this information is not available for all the industries listed.

TABLE A1.4: Summary of data for Work Package 1 from the main UK NORM industries

Type of industry	Work activity	Estimated number of workers[1]	Estimated Dose ranges[2] (mSv/y)	Comments
TIG welding	Welding and grinding Th rods	-	-	Estimates not available.
Zircon sands industry	Processing, milling and production of materials	100	<1 – 4	Number of workers in large-scale plants. All potentially exposed.
Titanium dioxide	Processing of ilmenite and rutile	1000	<1	Less than 10 workers (1%) have the potential to receive significant doses.
Steel castings	Use of zircon sand in moulds	10,000	<1 – 2	Approximate number of relevant workers in UK industry. The number receiving significant doses is expected to be very low.
Rare earth compounds	Preparation of glass additives	<100	<1 – 2	Work is typically on a small scale
Refractories	Use of zircon-containing materials	1000	-	
Ceramics	Use of zircon in glazes	1000	-	Estimated number of workers potentially handling glazing materials during ceramic production.
Glass production	Zircon in TV tubes	<50	-	The number of workers likely to handle Zr materials is expected to be very low.
Mg-Th alloy (aero industry)	Refurbishment of components	<50	-	All workers are assume to have potential for significant exposure

				if precautions not taken.

[1]Data based on estimates provided by the members of the UK Heavy Mineral Sands Association.
[2]Data taken from risk assessments made by NRPB RPA service. These are total doses, but typically inhalation of dust is expected to contribute at least 50% of the dose.

A1.5.3 Republic of Ireland - Input on exposures to NORM

The implementation of Regulations on the control of NORM materials is currently on-going in Ireland. In 2001, the Radiological Protection Institute of Ireland (RPII) started a project to identify the work activities involving significant exposure to natural terrestrial radiation sources other than radon, as required by Title VII of EURATOM 96/29. One of the objectives of the project is to make an inventory of the quantities and types of wastes.

RPII is currently investigating the power generation gas industry. In 2003, the range of industries being investigated may be enlarged to include bauxite processing (alumina production) and, if resources permit, cement production and mineral sands users. Table A1.5 summarises the information provided by RPII, upon request, for the SMOPIE project.

TABLE A1.5: Summary of data for Work Package 1 from the Republic of Ireland

Type of NORM industry	Number of workers[1]
Bauxite/Alumina Production	~400
Power Production – Peat	~500
Power Production – Coal	300
Power Production - Gas	~100
Mineral sands industry	To be determined
Cement production	To be determined
Others, e.g. ceramics, TIG welding, glass production, etc	Not known

[1]For bauxite processing and power production, the number of workers involved pertains to the total number of employees. The number of exposed workers is expected to be very much lower.

A1.5.4 EU – Work Package 1 input from NRG on TIG welding and TIO_2 industry

The German study discussed previously indicates that relatively large numbers of workers may be exposed as a result of the use of thoriated welding rods. It has proved extremely difficult to get an estimate of the number of such workers in other countries. Consequently, NRG has attempted to derive an estimate of the total number of workers in the EU that may be exposed to significant doses by inhalation in TIG welding. The methodology used is given in Appendix TIG.

The EU total figure is about 70,000 workers, based on a number of very broad assumptions. It is known that in some countries (e.g. the UK) the use of containment and extraction systems to minimise airborne dust from electrode grinding is recommended. If this practice is widespread, then the number of exposed persons will be very much lower than the figure estimated. In any case, the number of potentially exposed workers should decrease significantly as thoriated welding electrodes become replaced by lanthanide doped electrodes.

Notwithstanding the above, it is clear that this one work activity may affect a substantial number of workers. It is unfortunate, therefore, that details of the number of workers and the exposures received is so poorly known.

The total number of workers involved in the production of titanium oxide pigment has also been considered by NRG. From the annual Responsible Care Reports of one of the larger producers, a production plant of 100 ktonnes annually requires about 400 workers in total. A total of about 66,000 workers can be derived on the basis of the total TiO_2 production capacity in the European Union. The fraction of that workforce that might be exposed significantly during routine operations and maintenance can only be guessed, but that fraction is likely to be rather small (e.g. in the UK this figure is estimated to be 1%).

A1.5.5 Conclusions – Work Package 1 input from other sources

As might be expected, the other sources of information commissioned specifically for the SMOPIE project have provided data that are more relevant to Work Package 1. Even then, for many of the NORM work activities previously identified, there is no site-specific data on the doses received. It is suspected that, in many cases, this is simply due to the potential radiological hazard being unrecognised in the industries concerned.

It is important to distinguish between the total number of employees and the number of exposed workers. The latter is almost certainly a very small percentage of the total (and may even be 0% in some cases). For example, the French data includes estimates of all workers involved in the fertiliser industry. However, the fertiliser industry covers many production facilities not involving NORM, such as the production of nitrogenous fertilisers. The relevant NORM industries are those producing phosphoric acid or complex phosphate fertilisers from phosphate ore. No data on the numbers of workers involved in those sectors of the fertiliser industry could be made available. Moreover, it appears even more difficult to estimate the fraction of that workforce that is potentially exposed to significant doses by internal contamination. The number of workers involved in the trade and application of complex phosphate fertiliser produced directly from phosphate rock is even more difficult to estimate.

Due to the reasons given above, and the general lack of data on doses received, it is impossible to accurately determine the number of exposed workers. The most reliable information is considered that supplied directly from the industries concerned. From this, it is still only considered possible to derive “order of magnitude” estimates of the number of exposed persons. Although not ideal, these are considered to represent the best currently available data. This is discussed more in the following section.

A1.6 WP1 CONCLUSIONS – DOSES AND EXPOSED WORKERS

A1.6.1 Dose ranges

This information is **not** available from national dose registries or from other current European Research projects. There are, however some data from work done in response to Title VII of the Euratom BSS, and from sources specifically commissioned for the SMOPIE project.

From all the information considered so far, potential annual exposures by inhalation in NORM industries span a range from below 1 mSv to above 20 mSv. In many cases, doses have been modelled rather than being based on actual workplace measurements. Such estimated doses would appear to be grossly pessimistic in many cases.

In some cases, there are more realistic estimates of dose: in fact, these occupy the same dose range, i.e. from below 1 to greater than 20 mSv. Overall, there is insufficient data to provide any more than a broad indication of the doses involved, as shown in Table A1.6.

TABLE A1.6: Summary of data on dose ranges associated with NORM work activities

Potential annual dose from inhalation (mSv)	Type of NORM industry
Above 20 mSv	Rare earth processing (a few workers)
6 to 20 mSv	Grinding of thoriated electrodes Zircon milling (a few workers)
Below 6 mSv	All other NORM industries

A1.6.2 Estimates of number of exposed workers

The information is **not** available from national dose registries, current European Research projects, or work done in response to Title VII of the Euratom BSS. The exceptions to this are the German study (Table A1.1) and, to a lesser extent the on-going work in the Republic of Ireland, which do contain estimates of the number of exposed workers.

The information that has been gathered from other sources specifically for the SMOPIE project does provide a better indication of the number of exposed workers. Even then, only approximate, order-of-magnitude, estimates are considered possible. These estimates are shown in Table A1.7, and have been compiled using all the relevant data identified in Work Package 1. The estimates do not cover all industrial processes that may involve significant exposures to NORM by internal contamination. Also, there are work activities listed for which no reasonable estimate of the number of exposed workers can be given.

A1.7 WP1 – COMMENTS AND RECOMMENDATIONS

It has been surprisingly difficult to obtain estimates of the number of exposed workers and the doses received. Even obtaining data on the *total number* of employees has been difficult in some cases. Consequently, some comments and recommendations have arisen from undertaking Work Package 1, as follows:

- There is a lack of published data on the *actual* numbers of exposed workers and the doses received. Much more data based on industry surveys and workplace measurements is required to provide an accurate position of the situation in EU NORM industries.
- The implementation of Title VII of the European Directive 96/29/Euratom [10] has so far provided very little published data of the kind referred to above. It is recommended that any studies made in response to Title VII aim to include the number of workers and the *actual doses* received.
- Very much the largest NORM work activity, in terms of number of workers, appears to be the use of thoriated welding rods. Furthermore, there is evidence that inhalation doses can be significant from both welding and grinding activities. Despite this very little is known about the precise scale of the problem and it is recommended that this work activity warrants further specific study at the European level.

Table A1.7 SMOPIE Work Package 1 estimates of the number of potentially exposed workers in EU NORM industries.

NORM industry and work activity	Number of exposed workers	Basis for estimate
Thoriated electrodes, production, grinding and use	70000	Extrapolation of Dutch and German data
Phosphate fertiliser trade and use	10000	German data multiplied by 4
Oil and gas production, exposure to scale dust at maintenance	2000	Based on 1000 production installations and two workers potentially exposed annually per installation
Zircon sands, milling and processing	500	UK and German estimate multiplied by 5 for European Union
Rare earth industry, (Y, Ce, Eu, La, etc.)	400	Based on French data, multiplied by 3 for European Union.
Cement production, maintenance of clinker ovens	300	Based on 60 cement production plants and 5 exposed workers per plant
Coal-fired power plants, Maintenance of boilers	100	Based on 70 plants and 2 exposed worker per plant annually
Phosphoric acid production, scale removal	100	Ten plants producing phosphoric acid from phosphate rock. Ten exposed workers per plant.
Primary iron production, exposure to sinter dust	100	Based on 7.4 million tonnes total annual EU blast furnace primary iron production in 20 plants. Five exposed workers per plant
TiO_2 pigment, solid waste and Ra-scale	80	Based on 16 production plants, sulphuric acid and chloride process. Five exposed workers per plant.
Rare earth catalyst production, maintenance, scales	20	Largely replaced by much cleaner “concentrates” as raw material. Assumed number of plants 10, and two exposed workers per plant
Thermal phosphorus production	20	Based on Thermphos input into SMOPIE, one plant
Lead/zinc smelters	20	Number of plants 20 and 1 exposed worker per plant
Tantalum, niobium extraction from ores or slags	Not known	Number of plants at least 1.
Ground water treatment, scales and sludges	Not known	
Residues from past industrial activities	Not known	
Total (rounded)	**85 000**	

References

[1] Frasch, G., Petrová,K., Anatschkowa, E., Dose Registry in Europe: National Databases and International Statistics. Radiation Protection Dosimetry, Vol 96, Nos 1-3, pp 273-275 (2001).

[2] European Commission, Nuclear Fission and Radiation Protection Projects Selected for Funding 1999-2001, Annex IV, Radiation Protection and Radiological Sciences Summaries for Selected Projects.

[3] Council Directive 96/29/Euratom of May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation.

[4] European Commission, Reference levels for work places processing materials with enhanced levels of naturally occurring radionuclides, Radiation Protection 95, European Commission, Luxembourg 1999.

[5] Penfold, J.S.S., Degrange J-P, Mobbs, S.F. and Schneider, T., Establishment of Reference Levels for Regulatory Control of workplaces where materials are processed which contain enhanced levels of naturally-occurring radionuclides, Radiation Protection 107, European Commission, Luxembourg 1999.

[6] Chen, Q., Degrange, J-P., Gerchikov, M.Y., Hillis, Z.K., Lepicard, S., Meijne, E.I.M., Smith, K. R., van Weers, A., Effluent and Dose Control from European Union NORM Industries, Assessment of Current Situation and Proposal for a Harmonized Community Approach. Part I Main Report, Part II Appendices. June 2003. Submitted as Final Reports Issue 06, C6911/TR/01 to the European Commission.

[7] SSK, Radiation exposure at working places by natural radionuclides. Statements of the Commission on Radiological Protection. Berichte der Strahlenschutzkommission (SSK) des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit, Heft 10 (1997).

[8] Ordinance implementing the European Directives on Radiation Protection (Strahlenschutzverordnung) of July 2001.

[9] Timmermans, C.W.M., van Weers, A.W., Work activities involving exposure to natural radiation sources. Update of a survey carried out in 1999 under contract with the Ministry of Social affairs and Employment, June 2001 (in Dutch with English abstract).

[10] Survey of work activities involving exposure to natural radiation sources, Ministry of Social Affairs and Employment, Working Document no. 121, May 1999 (in Dutch with English abstract).

Appendix RP107

Estimates of annual inhalation dose in NORM industries

Potential annual doses to workers *solely from inhalation* of NORM have been estimated using the methodology in the Radiation Protection 107 report (RP-107) [1], for various industries and processing steps.

The original aim of RP107 was to produce reference levels for workplaces processing materials containing NORM using generic exposure scenarios. The industries, processing steps and exposure scenarios considered are summarised in Table AppRP107.1. The corresponding values of the exposure parameters are presented in Table AppRP107.2. These values are "normal" parameter values based on the review of previous studies and on working practices presented in Appendix A of the RP-107 report.

The various activity concentrations (Bq/g) of nuclides and nuclide segments considered for each industry and processing step are presented in Table AppRP107.3. These are the average values derived rom the available literature during the preparation of the RP-107 report. In some cases, actual activity concentrations may be significantly different: examples of this occur in the case studies in Work Package 2, and are noted in the relevant tables. The values of inhalation dose coefficients for each nuclide/nuclide segment have been extracted/derived from the ICRP Publication 68 [2].

The exposure scenarios rely on a series of conservative assumptions. Consequently, estimated doses are pessimistic, and ignore the effect of any radiological protection measures that may be in place. For these reasons, the dose estimates should be regarded as upper bounds of the exposure from dust inhalation. Where the estimates exceed a dose reference level (for example 1 mSv per year), the intention is that a more specific assessment should be undertaken to determine the actual doses (i.e. which will almost certainly be lower).

The results, in terms of estimated annual doses to workers from inhalation of NORM, are presented in Table AppRP107.4. A summary of the exposure scenarios giving the highest estimated doses is given in Table AppRP107.5.

References

[1] J.S.S Penfold, S.F. Mobbs, J.P. Degrange, T. Schneider, Establishment of reference levels for regulatory control of workplaces where materials are processed which contain enhanced levels of naturally-occuring radionuclides, Radiation Protection 107 report, European Commission, 1999.

[2] ICRP Publication 68, Dose Coefficients for Intakes of Radionuclides by Workers: A Replacement of ICRP Publication 61. Annals of the ICRP 24 (4) 1994.

Table AppRP107.1: NORM industries, processing steps and work activities considered

Phosphate industry - Phosphate ore stockpile - Wet process (Phosphogypsum stockpile; removal of cloth filters) - Thermal process (Calcium silicate slag stockpile; Pb/Po precipitated dust removal, exposure to volatilised Pb/Po fumes) - General fertiliser stockpile
Processing of metal ores - Ferro-Niobium (Pyrochlore stockpile; removal/handling of wastes and slag; removal of Pb/Po precipitated dust; exposure to volatilised Pb/Po fumes) - Tin smelting (Tin smelting slag stockpile; removal of Pb/Po precipitated dust; exposure to volatilised Pb/Po fumes) - General metal smelting (removal of Pb/Po precipitated dust; exposure to volatilised Pb/Po fumes)
Processing of zircon sands - Zircon sands stockpile; grinding of refractory products
- Thermal processing (removal of Pb/Po precipitated dust; exposure to volatilised Pb/Po fumes)
Manufacture of rare earths - Monazite/bastnaesite sand stockpile; removal/cleaning of radium bearing residues; handling of cerium concentrates for glass
Manufacture and use of thorium compounds - W-Th welding electrodes (grinding; use)
Titanium dioxide pigment industry - Ilmenite stockpile; removal of radium bearing scales/sludges from pipes/vessels
Oil and gas extraction industry - Removal of radium and lead bearing scales from pipes; removal of radium bearing sludges from vessels
Fertilisers - Stockpiles of K, P superphosphates, NP, PK, NPK triple superphosphate fertilisers

Table AppRP107.2: Data used in RP107 dose estimate methodology

Industry, process and materials	Exposure scenario	Air conc. (mg/m^3)	Exposure Time (h/y)	AMAD (μm)	RPE Protection Factor
Phosphate Industry					
Phosphate ore	stockpile	1	2000	5	
Wet process: phosphogypsum	sockpile	1	2000	5	
Wet process: cloth filters	scales&residues	10	100	5	2
Thermal process: CaSiO3 slag	sockpile	1	2000	5	
Thermal: Pb/Po precipitate	scales&residues (dust)	10	100	1	2
Thermal: Volatilised Pb/Po	scales&residues (fumes)	1	100	1	
General fertiliser	sockpile	1	2000	5	
Ferro-niobium					
Pyrochlore feedstock	stockpile	1	2000	5	
Wastes and slag	sockpile	1	2000	5	
Pb/Po precipitate	scales&residues (dust)	10	100	1	2
Volatilised Pb/Po	scales&residues (fumes)	1	100	1	
Tin smelting					
Tin smelting slag	sockpile	1	2000	5	
Po precipitate	scales&residues (dust)	10	100	1	2
Volatilised Po	scales&residues (fumes)	1	100	1	
Zircon					
Zircon sands	*specific*	5	2000	5	
Refractory products	*specific*	1	100	5	
Pb/Po precipitate	scales&residues (dust)	10	100	1	2
Volatilised Pb/Po	scales&residues (fumes)	1	100	1	
Rare Earth extraction					
Monazite/bastnaesite sand	stockpile	1	2000	5	
Radium bearing residues	scales&residues (dust)	10	100	5	2
Cerium concentrate for glass	*specific*	1	100	5	
Thorium products					
W-Th welding electrodes (grinding)	*specific*	2.5	16	5	
W-Th welding electrodes (use)	*specific*	0.06	1200	1	
Titanium dioxide industry					
Ilmenite feedstock	stockpile	1	2000	5	
Radium bearing scales	scales&residues (dust)	10	100	5	2
Oil & Gas extraction					
Removal of radium scales	specific	1	600		
Radium sludge removal	*specific*	1	600		
General metal smelting					
Pb/Po precipitate	scales&residues (dust)	10	100		2
Volatilised Pb/Po	scales&residues (fumes)	1	100		
Fertilisers					
Fertilisers – all types considered	stockpile	1	2000		

Note: a 1.2 m^3/h inhalation rate has been used in each exposure scenario.

Table AppRP107.3: Activity concentrations of the materials considered

Industry and material	Activity concentration (Bq/g)								
	Th-232	Ra+228	Th+228	U+238	Th-230	Ra+226	Pb+210	U+235	K-40
Phosphate Industry									
Phosphate ore	2.0E-1	1.8E-1	1.4E-1	1.0E+0	1.0E+0	1.0E+0	9.7E-1	4.5E-2	
Wet process: phosphogypsum and cloth filters	2.0E-2	7.0E-2	2.0E-2	2.0E-1	2.0E-1	8.0E-1	2.0E-1	9.0E-3	
Thermal process: CaSiO3 slag – see note 1.	3.0E-1	2.7E-1	2.1E-1	3.0E+0	3.0E+0	2.0E+0	3.0E-1	1.4E-1	
Thermal: volatilised Pb/Po and precipitate							1.6E+2		
General fertiliser	3.0E-2	2.0E-2	1.0E-2	9.0E-1	8.0E-1	4.0E-1	5.0E-1	4.1E-2	1.0E+0
Ferro-niobium									
Pyrochlore feedstock, wastes and slag	4.4E+1	3.9E+1	3.1E+1	8.0E+0	8.0E+0	8.0E+0	7.8E+0	3.6E-1	
Volatilised Pb/Po and precipitate							3.0E+2		
Tin smelting									
Tin smelting slag	7.0E-1	6.2E-1	4.9E-1	1.0E+0	1.0E+0	1.0E+0	9.7E-1	4.5E-2	
Volatilised Pb/Po and precipitate							2.0E+2		
Zircon									
Zircon sands and products – see note 2	1.0E+0	8.9E-1	7.0E-1	8.0E+0	8.0E+0	8.0E+0	7.8E+0	3.6E-1	
Thermal: volatilised Pb/Po and precipitate							1.3E+2		
Rare Earth extraction									
Monazite/bastnaesite sand	4.0E+2	3.6E+2	2.8E+2	2.0E+1	2.0E+1	2.0E+1	1.9E+1	9.0E-1	
Radium bearing residues		1.6E+3				2.3E+2			
Cerium concentrate for glass	4.0E+0	3.6E+0	2.8E+0	2.0E-1	2.0E-1	2.0E-1	1.9E-1	9.0E-3	
Thorium products									
W-Th welding electrodes	8.0E+1		8.0E+1		6.0E+0				
Titanium dioxide industry									
Ilmenite feedstock	3.0E-1	2.7E-1	2.1E-1	1.0E+0	1.0E+0	1.0E+0	9.7E-1	4.5E-2	
Radium bearing scales – see note 3		1.5E+3	1.5E+3			4.0E+2			
Oil & Gas extraction									
Radium scales		1.4E+1	8.0E+0			1.1E+2			
General metal smelting									
Volatilised Pb/Po and precipitate							1.0E+2		
Fertilisers									
Fertilisers, K	9.0E-3	8.0E-3	6.3E-3	3.0E-2	2.0E-1	5.0E-3	2.0E-2	1.4E-3	1.0E+1
Fertilisers, superphosphate	3.0E-2	2.7E-2	2.1E-2	6.0E-1	7.0E-1	5.0E-1	3.0E-1	2.7E-2	1.0E-1
Fertilisers, NP	4.0E-2	3.6E-2	2.8E-2	2.0E+0	2.0E+0	2.0E-1	2.0E-1	9.0E-2	4.0E-2
Fertilisers, PK	9.0E-3	8.0E-3	6.3E-3	4.0E-1	4.0E-1	2.0E-1	4.0E-1	1.8E-2	5.0E+0
Fertilisers, NPK	1.0E-2	8.9E-3	7.0E-3	4.0E-1	4.0E-1	2.0E-1	4.0E-1	1.8E-2	4.0E+0
Fertilisers, Triple-super-P	4.0E-2			2.0E+0	2.0E+0	6.0E-1	9.0E-1	9.0E-2	4.0E-2

1. The $CaSiO_3$ slag values of specific activity considered here have been extracted from a Canadian study referenced in the RP107 report. More recent values for the only European plant are lower: 0.1 Bq/g for Th-232+ and about 1 Bq/g for U-238+ and 0.01 Bq/g for Pb-210/Po-210. More details are given in Work Package 2
2. Work package 2 contains a case study for a UK plant, in which activity concentrations are lower: 0.7 Bq/g for Th-232+ and about 3 Bq/g for U-238+.
3. These scales are not a significant issue in all types of plant. Further information is given in Work Package 2.

Table AppRP107.4: Estimated occupational doses in the absence of any radiation protection measures

Industry and material	Exposure by inhalation (Sv/yr)													
	Th-232	Ra+ 228	Th+ 228	U+ 238	U- 234	Th- 230	Ra+ 226	Pb+ 210	Po- 210	U+ 235	Pa- 231	Ac+ 227	K- 40	**Total**
Phosphate Industry														
Phosphate ore	1.4E-5	7.1E-7	1.1E-5	1.3E-5	1.6E-5	6.6E-5	2.8E-5	2.7E-6	5.2E-6	6.5E-7	9.5E-6	6.6E-5		2.3E-4
Wet process: phosphogypsum	1.4E-6	2.8E-7	1.5E-6	2.7E-6	3.2E-6	1.3E-5	2.3E-5	5.5E-7	1.0E-6	1.3E-7	1.9E-6	1.3E-5		6.2E-5
Wet process: cloth filters	3.4E-7	7.0E-8	3.8E-7	6.7E-7	8.0E-7	3.3E-6	5.7E-6	1.4E-7	2.6E-7	3.2E-8	4.7E-7	3.3E-6		1.5E-5
Thermal process: $CaSiO_3$ slag – see note 1.	2.1E-5	1.1E-6	1.6E-5	4.0E-5	4.8E-5	2.0E-4	5.7E-5	8.2E-7	1.0E-6	1.9E-6	2.8E-5	2.0E-4		6.1E-4
Thermal: Pb/Po precipitate								9.0E-5	2.8E-4					3.7E-4
Thermal: Volatilised Pb/Po								1.8E-5	5.6E-5					7.4E-5
General fertiliser	2.1E-6	8.0E-8	7.6E-7	1.2E-5	1.4E-5	5.3E-5	1.1E-5	1.4E-6	2.6E-6	5.8E-7	8.5E-6	6.0E-5	7.1E-9	1.7E-4
Ferro-niobium														
Pyrochlore feedstock	3.0E-3	1.6E-4	2.3E-3	1.1E-4	1.3E-4	5.3E-4	2.3E-4	2.1E-5	4.2E-5	5.2E-6	7.6E-5	5.3E-4		7.2E-3
Wastes and slag	3.0E-3	1.6E-4	2.3E-3	1.1E-4	1.3E-4	5.3E-4	2.3E-4	2.1E-5	4.2E-5	5.2E-6	7.6E-5	5.3E-4		7.2E-3
Pb/Po precipitate								1.7E-4	5.3E-4					7.0E-4
Volatililised Pb/Po								3.4E-5	1.1E-4					1.4E-4
Tin smelting														
Tin smelting slag	4.8E-5	2.5E-6	3.7E-5	1.3E-5	1.6E-5	6.6E-5	2.8E-5	2.7E-6	2.1E-6	6.5E-7	9.5E-6	6.6E-5		2.9E-4
Po precipitate								1.1E-4	3.5E-4					4.7E-4
Volatilised Po								2.3E-5	7.1E-5					9.4E-5
Zircon														
Zircon sands – see note 2	3.4E-4	1.8E-5	2.6E-4	5.4E-4	6.4E-4	2.6E-3	1.1E-3	1.1E-4	2.1E-4	2.6E-5	3.8E-4	2.6E-3		8.9E-3
Refractory products	3.4E-6	1.8E-7	2.6E-6	5.4E-6	6.4E-6	2.6E-5	1.1E-5	1.1E-6	2.1E-6	2.6E-7	3.8E-6	2.6E-5		8.9E-5
Pb/Po precipitate								7.2E-5	2.2E-4					3.0E-4
Volatilised Pb/Po								1.4E-5	4.5E-5					5.9E-5
Rare Earth extraction														
Monazite/bastnaesite sand	2.7E-2	1.4E-3	2.1E-2	2.7E-4	3.2E-4	1.3E-3	5.7E-4	5.3E-5	1.0E-4	1.3E-5	1.9E-4	1.3E-3		5.4E-2
Radium bearing residues		1.6E-3					1.6E-3							3.2E-3
Cerium concentrate for glass	1.4E-5	7.1E-7	1.1E-5	1.3E-7	1.6E-7	6.6E-7	2.8E-7	2.7E-8	5.2E-8	6.5E-9	9.5E-8	6.6E-7		2.7E-5
Thorium products														
W-Th welding electrodes (grinding)	1.1E-4		1.2E-4			7.9E-6								2.4E-4
W-Th welding electrodes (use)	2.9E-4		2.7E-4			2.0E-5								5.7E-4
Titanium dioxide industry														
Ilmenite feedstock	2.1E-5	1.1E-6	1.6E-5	1.3E-5	1.6E-5	6.6E-5	2.8E-5	2.7E-6	5.2E-6	6.5E-7	9.5E-6	6.6E-5		2.5E-4
Radium bearing scales – see note 3		1.5E-3	2.8E-2				2.8E-3							3.3E-2
Oil & Gas extraction														
Removal of radium scales		1.7E-6	1.8E-5				9.3E-5							1.1E-4
Radium sludge removal		1.7E-6	1.8E-5				9.3E-5							1.1E-4
General metal smelting														
Pb/Po precipitate								5.7E-5	1.8E-4					2.3E-4
Volatilised Pb/Po								1.1E-5	3.5E-5					4.7E-5
Fertilisers														
Fertilisers, K	6.2E-7	3.2E-8	4.8E-7	4.0E-7	4.8E-7	1.3E-5	1.4E-7	5.5E-8	1.0E-7	1.9E-8	2.8E-7	2.0E-6	7.1E-8	1.8E-5
Fertilisers, P superphosphate	2.1E-6	1.1E-7	1.6E-6	8.1E-6	9.6E-6	4.6E-5	1.4E-5	8.2E-7	1.6E-6	3.9E-7	5.7E-6	4.0E-5	7E-10	1.3E-4
Fertilisers, NP	2.7E-6	1.4E-7	2.1E-6	2.7E-5	3.2E-5	1.3E-4	5.7E-6	5.5E-7	1.0E-6	1.3E-6	1.9E-5	1.3E-4	3E-10	3.6E-4
Fertilisers, PK	6.2E-7	3.2E-8	4.8E-7	5.4E-6	6.4E-6	2.6E-5	5.7E-6	1.1E-6	2.1E-6	2.6E-7	3.8E-6	2.6E-5	3.5E-8	7.9E-5
Fertilisers, NPK	6.8E-7	3.6E-8	5.3E-7	5.4E-6	6.4E-6	2.6E-5	5.7E-6	1.1E-6	2.1E-6	2.6E-7	3.8E-6	2.6E-5	2.8E-8	7.9E-5
Fertilisers, Triple-super-P	2.7E-6			2.7E-5	3.2E-5	1.3E-4	1.7E-5	2.5E-6	4.7E-6	1.3E-6	1.9E-5	1.3E-4	3E-10	3.7E-4

1. The individual doses corresponding to the European plant (see Work Package 2) are lower (total dose of the order of 0.2 mSv/y).
2. The individual doses corresponding to the UK plant considered in Work Package 2 are lower (total dose of the order of 3.6 mSv/y)
3. These scales are not a significant issue in all types of plant. Further information is given in Work Package 2.

Table AppRP107.5. Summary of NORM industries and processes with the highest estimated doses from inhalation, in the absence of any radiation protection measures

NORM industry and process	Estimated dose and exposure scenario	Comments
Rare earth extraction Exposure from work with monazite stockpiles	**50 mSv/y** Based on 2000 h/y, 1 mg/m^3, 5 µm AMAD, no RPE	Based on monazite concentrates (400 Bq/g Th+232). Monazite sand much lower (10 Bq/g); bastnaesite sand even lower.
Titanium dioxide Exposure from removal of Ra scales	**30 mSv/y –** see note 1 Based on 100 h/y, 10 mg/m^3, 5 µm AMAD, RPE PF = 2	Assumes 1500 Bq/g Ra+228, and 400 Bq/g Ra+226.
Zircon sand Exposure from work with sand stockpiles	**9 mSv/y** – see note 2 Based on 2000 h/y, 5 mg/m^3, 5 µm AMAD, no RPE	Assumes 8 Bq/g U+238 and 1 Bq/g Th+232.
Ferro-niobium Exposure to pyrochlore feedstock. Exposure to wastes/slags	**7 mSv/y** Based on 2000 h/y, 1 mg/m^3, 5 µm AMAD, no RPE	Assumes 44 Bq/g for Th+232 and 8 Bq/g for U+238.
Rare earth extraction Exposure from removal of Ra scales	**3 mSv/y** Based on 100 h/y, 10 mg/m^3, 5 µm AMAD, RPE PF = 2	Assumes 1600 Bq/g and 230 Bq/g for Ra+228 and Ra+226
All thermal processing of NORM Removal of dust from emission control systems	**0.2 –0.7 mSv/y** Based on 100 h/y, 10 mg/m^3, 5 µm AMAD, RPE PF = 2	Based on Pb+210 in range 100 – 300 Bq/g.
TIG welding Inhalation of welding fumes	**0.6 mSv/y** Based on 1200 h/y, 0.06 mg/m^3, 1 µm AMAD, no RPE	Assumes 2% Th welding rods (80 Bq/g Th-232 and Th-228). Available range is 1-4% Th.

1. The individual doses corresponding to the UK plant considered in Work Package 2 are typically 2-3 times lower (even in the absence of protection measures).
2. These scales are not a significant issue in all types of plant. Further information is given in Work Package 2.

Appendix Title VII/TENORMHARM

Information obtained from the Title VII and TENORMHARM projects

The information currently available from the Title VII and TENORMHARM projects that is of some relevance to SMOPIE Work Package 1 is shown in Table AppTVII/TENORM.1.

Several of the TENORMHARM national reports contain information on accumulated residues from past industrial activities involving NORM. They may presently not be relevant in relation to exposure to workers but may become so when remedial action is taken involving relocation of these residues or handling otherwise.

Some occurrences of considerably enhanced levels of NORM nuclides identified in the national studies have not been included in Table A1.6 but may nevertheless be of interest because of the potential occupational exposures. For example, there are reports of high radium concentrations in sludges from the purification of ground water, and from the treatment of waste-water from coal mining.

Table AppTVII/TENORM.1 Summary of potentially significant NORM industries from the EU Title VII study and the TENORM project

Industry or work activity	Potentially significant liquid discharges	Potentially significant aerial discharge	Potentially significant solid residues	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK	Romania	Hungary	Poland	Czech Rep.	Slovenia
Onshore oil / gas	Yes, discharge no (re-injection)	No	Yes, sludges, scales		Y	Y			Y		Y		Y	Y				Y	Y	Y	Y	Y	Y
Offshore oil / gas	Yes, produced water, scale	No	Yes, sludges, scales		Y	Y	Y	Y		Y	Y		Y					Y					
Phosphoric acid	Yes, if phosphogypsum is discharged	No	Yes, if phosphogypsum is stockpiled	Y			Y	Y	Y										Y		Y		
Phosphate fertiliser *)	Yes / no, depending on process	No	Yes / no, depending on process	Y	Y	Y	Y	Y	Y		Y		Y		Y	Y	Y		Y		Y	Y	
Thermal phosphorus	Yes, ^{210}Po, ^{210}Pb	Yes, ^{210}Po, ^{210}Pb	Yes, calcined dust and slag										Y										
TiO_2 pigment	Yes no depending on process	No	Yes, solids from liquid waste treatment			Y		Y	Y		Y		Y			Y		Y			Y	Y	
Steel	Yes / no depending on waste water treatment	Yes, ^{210}Po, ^{210}Pb	Yes, blast furnace and sinter dust	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Cement	No	Yes, ^{210}Po, ^{210}Pb	No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y
Coal fuelled power plants	No	No	Bottom and fly ash	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Bricks and roofing tiles	No	Yes, ^{210}Po	No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Tin smelters (closed down)	No	Yes, ^{210}Po, ^{210}Pb	Slag, slag wool, historical																				
Metal extraction from tin slag	No	Yes, ^{210}Po, ^{210}Pb	Yes, slag			Y																	
Lead / Zinc smelter	No	Yes, ^{210}Po, ^{210}Pb	Yes, cobalt-cake	Y		Y	Y	Y	Y		Y		Y		Y	Y	Y	Y	Y		Y		
Copper smelter	No	Yes, ^{210}Po, ^{210}Pb	NK	Y		Y		Y	Y							Y	Y		Y		Y		

*) Include production with phosphoric acid produced elsewhere

Appendix Germany

Data from a 1997 German study in response to Title VII of 96/29/EURATOM

Information on the range of NORM work activities, categorised according to annual dose ranges, is reproduced in Table AppGerm.1 [1]. Note that, apart from a few exceptions, only work activities involving NORM with activity concentrations above 1 Bq/g were considered. The report also acknowledges that more information needs to be collected.

Table AppGerm.1. Summary of work activities in Germany with enhanced exposure to natural radiation sources under normal conditions.

Type of industry	Type of work activity or material	Dose category (mSv/y)[1]
Optical industry	Polishing powder Thorium in glass	< 1 n.a
Dental branch	Production of dental prostheses	< 1
Phosphate industry	Fertiliser production Fertiliser trade Fertiliser use Phosphoric acid production Application of phosphogypsum	n.a 1 – 6 1 – 6 n.a. n.a.
Sulphuric acid production (pyrite)	Pyrite roasting Processing of slag	< 1 < 1
Use of coal /powder coal residues	Power generation Use in chemical industry Cokes production and use (e.g.. steel production.) Building materials	< 1 < 1 < 1 < 1 ≈1
Grit blasting (slags)	Grit blasting	< 1
W-Th welding electrodes	Production of electrodes Transport and storage of electrodes Use of electrodes	1 – 6 1 – 6 6 – 20
Th in gas mantles	Production of gas mantles Transport and storage of gas mantles Replacing gas mantles	6 1 – 6 < 1
Minerals	Zircon sand (foundries) Monazite (home) Pyrochlore ore (Ce, Nb) Wolfram, titanium oxide	1 – 6 < 1 1 – 6 < 1
Natural stone	Production and application	< 1
Oil and gas production	Scale deposits in vessels and tubulars	< 1
Mining	Scale deposits in water pipes /pumps	< 1
Scrap recycling	Tubulars with scale Use of slags in road construction Disposal of filter dust	≈1 ≈1 < 1
Copper production	Use of copper slag	1 – 6
Aluminium production	“Rotschlamm”	< 1

[1]Dose refers to total annual effective and committed effective dose, excluding radon.
n.a. means that the work activity is not currently undertaken in Germany.

References

[1] SSK, Radiation exposure at working places by natural radionuclides. Statements of the Commission on Radiological Protection. Berichte der Strahlenschutzkommission (SSK) des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit, Heft 10 (1997).

Appendix TIG

TIG welding – Review of data and estimation of number of exposed workers

Recent Dutch reports

Recently a Dutch report [1] has been published on "Radioactivity in consumer goods". This includes a consideration of TIG welding with thoriated welding rods. The following information is taken from that report.

- Between 45 and 80% of TIG welding rods currently contain thorium; lanthanum doped rods will probably become the future standard.
- The percentage (by weight) of thorium oxide in welding rods was initially between 1 and 2%, but welding rods with 2 – 4% have also been produced.
- EN 26848:1991 specifies the codes and colour codes for tungsten electrodes from WT-4 blue (0.35 – 0.55 % ThO_2) to WT-40 orange (3.8 – 4.2 % ThO_2). In the Netherlands, WT20 with 1.70 – 2.20 % ThO_2 are the most common, although no information on the numbers sold is available.
- The annual sales of thoriated electrodes in recent years amounts to 4 – 5 million in the US, over 2 million in France, and 4.6 – 6.2 million in Germany. On this basis, the number of tungsten electrodes used annually ranges from 0.02 to 0.07/y per head of population. Applying this ratio to the Netherlands suggests that 0.3 to 1 million electrodes are used each year.

The RIVM report assumes there are 20,000 TIG welders in the Netherlands, each using an average of 10 electrodes per year. However, it is not known how many full time TIG welders this represents in practice. A recent report on the labour market for welders provides the following information [2]:

- the total number of professional welders is 75,000; and
- about 40% of the companies use TIG welding.

From this, the number of Dutch TIG welders can be estimated at about 30,000 in a population of 16 million (about 2000 TIG welders per million inhabitants). This figure is almost certainly an overestimate because companies using TIG welding do not necessarily employ all workers for this type of welding.

The estimated radiation doses to TIG welders vary considerably and depend strongly on the contribution from grinding of the electrodes. Another significant (mostly unknown) factor is whether protective measures against dust inhalation are taken. The following ranges are cited in the RIVM report from different studies:

- 170 µSv/y average (USA, 1987 [3]).
- 160 µSv/y average (Netherlands, 1992 [4]).
- 4 – 2900 µSv/y (USA, 1999 [5]).
- 2 – 3800 µSv/y (Germany, 1999 [6]).
- 2 – 20 000 µSv/y (Germany, 2000 [7]).

Derived number of exposed workers

From the Dutch number of about 2000 TIG welders per million inhabitants, the estimated number of TIG welders in all EU countries can be derived. It should be noted that this derivation is based on the unproven assumption that the Dutch data can be extrapolated across all welding companies in all Member States.

From the information presented earlier, it is clear that exposures to thorium by inhalation can be significant. However, the information does not allow an assessment of the actual dose distribution in the potentially very large population of TIG welders. The German study described in section 4.5, estimates that 50, 000 TIG welders may receive doses in excess of 1 mSv/y [8]. This is about one-third of the total number of TIG welders (170,000) derived from the Dutch report data. This difference may be due to the progressive replacement of thoriated electrodes by lanthanium doped electrodes, and the use of dust control measures during grinding.

For the purposes of SMOPIE Work Package 1, it is considered reasonable to assume that 10% of TIG welders may receive significant doses, e.g. above 1 mSv/y. The results of this assumption are shown in Table AppTIG.1. For Germany, therefore, the derived number of exposed workers is estimated to be 17,000 welders, about a factor of three lower than the estimate in reference 8.

Table AppTIG.1 Estimated number of TIG welders in the European Union, number of and potentially exposed welders

Country	**Inhabitants millions**	**Number of potentially exposed TIG welders[1] (thousands)**
Austria	8,2	1600
Belgium	10,3	2000
Denmark	5,4	1000
Finland	5,2	1000
France	59,6	12000
Germany	83	17000
Greece	10,6	2000
Ireland	3,8	800
Italy	57,7	11000
Luxembourg	0,4	100
Netherlands	16	3000
Portugal	10	2000
Spain	40	8000
Sweden	8,9	2000
United Kingdom	59,6	12000
Total (rounded)	**378,7**	**70 000**

[1]Based on 2000 TIG welders per million inhabitants, 10% of which can receive doses from inhalation that potentially exceed 1 mSv/y.

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Appendix France

Summary of data from the French NORM industry

Introduction

The following paragraphs present a summary of the available data (production, total number of workers, and annual doses from inhalation) for the main French NORM industries.

Number of workers

The number of workers employed in the main NORM processing companies in France is presented in Table AppFr.1. It should be noted that these are the total number of employees, not the number of exposed employees.

Table AppFr.1 : Number of workers employed in the main French NORM industries

Type of industry	Number of factories	Number of workers	*Main firms*
TiO_2 pigment [8]	3	1000	Millennium and Huntsman Tioxide
Phosphoric acid and phosphate fertilisers [8]	51	6 600	Grand Paroisse, Kemira. Number of workers includes all fertilisers
Refractory ceramics [9, 10]	-	4 242	Sté Européenne des Produits Réfractaires (SEPR)
Steel industry [9]	39	36 447	Ascométal, Imphy Ugine Précision, Ispat Unimétal, Saint Gobain PAM, Sidéco, Sollac, Ugine SA, Ugine Savoie Imphy, V et M France
Cast iron foundry [10]	-	12 599	
Steel foundry [10]	-	7 123	
Non ferrous metals [9]			Aluminium Dunkerque, Aluminium Péchiney, Coulée Continue de Cuivre, Engelhard-Clal, Lensoise de Cuivre, Métaleurop Nord, Péchiney Rhénalu, Softal, Tréfilmétaux, Union Minière France
Aluminium	51	11 021	
Lead, zinc, tin	15	2 209	
Copper	48	5 556	
Other non ferrous metals	28	3 079	

Exposures due to inhalation of NORM

Some data on NORM exposures have been collected by a French expert group on enhanced natural exposure [1] and provided to the inter-ministerial committee on the implementation of the 96/219 EURATOM Directive [2]. These data are presented in Table AppFr.2. This shows that data was available for only three types of industrial activities, i.e.:

- Zirconium industry: the most exposed workers are estimated to receive internal exposures in the range 1 - 7 mSv/year. This is based on air sampling results and an assumed annual exposure time of 1700 to 2000 hours per year.
- Rare earth industry: the average internal exposure of 127 monitored workers in the RHODIA rare earth extraction plant in 1997 was 1.5 mSv. In some cases, individual doses could exceed 20 mSv/year.
- Use of coal powder/residues: the exposure of a worker spending 200 h/year on a fly ash dump has been estimated as 0.15 mSv/year.

Table AppFr2: Data on exposures from NORM inhalation collected by a French expert group

Type of industry	Type of material	Type of Work activity	Workers Internal dose		Number of workers exposed
			Estimated	Measured	
Optical industry	Use of abrasive powders with high U and Th content. Use of glass compounds with high Th and U content (up to 10% in mass)[3]	Glass polishing and cutting	Can exceed 1 mSv/y [3]		
Metal smelting	Tin ore (U, Th content up to 1 Bq/g), bismuth ore (Bi-210, Pb-210, 100 Bq/g), rutile, bauxite (U, Th, 1 Bq/g), colombite (Th content up to 50 Bq/g)[3]		Can exceed 1 mSv/y [3]		
Colouring pigment	Ilmenite, rutile, for TiO2 production, with U and Th content up to 1 Bq/g [3]		Can exceed 1 mSv/y [3]		
Zirconium industry	Ores with U content up to 5 Bq/g and Th content up to 1 Bq/g [3]		Can exceed 1 mSv/y [3]		
			From 1 to 7 mSv/y for the most exposed workers [4, 5]		
Rare earth industry	Ores (monazites,…) with U content of 10 Bq/g and Th content up to 1 000 Bq/g [3]			Can exceed 20 mSv/y Average value 1.5 mSv/y [6]	127 monitored workers
Use of coal powder/ residues	U content of 0.2 Bq/g, Th content up to 10 Bq/g [3]	Fly ash dump	0.15 mSv/y [7]		

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