

ASSESSMENT OF IONIZING RADIATION
EXPOSURES IN INDUSTRIES AND PROFESSIONAL
ACTIVITIES IMPLEMENTING RAW MATERIALS
CONTAINING NATURALLY-OCCURRING
RADIONUCLIDES NOT USED BECAUSE OF THEIR
RADIOACTIVE PROPERTIES.

Review on enforcement of Order of 25 May
2005 on these activities.

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Abstract

Some industrial processes concentrate natural radionuclides contained in the raw materials, co-products or in production wastes. This phenomenon is called “enhanced natural radioactivity” or “technologically enhanced natural radioactivity”.

In 1996, the basic safety standards Euratom 96/29 directive regulated the issue of enhanced natural radioactivity on a European level. Transposed in French regulations in the Public Health Code and the Labour Code, this “new” issue, from a regulation point of view, was subject to an interministerial Order published on 1st June 2005¹. It defined, in particular, in annexe 1 the list of categories of professional activities concerned, i.e.:

- Coal combustion in thermal power stations;
- Treatment of tin, aluminium, copper, titanium, niobium, bismuth and thorium ores;
- Production of refractory ceramics and glassmakings, foundry, steel industry and metallurgy activities using refractory ceramics;
- Production or use of compounds containing thorium;
- Production of zircon and baddeleyite, and foundry and metallurgy activities using zircon and baddeleyite;
- Production of phosphate fertilizer and manufacturing of phosphoric acid;
- Treatment of titanium dioxide;
- Treatment of rare earth and production of pigments containing rare earth;
- Treatment of underground water by filtration for the production of:
 - water for human consumption;
 - mineral waters;
- Spas.

These categories of professional activities are liable to concentrate the naturally occurring radioactivity of raw materials in the facilities, co-products and wastes linked to production, or equipments from the facilities. As such, the Order requires from industrial parties concerned to carry out an assessment of the doses received by workers and an estimation of the doses received by the population which is caused by the installations where these ones are subject to permit according to the Environmental Code, either by the ICPE (Installation Classified for the Protection of the Environment) or by Laws on water.

The obligation for these industrial parties to carry out these dose assessments now allows the ASN to draw up a first report on the exposure of workers and the population to enhanced natural radioactivity, following reception of more than 80 dossiers.

The identification of the industrial parties concerned was undertaken based on information supplied by the ICPE nomenclature coupled with software of management of database on classified installations (GIDIC), and thanks to the study held by the Robin des Bois Association, at the request of the ASN, on enhanced natural radioactivity in France². However, the identification of the industrial parties concerned remains only partial so far, mainly due to the lack of appropriateness between the professional activity categories endorsed by the Order and the GIDIC database. In September 2009, more than 80 studies were received by the ASN and

¹ Order of 25th May 2005 concerning Professional Activities Involving Raw Materials Containing Naturally-Occurring Radionuclides for Purposes Other Than Their Radioactive Properties

² Technologically enhanced natural radioactivity, Robin des Bois Association, December 2005, ref. [8]

the IRSN. It is notable that, for spas¹, no data was submitted in enforcement of the Order of 25th May 2005, and that only one study was carried out for the treatment of underground water by filtration. An estimation of the representativeness of the studies received is put forward in this report, by professional activity category.

The assessments carried out by the IRSN² show that the vast majority of the studies received look at the exposure of workers: in 96% of the dossiers endorsed by the Order, the situation of the workers is taken into account and 90% of the dossiers include a dose evaluation. The exposure of the public is handled more succinctly: In 71% of the dossiers endorsed by the Order, the public situation is taken into account, but only 23% evaluate the doses received by the population as a result of exposure to the installation.

With regard to worker exposure, 16% of the estimated doses are greater than 1 mSv / per year. These relate to:

- ore processing industries;
- production of refractory ceramics and glassmakings, foundry, steel industry and metallurgy activities using refractory ceramics;
- production or use of compounds containing thorium;
- production of zircon and baddeleyite, and steel industry and metallurgy activities using zircon and baddeleyite.

The data available relating to the exposure of the population was compared to the data available in the literature for each professional activity category. This comparison revealed no major difference. However, there was not a large amount of data available.

The assessment presented in this report therefore allows us to draft a statement on the exposure of workers and the population to enhanced natural radioactivity for the first 8 professional activity categories. Proposals are made relating to the monitoring of these industries and, for some of them, the drafting of an inspection programme will enable the radioprotection of the workers and the population to be controlled. For the industries where the workers' level of exposure is lower, yet still liable to exceed 1 mSv / per year if no exposure reduction measure is put in place, a follow-up must be carried out in order to develop its optimisation.

With regard to the management of wastes from enhanced natural radioactivity, the ASN has drafted the report of solutions for the management of wastes from enhanced natural radioactivity, demanded by law no. 2006-739 of 28 June 2006 on the programme on sustainable management of radioactive materials and wastes by drawing on the studies outlined in this report. The ASN has also drafted recommendations recommending, in particular, a re-enforcement of the recording and traceability of enhanced natural radioactivity wastes in order to improve the handling of the management of these wastes.

Development paths on the existing national regulation, as a result of conclusions drawn for each professional activity category, are put forward, in particular a new list of professional activity categories endorsed by the regulation, summary of those which already exist and those categories which may be added.

¹ Also subject to requirements of Order of 22nd July 2004 on risk management modalities linked to radons in public places.

² Data presented by the IRSN at the workers group meeting on 4th September 2009. The June 2009 data is given in the IRSN/DRPH/SER report no. 2009-11 cited in the references [2].

Lastly, as part of the review of the Euratom 96/29 directive, the consequences of the application of this new directive in France, in particular the introduction of an exemption threshold of 1Bq / g and the definition of these industries as practices (in the sense of the first article of the Euratom 96/29 directive) are studied in this report.

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1 Introduction

The industrial transformation of raw materials naturally rich in radionuclides (i.e. those with concentrated natural radioactivity) may generate residues or co-products from manufacturing whose specific activity may be higher than that of the original material. We, therefore, talk about materials having a technologically enhanced natural radioactivity. Handling these materials may lead to an increase in exposition to natural source ionizing radiation in relation to that caused by radioactivity from the environment. The effective dose received by workers in addition to the exposure to the natural radioactivity of the environment will hereafter be referred to as the “added effective dose”. On an international level, the industries concerned are, for example, production of gas and petrol, coal or uranium mines, treatment of bauxite ores...

Exposure is caused by the following uranium ^{238}U chains: ^{238}U uranium, ^{232}Th , as well as ^{40}K potassium. The materials liable to lead to significant doses are commonly known as NORMs (naturally-occurring radioactive materials) or TENORMs (technologically enhanced naturally-occurring radioactive materials).

The specific activities of the raw materials, soils, ores and other materials are very variable. For comparative purposes, see the data below [2]:

	^{238}U	^{232}Th	^{40}K
Earth's crust	0.04	0.04	0.4
Soil	0.035	0.035	0.37
Granite	0.052	0.048	1.1
Limestone	0.015	0.005	0.09
Phosphogypsum	0.2	0.017	0.06
Phosphate	11.3	0.03	0.2
Zircon	4	0.5	0.02
Monazite	10	600	0.01

Table 1: Examples of ^{238}U , ^{232}Th et ^{40}K (Bq/g of dry material) activities of certain materials or sub-products [1]

These specific activities are for comparison with those presented in the dossiers received by the ASN in application of the Order of 25th May 2005 and listed by the IRSN [2].

2 Presentation of national regulation

Published in 1996, the Euratom 96/29 directive¹ regulates the issue of enhanced natural radioactivity by asking the Member States to draft a list of activities affected, and to impose measures allowing the exposure of workers to be reduced or monitored ([6]). This directive was transposed to France by articles L.1333-10 and R.1333-13 of the Public Health Code as well as by articles R.4457-1 to 5, R.4457-13 and R.4457-14 of the Labour Code. The “NORM” industries are defined as those industries using materials containing natural radionuclides not used for their radioactive properties, fissile or fertile. If this is not the case, the industries concerned, considered as nuclear activities, are subject to the declaration and authorisation system cited in the Public Health Code (article L.1333-4).

¹ Euratom 96/29/ directive setting the basic standards on health public and employee health protection against dangers caused by ionizing radiation

The Order of 25th May 2005 concerning industrial activities involving raw materials containing naturally-occurring radionuclides for purposes other than their radioactive properties, taken in application of these articles, targets the following ten professional activity categories in annexe one of the Order:

1. Coal combustion in thermal power stations;
2. Treatment of tin, aluminium, copper, titanium, niobium, bismuth and thorium ores;
3. Production of refractory ceramics and glassmakings, foundry, steel industry and metallurgy using refractory ceramics;
4. Production or use of compounds containing thorium;
5. Production of zircon and baddeleyite, and foundry and metallurgy activities using zircon and baddeleyite;
6. Production of phosphate fertilizer and manufacturing of phosphoric acid;
7. Treatment of titanium dioxide;
8. Treatment of rare earth and production of pigments containing rare earth;
9. Treatment of underground water by filtration for the production of:
 - water for human consumption;
 - mineral waters;
10. Spas.

These professional activity categories are part of the list that is generally accepted at an international level ([6], [3]).

Although cited in the literature, the oil and natural gas extraction industries are not included in the list above for legal reasons; in fact, these industries are governed by the “Règlement Général des Industries Extractives” (RGIE) taken by Order in application of the Mining Code and cannot, therefore, be endorsed by an Order taken in application of the Public Health Code and Labour Code.

For the activities endorsed in the Order of 25th May 2005, assessment studies of the doses received by the public and workers must be carried out, as required by the Public Health Code and the Labour Code, respectively (see Annexe 1 and Annexe 2). These studies enable the evaluation of doses received by workers and the public due to exposure to ⁴⁰K and ²³⁸U, ²³⁵U and ²³²Th lines, in addition to those due to naturally occurring radioactivity in the environment. The Order defines the implementation modalities for these studies. It also cites the possibility for the operator or the head of the establishment to refer to a study carried out for a similar installation, provided that the relevance of the results for its installation is outlined.

In order to identify the industrial sites affected by the Order of 25th May 2005, the MEDD bill of 11th July 2005¹ proposes comparisons between the professional activity categories 1 to 8 of the Order and the sections defined in the nomenclature of installations classified for the protection of the environment, for which a database is available. Nevertheless, the ICPE sections identified are less restrictive than the professional activity categories defined in the Order.

The studies required by the Order of 25th May 2005 under article R.1333-13 of the Public Health Code are aimed solely at the installations subject to authorisation under the Environment Code, either under the ICPE (Installation Classified for the Protection of the Environment) system or under the law on water. These studies must allow assessing the impact on the population living next to the installation or on the members of the public who use or consume products made using materials produced by the installation.

¹ MEDD bill of 11th July 2005 on industrial activities using raw materials naturally containing radionuclides – Implementation of the requirements of the Order of 25th May 2005

With regard to the application of the Labour Code, the studies must contain an evaluation of the dose received by workers in these industries. If this dose exceeds 1 mSv per year, measures have to be taken in order to reduce the exposure. If these measures do not reduce the exposure level below 1 mSv per year, the employer must comply with articles R.4451-1 to R.4456-28 of the Labour Code, in accordance with article R.4457-13 of the same code. The studies are required for all industries belonging to the professional activity categories concerned.

These companies were subject to information and a specific request jointly carried out by ASN and DRIRE, following the publication of the Order of 25th May 2005. The companies were identified based on information supplied by the ICPE nomenclature and by the study carried out by the Robin des Bois Association, at ASN's [8] request. The information and control action allowed reaching some of the industrial parties concerned.

With regard to the management of enhanced naturally occurring radioactivity wastes, the MEDD bill of 25th July 2006¹ proposes that these wastes are removed at a wastes storage centre subject to an acceptability study being carried out at the responsibility of the operator of the centre. This acceptability study essentially aims at analysing the radiological impact on the public of taking in these wastes at a wastes centre. A guide aimed at specifying the methodology for the evaluation of the radiological impact was published by the IRSN in 2006 [1]. Furthermore, the ASN drafted the report for solutions for the management of enhanced naturally occurring radioactivity wastes, required by law no. 2006-739 of 28th June 2006 of the programme on the sustainable management of radioactive materials and wastes (see [7] and §3.5).

3 REVIEW OF THE APPLICATION OF NATIONAL REGULATION

This report strives to draft a review of the exposure of workers and the population to enhanced naturally occurring radioactivity using information contained in the bibliography, dossier guidelines (see Annexe 6) and advices of the IRSN (cited in references [2], [9], [16] and [18]). The advice cited in reference [2] enabled the drafting of the paragraphs on the exposure of the population and the quality of the studies received by professional activity category. The representativeness of the studies received is assessed globally, then for each professional activity category, based on information provided by the MEEDM² (Ministry for ecology, energy, sustainable development and the sea) and the database from the site Internet Kompas³.

The detailed report of the analysis of the studies received in application of the Order of 25th May 2005 is presented by professional activity category in Annexe 3.

A summary is given below.

3.1 Source of studies

The publication of the MEDD bill of 11th July 2005 enabled correlations to be made between the existing ICPE sections and the first 8 professional activity categories defined in annexe 1 of the Order of 25th May 2005, for which there exists no ad hoc database. The correlation between these two nomenclatures is, however, limited as the ICPE sections are less restrictive. In fact, if we take

¹ MEDD bill of 25th July 2006 concerning classified installations – Acceptance of enhanced or concentrated naturally occurring radioactivity waste in waste facilities

² Database GIDIC of DRIRE, and public database on installations classified for environmental protection: <http://installationsclassees.ecologie.gouv.fr>

³ www.kompass.fr

the example of coal combustion in thermal power stations (category no. 1 of the Order), the corresponding ICPE section is “combustion”.

In 2006, the ASN decided to focus the control action on companies subject to authorisation under the Environment Code, in order to target the companies obliged to carry out an evaluation study of the doses received by workers and the population, potentially taking in larger quantities of NORM materials. The ASN, therefore, approached the DRIREs in order to obtain a list of companies affected with the aid of database management software for data on classified installations (GIDIC), based on the aforementioned bill. A standard mail was then sent to the identified industrial parties in order to find out if they were concerned or not by the Order of 25th May 2005. The knowledge of the industrial parties concerned is not, however, exhaustive. In fact, not all regions have been covered by this identification process (Ile de France, Normandy, Picardy, Franche-Comté, Auvergne, Rhône-Alpes, Languedoc-Roussillon, PACA (ie, Provence-Alpes-Côte d’Azur region) and Corse are not covered), and not all the industrial parties contacted have responded.

As a follow up to this information action, the majority of dossiers formulated in application of the Order were received in 2007, in particular due to the obligation to carry out a study on the impact on the public before the 1st June 2007 (two years after the publication of the Order).

3.2 Synthesis of results of specific activity measurements

The summary of specific activities of NORM materials presented in the IRSN report cited in the reference [2] enables the comparison of specific activities by product type (wastes, raw materials...) for each professional activity category. This is detailed in Annexe 4, where the diagrams showing the distribution of specific activities by professional activity category and by type of material (raw material, products, wastes) are shown.

The materials for which the specific activity of a radionuclide (except ⁴⁰K) may exceed the exemption threshold of 1 000 Bq/kg recommended by the AIEA [4]¹ are:

- flying ashes or fireplace ashes (wastes) produced during the combustion of coal;
- wastes produced during water filtration (for example resins);
- phosphates and fertilizers produced using the latter;
- refractories (for example refractory blocks or moulds) and the wastes generated by their manufacture or use;
- products containing tin;
- products and wastes generated when using thorium;
- wastes generated during the treatment of titanium ores (for example tartars);
- finished products containing rare earth (for example rare earth alloys);
- wastes generated during the manufacture of glass (for example dust in the furnace chamber);
- zircon, finished products made from zircon (for example abrasives) and the wastes generated.

¹ The AIEA defines the notions of exemption, release and exclusion in the RS-G-1.7 document from 2004 [4], for NORM industries and introduces a set of values under which the following do not need to be regulated:

- ⁴⁰K : 10Bq/g
- Any other radionuclide of a natural origin: 1Bq/g

Among these products the following products are also affected by specific activities that often far exceed the exemption threshold recommended by the AIEA:

- phosphates,
- refractories and wastes generated during their manufacture or use,
- products containing tin,
- finished products and wastes generated by the use of thorium,
- zircon, finished products and associated wastes,
- wastes generated during water filtration,
- wastes generated during the treatment of titanium ores,
- finished products containing rare earth.

3.3 Synthesis of studies on the dosimetry of workers

The IRSN report cited in reference [2] provides information for the summary below of the dose evaluations presented in the studies by professional activity category.

3.3.1. Combustion of coal in thermal power stations

Figure 1 below shows, for each of the studies received on the abscissa, the effective added doses for the workers placed in order.

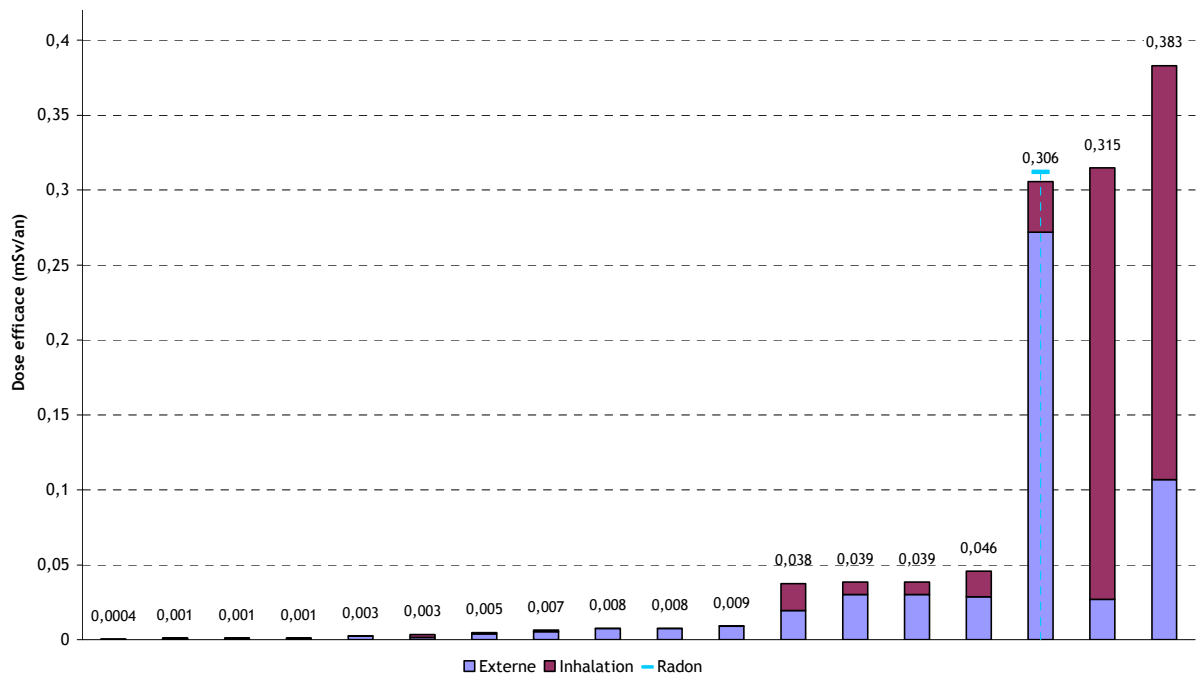


Figure 1: Combustion of coal – Effective added doses for workers (mSv/ year) [2]

3.3.2 Treatment of tin, aluminium, copper, titanium, niobium, bismuth and thorium ores

Figure 2 below shows, for each of the studies received on the abscissa, the effective added doses for the workers placed in order.

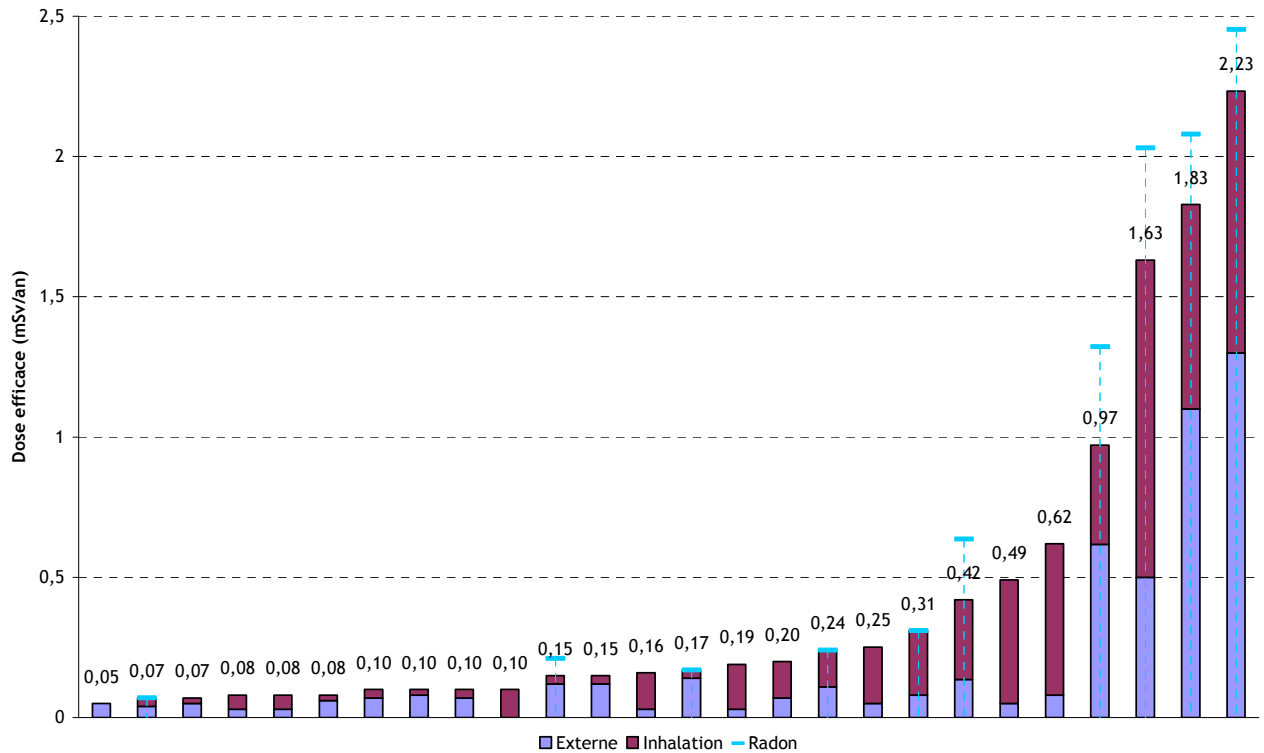


Figure 2: Treatment of minerals - Effective added doses for workers (mSv/ year) [2]

3.3.3 Production of refractory ceramics and glassmaking, foundry, steel industry and metallurgy activities using refractory ceramics

Figure 3 below shows, for each of the studies received on the abscissa, the effective added doses for the workers placed in order.

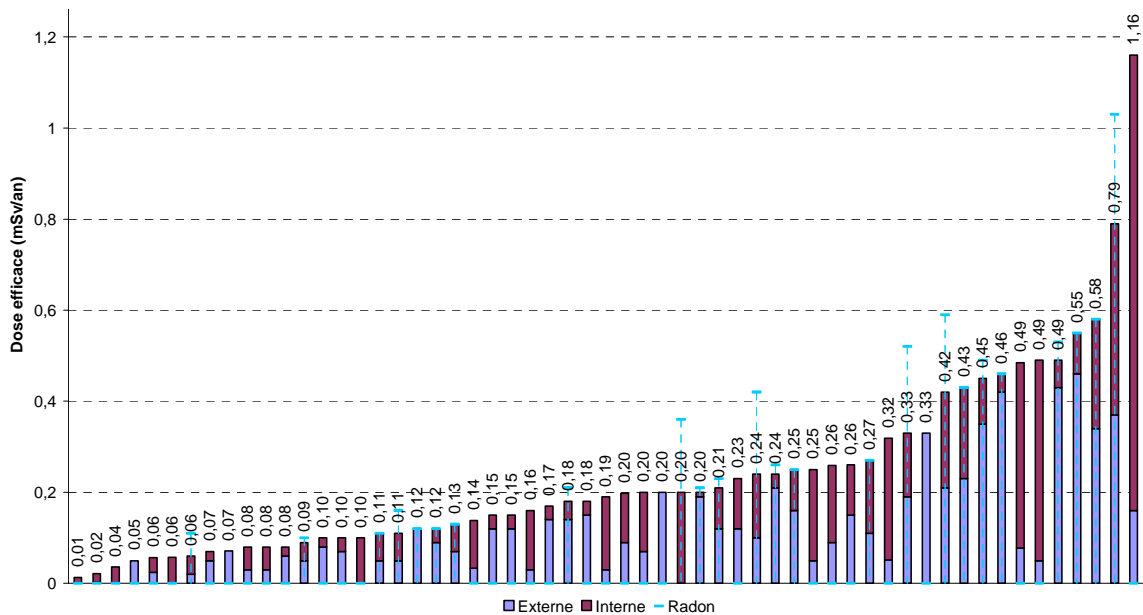


Figure 3: Refractories – Individual effective added doses for workers (mSv/year) [2]

3.3.4 Production or use of compounds containing thorium

The effective individual doses range from $1.3 \cdot 10^{-4}$ mSv/ year and 81.7 mSv/ year, depending on the workstation and the wearing of individual protective equipment.

3.3.5 Production of zircon and baddeleyite, and foundry and metallurgy activities using zircon and baddeleyite

Figure 4 below shows, for each of the studies received on the abscissa, the effective added doses for the workers placed in order.

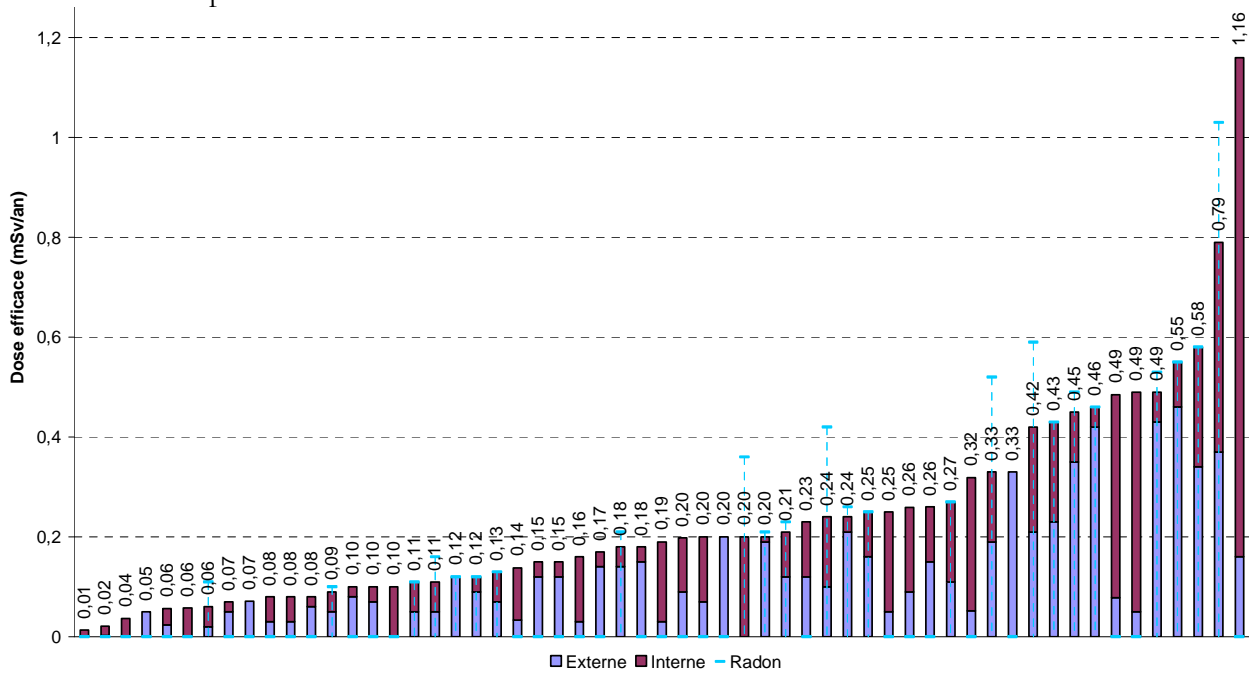


Figure 4 : Zircon - Individual effective added doses for workers (mSv/ year) [2]

3.3.6 Production of phosphate fertiliser and the production of phosphoric acid

The phosphate fertiliser production installations do not seem to cause any significant exposure for the workers as the production of phosphoric acid does not take place on these sites.

3.3.7 Treatment of titanium dioxide

The industries carrying out the treatment of titanium dioxide are the same as those who carry out the treatment of the titanium ore cited in paragraph 3.3.2.

3.3.8 Treatment of rare earth and the production of pigments containing rare earth

Exposure of workers to enhanced natural radioactivity (thorium 232) is greater than 1 mSv/year for some workplaces.

3.3.9 Treatment of underground water by filtration for production of water for human consumption and mineral waters

Workers may be exposed during maintenance or cleaning, or due to the release of radon in the installations. Further information is expected and no final conclusion can be drawn at this stage.

3.3.10 Spas

The data supplied is incomplete and does not enable a report to be made on workers' exposure.

3.3.11 Sectors not affected by the Order of 25th May 2005

The list of activities cited in the Order of 25th May 2005 is not exhaustive. As such:

- In the oil and gas extraction industry, the exposure of workers can be significant due to maintenance interventions on the installations, as well as the management of NORM wastes which results.
- In geothermal activity, as in the papermill industry, the phenomenon of the concentration of the natural radioactivity used seems roughly the same as that in oil and gas extraction: that natural radioactivity concentrates in the bends, valves, filters,... in the pipes.

However, we do not have any dose evaluations for the workers or the public carried out by the industrial parties.

In the evaluation of doses received by the workers linked to the enhanced natural radioactivity, two sets of figures seem to set themselves apart. Some industries significantly concentrate the natural radioactivity of their raw material in manufacturing wastes or co-products. This is the practice at the Rhodia, Cezus and Millenium Chemical sites and the sites of users of elements containing thorium.

The other case relates to industries whose procedures do not concentrate or only slightly concentrate the natural radioactivity of their raw material but use, a priori, materials that are naturally concentrated in natural radioactive elements. This is the case at the coal combustion installations, installations using refractory ceramics, installations producing phosphate fertilisers from pre-processed minerals or using zircon. We can, however, find wastes or co-products, for example, concentrating ²¹⁰Pb following a thermal treatment, following the example of thermal silica.

Among these, however, the coal combustion, refractory ceramic usage and phosphate fertiliser production installations do not seem to oblige their workers to radioprotection actions. On the other hand, the oil and gas extraction, geothermal science, and papermill industry sectors, companies that specialise in manufacturing chimney (assembly-dismantling of refractory ceramic ovens) as well as the companies that recycle refractory products containing zircon, should be included in the regulation.

Particular attention must be given to dismantling operations, liable to be carried out by external companies, and to long-life low activity (FAVL) wastes management procedures: for example, the pipes used for the extraction of gas or oil, the equipment contaminated with radium 226 from the zirconium or titanium dioxide production sites, the thermal silica or dust liable to concentrate the ²¹⁰Pb, whose radioactivity cannot be detected unless appropriate measures are in place.

Lastly, the dose evaluations that may be received by workers in accident situations are not supplied, although the Order requires that, “if accidental situations are liable to strengthen the level of radiological exposure to the workers, these situations must be taken into account.”

3.4 Synthesis of studies on exposure of the population

Below is a summary of the dose evaluations presented in the studies by professional activity category.

3.4.1 Combustion of coal in thermal power stations

Exposure of the public living near the installations seems to be very low, around a few μSv . The predominant exposure route is the internal exposure.

With regard to the exposure of the public by assessment of the ashes in the construction materials, in light of the directions taken by the review project of the Euratom “basic standards” directive and in application of article R.1333-13 of the Public Health Code, a regulatory control must be applied with regard to the reuse of the ashes in these products (see chapter 4).

3.4.2 Treatment of tin, aluminium, copper, titanium, niobium, bismuth and thorium ores

The exposure of the people living near the installations is low, ranging from 80 $\mu\text{Sv}/\text{year}$ and 140 $\mu\text{Sv}/\text{year}$.

3.4.3 Production of refractory ceramics and glassmaking, foundry, steel industry and metallurgy using refractory ceramics

Figure 5 below shows, for each of the studies received on the abscissa, the effective added doses for the population placed in order.

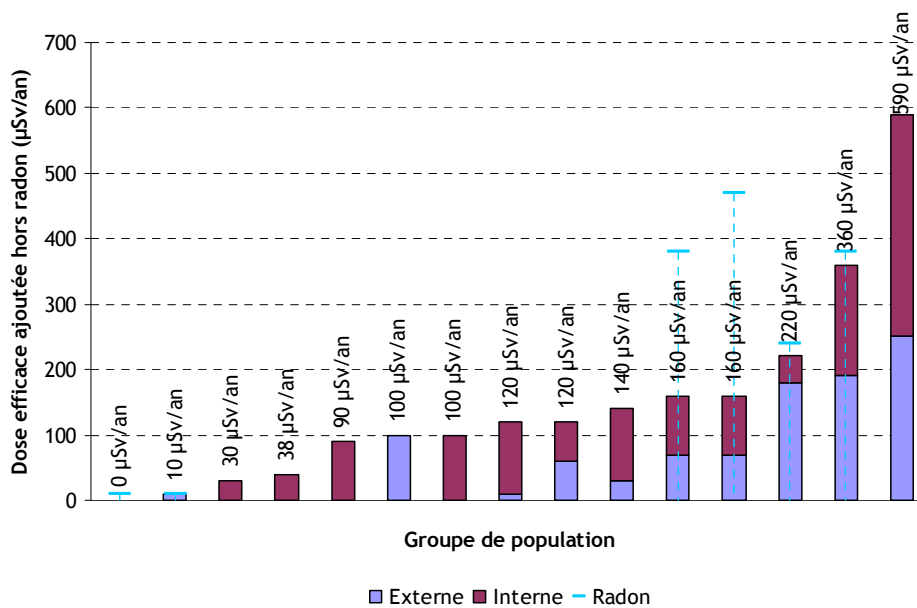


Figure 5: Refractory – Individual effective added doses for the public ($\mu\text{Sv}/\text{year}$) [2]

In addition, the generic study for the glassmaking activities passed on by the FCSIV shows that no significant radiological impact on the public is expected as a result of the glassmaking activities.

3.4.4 Production or use of compounds containing thorium

Figure 6 below shows, for each of the studies received on the abscissa, the effective added doses for the population placed in order.

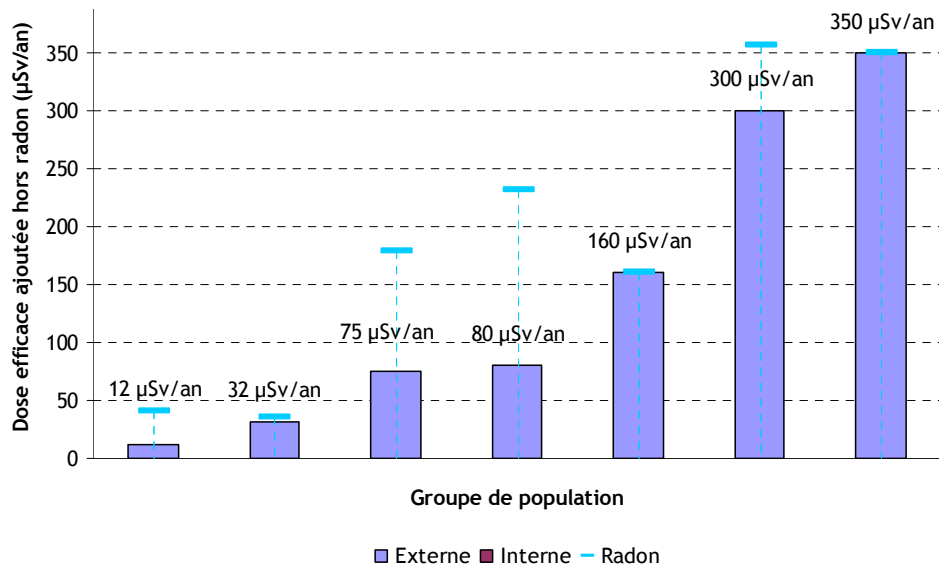


Figure 6: Thorium – Individual effective added doses for the public (µSv/year) [2]

3.4.5 Production of zircon and baddeleyite, and foundry and metallurgy activities using zircon and baddeleyite

Figure 7 below shows, for each of the studies received on the abscissa, the effective added doses for the population placed in order.

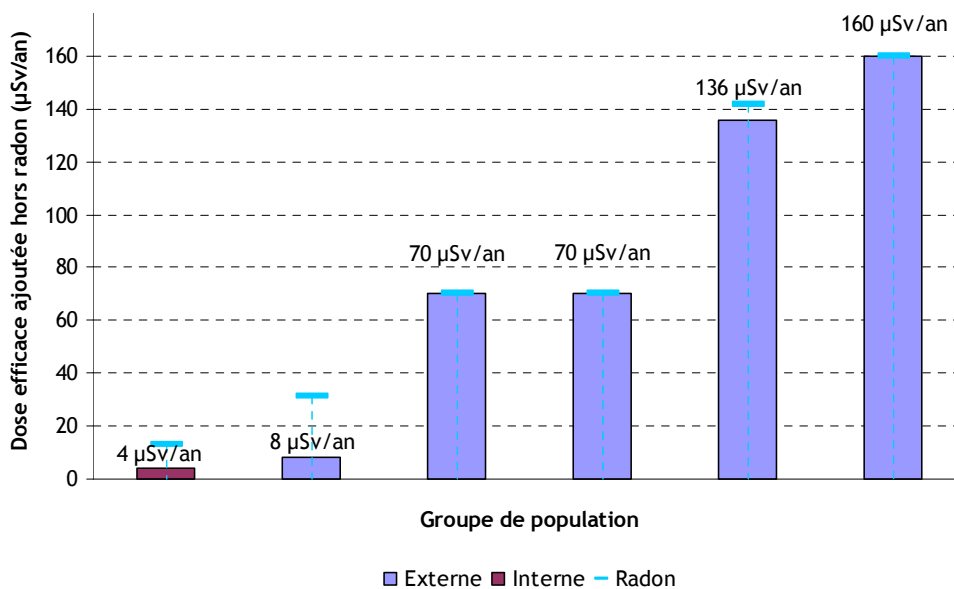


Figure 7: Zircon – Individual effective added doses for the public (µSv/year) [2]

3.4.6 Production of phosphate fertiliser and production of phosphoric acid

The studies received show that the effective added dose without radon is 25 µSv/year for the people living near the installations.

3.4.7 Treatment of titanium dioxide

The industries carrying out the treatment of titanium dioxide are the same as those who carry out the treatment of the titanium ore cited in paragraph 3.4.2.

3.4.8 Treatment of rare earth and the production of pigments containing rare earth

Figure 8 below shows, for each of the studies received on the abscissa, the effective added doses for the population placed in order.

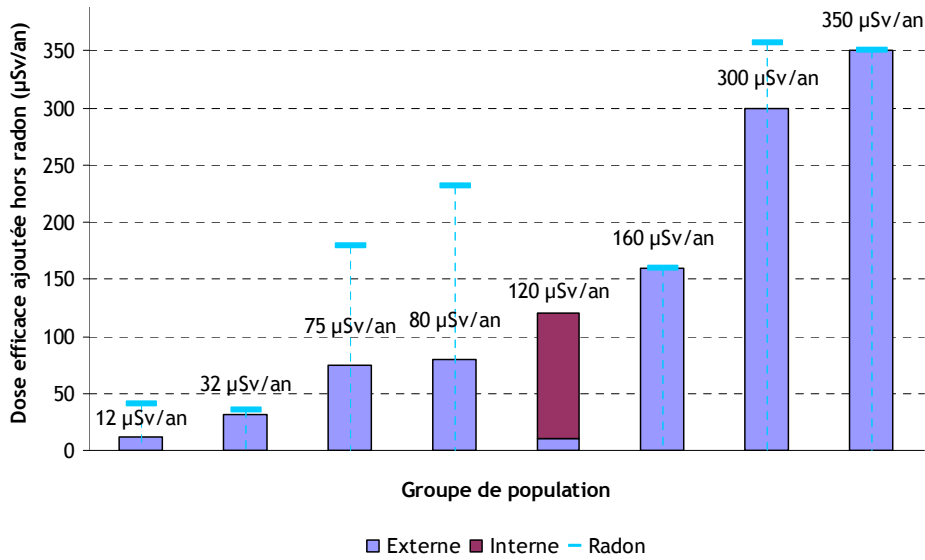


Figure 8: Rare earth– Individual effective added doses for the public (µSv/year) [2]

3.4.9 Treatment of underground water by filtration for producing water for human consumption and mineral waters

No study was received on the exposure of people living near the underground water treatment installations.

3.4.10 Spas

No study was received on the exposure of people living near the spas.

With regard to the exposure for the population, the IRSN [2] notes that the studies received are too often incomplete thus inhibiting a true dose evaluation. This can be explained by the lack of knowledge on the subject on the part of the industrial parties concerned, but also by the resources required for carrying out an evaluation of the doses received by the public. The dose calculations are rarely rigorous. The IRSN estimates that the impact of the installations on the public can be perhaps assessed by a quantitative measure using a rigorous dose calculation, or assessed qualitatively using a detailed study of the transfer channels. The IRSN also notes that the calculations lead to doses around several hundred microsieverts per year and generally lower than 1 mSv/ year which is the exposure limit of the public to any nuclear activity. The IRSN suggests that the industrial parties evaluate the doses received by realistic population groups and based on a realistic scenario, as is done so for basic nuclear installations.

The IRSN [2] notes that the activity categories that generate effective doses received by the public that are deemed to be high are those relating to:

- the treatment of ores (maximum effective dose of 1.33 mSv/year – this dose is not taken into account in the final report as the scenario is not a real-life situation),
- the production of refractory ceramics and glassmaking, foundry, steel industry and metallurgy activities using refractory ceramics (maximum effective dose of 0.6 mSv/year),
- the production or use of compounds containing thorium (maximum effective dose of 0.3 mSv/year),
- the treatment of rare earths and the production of pigments containing rare earths (maximum effective dose of 0.3 mSv/year).

3.5 Management of enhanced natural radioactivity wastes

In July 2009, the ASN submitted a report on solutions for the management of enhanced natural radioactivity wastes (or RNR wastes) to the Minister for Ecology, Energy, Sustainable Development and Sea responsible for green technology and climate negotiations as well as to the Minister for Sport and Health. This report was submitted in response to Order no. 2008-357 of 16th April 2008 setting the instructions relating to the national Plan for the management of radioactive wastes and materials.

This report cited in reference [7] puts forward recommendations on the management of these wastes, no matter whether it comes from industries regulated by the Order of 25th May 2005 or not. To draft this report, the ASN drew on the studies from the Robin des Bois Association, cited in references [8] and [23] (looking at enhanced natural radioactivity in France and phosphogypsum and coal ashes), on the information contained in the dossiers received in application of the Order of 25th May 2005 (see Annexe 5), and on the information available in the ANDRA national inventory.

In this report, the ASN notes that:

- the exhaustive inventory of RNR wastes is difficult to draw up due to the large number of industrial parties concerned and the large variety of industry sectors concerned;
- the RNR wastes is divided into two categories: long-life, very low activity wastes (TFAVL) which represents the largest volumes, and the long-life, low activity wastes (FAVL) which has smaller volumes. The FAVL wastes is generated by a few companies in France (Rhodia in La Rochelle, Cezus in Jarric, Millenium Inorganic Chemicals in Thann, the oil and gas extraction installations...);
- the RNR TFAVL wastes is removed either at the storage centre for dangerous, non-dangerous and inert wastes, by internal discharge or at the ANDRA storage centre for TFA wastes;
- there are phosphogypsum and ash dumps, defined as RNR wastes;
- the RNR FAVL wastes are generally stored at the industrial parties' site as there currently often do not exist any removal channels.

In general, the ASN considers that the choice of the removal channel for RNR wastes must be consistent with the radiological activity of wastes to be removed. The recommendations provided in the report do not deeply question the management procedures for these wastes but aim at improving the existing management channels.

The main recommendations drawn by the ASN relate to:

- a re-enforcement of the inventory and the traceability of enhanced natural radioactivity wastes in order to improve the management control over these wastes;
- an analysis of past experience of the application of the bill of 25th July 2006 with all those affected in order to secure and optimise the storage of enhanced natural radioactivity wastes in the storage centres for dangerous, non-dangerous and inert wastes and to ensure the consistency with the storage centre for very low activity wastes operated by Andra;
- an account of the radiological risk with regard to the management of ashes and phosphogypsum;
- the drafting of an inventory of the valorisation channels of the residues containing enhanced natural radioactivity and, secondly, the drafting of radiological impact studies for workers using these residues and the public, based on a radiological characterisation of the residues in question;
- the implementation of a study by the industrial parties concerned in order to decontaminate the scraps contaminated by deposits / tartars containing enhanced natural radioactivity before any evaluation project;
- the study of Andra providing storage solutions for the industrial parties occasionally producing enhanced natural radioactivity wastes to be stored in the future storage centre for FAVL wastes in order to improve storage conditions for this wastes and to avoid scattering this type of wastes on the territory;
- the implementation of measures aimed at securing the funding for the management of enhanced natural radioactivity wastes, in particular for wastes showing high doses of radioactivity justifying their storage in the future storage centre for FAVL wastes, and for the internal storages justifying the implementation of long-term surveillance measurements.

4 Development perspectives

4.1 Development perspectives of national regulation

In the short term, based on information contained in this report, the list of professional activity categories affected by the current Order may be modified as follows:

1. the treatment of tin, copper, titanium, niobium, bismuth and thorium ores;
2. the production, maintenance or use of compounds containing thorium;
3. the production, use or industrial transformation of zircon and baddeleyite, or of products containing zircon and baddeleyite;
4. the production of phosphoric acid;
5. the treatment of rare earths and pigments containing rare earths;
6. the treatment of underground water by filtration for the production of:
 - water for human consumption,
 - mineral waters;
7. spas;
8. paper mills.

Section no.3 corresponds to resume sections no.3 and no.5 of the Order of 25th May 2005. The term “products containing it” is aimed at the industries producing products made from zircon (refractory ceramics, refractory concrete...). The industrial transformation of zircon and baddeleyite would be aimed at industries that transforming zircon into zircon flour and that, nowadays, are not regulated despite the use of significant quantities of zircon, possibly in powder form.

The section “treatment of titanium dioxide” would be removed, as it is the equivalent of the section “treatment of titanium ore.”

The oil and gas extraction and the geothermal science installations are regulated by the general regulation on extraction industries (RGIE or Mining Code), and cannot, therefore, still figure in an Order taken in application of the Labour Code and the Public Health Code.

The production of a good practices guide for industrial parties using zircon (for example) could allow for an improvement in the radiological risk evaluation for the workers concerned, as well as the implementation of techniques, working procedures and actions by the industrial parties in order to avoid or reduce the workers’ exposure, as outlined in articles R.4457-3 and R.4457-4 of the Labour Code.

For aspects relating to the public, the IRSN estimates that the impact on the public of the concerned installations could be assessed either quantitatively using a rigorous dose calculation or qualitatively using a detailed study of transfer channels.

Lastly, the drafting of the dossiers by the industrial parties, allowing a report on exposure to enhanced natural radioactivity in the NORM industries to be drawn up, is not subject to a periodic update; this may be requested following any modification to the installations or working conditions liable to increase the doses received, in relation to the initial evaluation.

In the medium term, as the following paragraph underlines, national regulation will be forced to change in order to implement the requirements that are currently being put together on a European Union level.

4.2 Possible development of European Regulation

In order to facilitate the implementation of the Euratom 96/29 directive (Title VII), the European Commission published the RP 122 document, “Radiation Protection 122 – Part II” in 2001[3]. This document relates to the application of the notions of exemption and clearance for natural sources of ionizing radiation, where the materials are not used for their radioactive properties and proposes values for different materials.

In 2004, the AIEA also defined the notions of exemption, clearance and exclusion in the RS-G-1.7 document [4], for the NORM industries, and introduces a set of values below which no regulation is required:

- ^{40}K : 10Bq/g
- Any other radionuclide of natural origin: 1Bq/g

In support of the review of the Euratom/96/29 directive undertaken by the European Commission, an advisory note, based on the past experience of the Member States in the field and the available international literature, recommends amending the current Title VII, “Exposure to natural radioactivity”[5]. Above and beyond an exemption threshold, the industries using materials containing natural radionuclides not used for their radioactive, fissile or fertile properties would be subject to the requirements of the new directive.

Based on the advisory note, the directive project, examined in November 2009 by the Expert Committee of article 31, acknowledges the numerical values of AIEA and considers that:

- below these concentrations, there is no need to regulate;
- above these concentrations, exposure linked to enhanced natural radioactivity must be considered as “planned” exposure. In particular, the radioprotection system of the workers exposed to the radioactivity and of the public would be identical to that which is applied to the other practices.

Furthermore, the directive project states that the exemption thresholds are not applicable if the NORM materials are valorized in the construction materials, or if the installation is likely to impact the resources of water used for human consumption.

The existing French regulation on the NORM industries, based on the evaluations of doses received by the workers and the public, differs, therefore, on this point, from the European Community approach proposed in this document.

The report cited in reference [22], also proposes that the identification of the companies concerned by the regulation on the NORMs be based on the use of materials, the list of which would be specified at national level, taking into account a positive list such as that annexed to the directive project. This approach has the advantage of being able to cite specifically the natural sources of ionizing radiation, provided that the list of materials concerned can be periodically updated, and that the industrial parties can be easily identified by this way.

5 Conclusion

The implementation of the Euratom 96/29 directive into national law lead to the regulation of exposure of workers and the public to enhanced natural radioactivity in 2005. The choice of professional activity categories concerned was made based on the information contained in the international or European Community bibliography (see Annexe). In France, the thin line between this regulation and the regulation on installations classified for the protection of the environment lead to the publication of the MEDD bill of 11th July 2005, aid to the identification of those industrial parties obliged to carrying out an estimation of the doses received by the public.

Considering the information available prior to the publication of this regulation both at a European Community and a French level, this first report jointly carried out by the ASN and the IRSN based on around 80 studies, allows the NORM industries, with the exception of those used in spas and underground water treatment installations, to raise their level of knowledge on the exposure of workers and the public.

This report allows the development paths for national regulation to be forecasted by gathering the conclusions of the ASN and IRSN analyses for each professional activity category. In particular, it is proposed to have a new list of professional activity categories endorsed by the regulation, a synthesis of the existing professional activity category activities and categories that could be added.

Lastly, this report can also act as preparation for the implementation of the future European directive currently being developed: under this European directive, the industries using NORM materials would no longer be considered in a specific manner, but as “practices”, i.e. like the other nuclear activities, with the introduction of exemption thresholds for the NORM materials, in replacement of the approach by dose assessment currently in use. In this regard, this report

was submitted to the experts of the permanent radioprotection group (GPRAD), who were approached in light of the regulatory modifications ahead.

ANNEXES

Annexe 1: technical modalities for carrying out the evaluation of doses cited in article 3 of the Order

The organisation head of an activity or an professional activity category that figures in annexe 1 carries out an evaluation of the doses received by the workers in accordance with the methodology developed below, except if a study corresponding to their activity excludes all risk of significant exposure for the workers.

1. Description of the site, products and processes

The study provides:

1. The location of the establishment;
2. The source, quantities, physical and chemical forms and the radiological characteristics of the raw materials or substances present on the site and liable to containing natural radionuclides;
3. A description of the manufacturing processes using these raw materials or substances;
4. The physical and chemical forms and the radiological characteristics of the intermediary products and the finished products at the different stages of manufacture, including those of the wastes produced;
5. The quantities and the radiological characteristics of the liquid or gaseous effluents produced during manufacture and, if necessary, a description of the treatment and storage processes before their removal;
6. The outlets used for the removal of the wastes and effluents produced.

2. Characterisation of the notion source

The radiological characterisation of the raw materials, intermediary products, finished products, wastes and effluents take into account the 40K and the ^{238}U , ^{232}Th and ^{235}U chains, or present the criteria allowing for the justification for not taking these into account. This characterisation can be based on the standards in force or on a requirements document drafted by the IRSN.

3. Identification of workplaces and scenarios liable to exposure

The study shall name the workplaces where the workers are liable to being exposed to ionizing radiation. Where necessary, the workplaces relating to the supply of raw materials, the removal of wastes, the maintenance and the dismantling of the installations must be taken into account.

The study shall name the potential ways in which the operators may be exposed, and in particular exposure by external radiation, by inhalation of dust and inhalation of radon, as well as the different scenarios that may lead to such exposure. The description of the activities carried out, the number of individuals affected as well as the potential protection measures used are given. If accidental situations are liable to increase the workers' radiological exposure, these situations must be taken into account.

4. Evaluation of doses

The study shall include an evaluation of the total effective doses and equivalent doses of the workers affected at the pre-identified workplaces. This evaluation takes into account the realistic exposure parameters. This can be done through establishing a model carried out by software calculating the radiological exposure, completed by on-site measurements. If increased assumptions are found, the study must outline their influence on the results.

Based on these exposures at workplace, the study shall determine the effective doses received by the workers in order to demonstrate the individual exposures liable to reach or exceed an effective dose of 1 mSv per year.

The calculation of effective doses and equivalent doses is carried out in accordance with the requirements of the Order taken in application of article R 231-80 of the Labour Code.

For the evaluation of the doses received by the workers, the head of the establishment can also base this on an evaluation carried out for a similar installation. In this case, he or she shall give proof of the similarity between the parameters of exposure of the workers and those of the evaluation being used as a reference.

5. Measures for reducing exposure

The study shall provide the actions to be undertaken or the existing actions in order to reduce exposures. If necessary, the head of the establishment shall define radiological activity levels of the raw materials in order to ensure compliance with the workers' exposure limits.

Annexe 2: technical modalities for carrying out the studies cited in article 2 of the Order

The studies required for measuring the exposure to ionizing radiation and the estimation of doses which the public is liable to be subjected to, outlined in article 2, include the following information:

1. The location of the installation as well as its situation with regard to regulation on installations classified for the protection of the environment;
2. The source, the quantities, the physical and chemical forms and the radiological characteristics of the raw materials or substances used or stored, and liable to containing natural radionuclides;
3. A description of the manufacturing processes using these raw materials or substances;
4. The physical and chemical forms and the radiological characterisations of the intermediary products and finished products at the different stages of manufacture, including those of the wastes produced;
5. The quantities and the radiological characteristics of the liquid or gaseous effluents produced and, if necessary, a description of the treatment and storing procedures before their removal;
6. The outlets used for the removal of the wastes and effluents produced;
7. If necessary, the storage modalities for the finished product, before the product is made available on the market;
8. Measures set up to reduce exposure;
9. An evaluation of individuals' levels of exposure to ionizing radiation, with identification of the population groups exposed chosen for this estimation and, if necessary, the results of the dosimetric monitoring implemented.

The radiological characterisation of the raw materials, intermediary products, finished products, wastes and effluents outlined under points 2, 4 and 5 of this annexe takes into account, in particular, the ^{40}K and the ^{238}U , ^{232}Th and ^{235}U chains, or provides the criteria justifying why they are not taken into account. This characterisation can be based on the standards in force at the time or on a requirements document drawn up by the IRSN.

For the dose evaluations cited in point 9, the operator may draw on a radiological impact study carried out for a similar installation or draw on a generic study. In this case, he shall demonstrate that the results can be transposed to his installation, given the manufacturing processes, material, wastes and effluent characteristics and the exposure scenarios for the population groups taken as a reference.

Annexe 3: Review by professional activity category

All professional activity categories concerned, and considering only the installations subject to authorisation, the number of establishments listed by the ASN and the DREALs amounts to 319 (not including the following regions: Normandie, Picardie, Franche-Comté, Auvergne, Rhône-Alpes, Languedoc-Roussillon, PACA and Corse). Within this group, a number of companies are not affected by the regulation due to the inadequacy between the ICPE nomenclature and the professional activity categories of the Order. The number of companies listed but not affected has not been specifically identified, except for those who have responded to the requests from the ASN and the DRIRE.

If those companies not subjected to authorisation are also taken into account, the Order would apply to at least over 600 establishments, if we look at the information obtained using the list carried out by the ASN and the report from the Robin des Bois Association¹.

The report is provided below by professional activity category.

1 Combustion of coal in thermal power stations

1.1 French situation

The main coal combustion companies in France that operate in order to provide electricity are EDF (Electricité de France) and SNET (Société Nationale d'Electricité et de Thermique). EDF has six coal thermal power stations and SNET has four. The ashes resulting from the coal combustion have previously been stored in dumps, and they are now used after production in cement type construction products, for road works as a filling material or as the gypsum product in the desulphurization of smoke fumes. Other coal combustion installations allow heat or energy to be produced for urban networks, sugar mills, paper mills...

According to the MEEDM figures, there are 40 thermal power stations across France (fuel not specified).

The Surschiste, Calcie et Spi companies, for example, are specialists in the valorisation of ashes.

1.2 List of dossiers received

Endorsed by the regulation

- EDF and SNET, evaluation of radiological exposure linked to flying ash produced by coal based thermal power stations in France, First stage: Exposure of workers, 2003 (no.1)
- Solvay-Carbonate France, combustion of coal in power stations, production of energy to supply a carbonate production unit, Smart Subatech (no.14)
- CEPN, dehydration generic study, 2006 (no.15)
 - Sun Deshy, fodder dehydration (no.16)

¹ The list of establishments was drafted by the ASN in 2006 and 2007 using regional databases from the Ministry of Ecology (GIDIC). The lists of establishments were distributed by divisions of ASN.

- Prodeva, fodder dehydration (no.24)
- Cristal Union, fodder dehydration (no.27)
- Euroluz, fodder dehydration, (no.28)
- Alfaluz, fodder dehydration (no.29)
- Capdea, fodder dehydration (no.30)
- EDF, combustion of coal in power stations, production of electricity, worker generic study and further information, 2007 (no.19)
- Metz Electricity Factory, combustion of coal in power station, production of electricity, heat and heated water, Algade, 2007 (no.53)
- Novacarb, combustion of coal in power station, production of energy to supply a carbonate production unit (no.54)
- Elyo Suez, combustion of coal in power station, production of heated water, (n°57)
- Storaenso, combustion of coal in power station, production of electricity to supply a paper mill, Algade, 2007 (no.58)
- EDF, combustion of coal in power stations, production of electricity, population study, 2007 (no.69)
- SNET, combustion of coal in power stations, generic study, 2008 (no.79)

The two main operators of coal power stations (EDF and SNET) responded to the Order of 25th May 2005, through a study carried out by the CEPN. The dossiers drafted by Solvay-Carbonate, Elyo Suez, Novacarb and the fodder hydrators brought no new information in relation to the EDF, CEPN, SNET, Storaenso and UEM studies.

1.3 Characterisation of materials

The radionuclides contained in the coal are mainly found in the ashes, the combustion concentrating them in there at a factor of between 6 and 8 in relation to the coal.

	²³⁸ U	²³² Th	²³⁵ U	⁴⁰ K
Coal	0.0048 → 0.080 (²³⁴ Th)	0.0011 → 0.030 (²²⁸ Ac)	0.00069 → <0.050	
Furnace ashes	0.062 → 0.160	0.093 → 0.157	0.003 → <0.050	
Flying ashes	0.042 → 0.248	0.025 → <0.250	0.002 → <0.040	
Deposits on boiler tubes (EDF)	0.193 (²²⁶ Ra) ; 0.055 (²¹⁰ Pb)	0.108	-	0.451
Gypsum from the desulphurisation (EDF)	0 (²²⁶ Ra) ;	0	-	<0.0032

Table 2: specific activities in Bq/g, dossiers no. 1, 14, 19, 53, 54, 57, 58, 79

The measurements of ²¹⁰Pb in the soot of the UEM (dossier no.53), shows a specific activity of 1.06Bq/g in ²¹⁰Pb, in other words around 10 times more than for the parent radionuclides. This is the only measurement showing a significant concentration in 210 lead in the measurements taken in the ashes.

1.4 Workers' exposure

The study cited in reference [10] makes reference to exposures ranging from a few μSv to a few dozen μSv/ year for workers in contact with ashes whose specific activity is 0.10Bq/g. For higher specific activities, inhalation linked to handling ashes may lead to exposure doses of between 0,1 and 1 mSv/ year. Particular attention must be paid to wastes resulting from desulphurisation process and deposits formed on the steam generator tubes in the combustion chamber [11].

Description of processes

Two types of processes exist: combustion of coal grounded and crushed in the chamber, or combustion on a fluid bed. Only the first process was evaluated and is presented here.

The coal is crushed after being ground in a combustion chamber. Two types of ashes are produced: firebox or clinker ashes (gathered in an ash pit or a descender placed under the boiler), and the flying ashes or soot, gathered after dusting away fumes. The factor of concentration between the coal and the ash ranges between 6 and 8. The ashes are deposited in an ash park by dump truck or large carrier, or stored in silos by mechanical means before being loaded onto lorries for further use.

With regard to the Cordemais power station (EDF), the desulphurisation of steam takes place after the filtration of the flying ashes, and uses around 35,000 tonnes of limestone per year. The gypsum produced from this operation is also used in construction. As the filtration of the flying ashes has a yield of over 99%, the gypsum resulting from the desulphurisation contains around 3.5% of flying ash.

According to the international bibliography, deposits with a high 210 lead content (above 100Bq/g) can form around the steam generator tubes placed in the combustion chamber [11]; an intense exposure risk therefore exists while repair or maintenance operations are being carried out on these parts.

Evaluation of doses

The main workplaces liable to being exposed are linked to the presence of ash or deposits of 210 lead mentioned above: the maintenance and cleaning work on the combustion, fumes filtration, transport and ashes storage installations are, therefore, affected.

The evaluation of the doses received by the EDF and SNET workers were carried out based on the 2003 CEPN study (dossier no.1), and completed in 2007 and 2008 (dossiers no.19 and no.79). The following workplaces may be exposed:

- ash pit emptying;
- patrols and interventions under the dust collectors;
- moistening the ashes;
- loading and levelling in the ash park;
- loading of ashes onto the lorries for later use.

The potential exposure of the workers in these posts is linked to the proximity of the ashes or to the maintenance operations on the equipment that may contain ash. The missing information concerning the maintenance or cleaning of the steam generator tubes [11] were subjected to a particular point during the inspection on 18th April 2008 at the Cordemais power station.

In the CEPN study, the dose evaluations for these workplaces were undertaken by establishing a model template, based on the measurement of specific activities of EDF-SNET ash samples, activities similar to those measured on a second sampling carried out in 2005 for ashes from the EDF power station in Blénod. The 2007 EDF study has completed these templates with dust measurements and dose deposits for the workplaces situated near the ash pit, dust collectors, soot, ash loading points and the ash park (all exposed places are included). This study draws on the conclusions of the 2003 study to support its results, a study according to which the doses received by the workers are under 1 mSv/ year. The dose deposit measurements for these different workplaces are on the same scale as the natural background. As such, the air volume

activity measurements (carried out by removing dust from the filters) show activity levels below the detection limits of the apparatus used (see annexe 1 of dossier no. 19). The calculations have, therefore, been carried out based on the knowledge of specific activities of ashes and the amount of dust in the air. The measurements carried out by EDF show an hourly exposure lower than the results of the CEPN template. The SNET dossier (n°79) offers little further information.

The dose evaluations carried out by EDF based on this information are provided in the table below; exposure to naturally occurring radioactivity in the environment is deducted.

Workplace	Hours of work	Added effective dose	Ways of being exposed that were studied
Roundsman	– 60h: patrol around underpasses (dust collectors) – 360h : emptying ashes pit	≤0.01 mSv/year	Radiation exposure + ashes inhalation
Maintenance worker	40h: intervention on underpasses	≤0.01 mSv year	Radiation exposure + ashes inhalation
Handling agent	400h: moistening ashes	≤0.02 mSv/year	Radiation exposure + ashes inhalation
Lorry driver	400h: loading ashes	≤0.01 mSv	Radiation exposure + ashes inhalation
Ashes park vehicle driver	1800h: loading and levelling ashes park	≤0.14 mSv	Radiation exposure + ashes inhalation
Maintenance of steam generators	300h: cleaning and intervention on steam generators	7.08.10 ⁻³ mSv/year	Inhalation of deposits in steam generators

Table 3: EDF workplaces, dossier no. 19

The assessment of the EDF dossier by the IRSN shows that the measured specific activities of the ashes are consistent with the international bibliography. With regard to the dose evaluation, the exposure pathways used (dust inhalation, radon inhalation and external exposure) are relevant, but no radon measurement in the air was carried out. The “ashes ingestion” and “external radiation exposure through skin contamination” exposure pathways are deemed to be negligible. The fact that the dose rates measured by EDF in their installations are at the same level as local natural radioactivity does not draw any comments from the IRSN.

With regard to the deposits around the steam generators [11], EDF states that brushing by steam is carried out automatically and daily in order to prevent any deposits forming. Furthermore, prior to any maintenance being carried out, cleaning using water is carried out in the combustion chamber: the wastes produced by these two activities are collected in the ash pit and mixed with the firebox ash. An evaluation of the doses received by a worker working on the steam generators and a worker exposed to the gypsum, is submitted by EDF [12]. For this dose evaluation, samples were carried out in the steam generator tubes, in the ashed water resulting from the cleaning as well as on the mats used to transport the gypsum, in order to measure the specific activity of these materials, which is at the same level as that of the combustion ash, including those for the ²¹⁰Pb radionuclides. The ashed water shows natural radioactivity which is two times greater than that measured in the Blénod ash. (see Table 2). The gypsum resulting from the desulphurisation process has a far lower level of natural radioactivity. Based on these measurements, the internal doses undertaken during the cleaning of the steam generators (300 hours of exposure for the same agent) or when in close proximity to the gypsum (1600 hours of exposure for the same agent) are evaluated at $5.16 \times 10^{-4} \mu\text{Sv}/\text{year}$ and $17 \mu\text{Sv}/\text{year}$ respectively, for a dust level of $2\text{mg}/\text{m}^3$.

At Storaenso and UEM, the dose rate photon measurements and the measurements of the dose rate of radon from the transport or combustion installations does not show any increase in comparison to the natural background. The background increases in ash storage parks by between 2 and 1.5 times as a result of the photon deposits. The highest levels of photon output (around 200 per second) measured on their installations are linked to the presence of refractory ceramics. Only the alpha volumic activity of the dust in the air differs from the local natural level (4.3mBq/m³ for the UEM, 9.6mBq/m³ for Storaenso). The estimations made using these measurements do not involve any doses greater than 315 µSv/ year (see Tableau 4). Given the absence of measurements greater than the background noise for the majority of the workplaces, the dose evaluations retain the maximum values for a fictional exposure scenario.

Workplace	Hours of work	Added effective dose	Ways of being exposed that were studied
Storaenso: dose calculation based on measured maximum values	– 150 h to 0.25 µSv/h (contact with injection bends in refractory ceramics) + 1785 h to 9.6mBq/m ³ of EAVL (crane operator)	0.315 mSv/year	External exposure, dust inhalation
UEM : dose calculation in the basis of maximum values	– 150 h to 0.23 µSv/h (contact with boiler refractories) + 1600 h at 4.3 mBq/m ³	0.135 mSv/year, background noise deducted for radiation exposure	External exposure, dust inhalation

Tableau 4: workplaces Storaenso, UEM (dossiers no. 58 and 53)

The summary of effective added doses for the workers is given in paragraph 3.3.1 of the body of the report.

1.5 Exposure for the public

Eleven studies evaluate the exposure to the people living next to thermal power station coal combustion installations. Among these eleven studies, only two evaluate the dose received by the public. Contrary to the internal exposure caused by dust, exposure due to radons and external exposure were not examined closely enough. The industrial parties should take into account all exposure channels or, if necessary, explain why one or several exposure channels have not been considered.

The effective added doses excluding radons range from between 3.10⁻⁴ µSv/ year and 0.06 µSv/ year. The IRSN underlines the fact that these doses are weak. The predominant exposure channel is internal exposure. This is consistent with the data published by the NRPB [13].

1.6 Quality of the studies received

15 studies evaluate the exposure of the workers in thermal power station coal combustion installations. The studies drawing on the reference studies but not demonstrating the relevance of the results of the reference study to their installation, have not been taken into account: only 9 studies and 37 workplaces were used for the analysis.

With regard to the standard operation of the installation, the description of the processes is judged to be generally satisfactory and allows the workplaces to be identified. The exposure channels were, overall, well evaluated. Only exposure due to radon was not closely examined or measured. Nevertheless, the IRSN underlines that the measurements carried out show weak

concentrations of radon. Three-quarters of the individual effective doses calculated are individual effective added doses not taking into account the dose caused by radon and 60% of them are based on a duration of exposure that is not specific to the workplace. In order to evaluate an individual effective dose received by the workers in the most realistic manner possible, the IRSN deems it desirable to use durations of exposure that are adapted to the installation.

The IRSN estimates that the maintenance and dismantling of the installations must be taken into account and described in the evaluations in accordance with the Order of 25th May 2005.

1.7 Result

The evaluations of the doses received by the workers, submitted in 2003 by the CEPN, have not been questioned following the in-depth studies carried out after the publication of the Order of 25th May 2005 (EDF, Storaenso, UEM). The effective doses received (risk of inhalation of dust and gamma radiation exposure) are around ten or hundreds of μSv /per year, depending on the scenarios used and for specific ash activities of 0.10Bq/g.

The radioprotection aspects of the workers offer little concern, and it does not seem to be necessary to carry out a specific regulatory control (inspections, setting a frequency for carrying out evaluations of doses received by the workers).

With regard to the exposure of the people living near the installations, this also appears to be very low, around a few μSv .

With regard to the exposure of the population by use of the ash in construction materials and consumer goods, given the direction taken by the review project of the “basic standards” Euratom directive, and in application of article R.1333-13 of the Public Health Code, a regulatory control must be applied on the recovery of ashes in these products.

The application of exemption thresholds as defined in reference [5] and in the paragraph “Notion of exemption for natural sources of radiation” would lead to the exemption of the following dossiers:

- CEPN, dehydration generic study, 2006 (no.15)
 - Sun Deshy, fodder dehydration (no.16)
 - Prodeva, fodder dehydration (no.24)
 - Cristal Union, fodder dehydration (no.27)
 - Euroluz, fodder dehydration, (no.28)
 - Alfaluz, fodder dehydration (no.29)
 - Capdea, fodder dehydration (no.30)
- EDF and SNET, evaluation of radiological exposure linked to the flying ash produced by coal based thermal power stations in France, First stage: Exposure of workers, 2003 (no.1)
- EDF, coal combustion in thermal power stations, production of electricity, worker generic study and supplements, 2007 (no.19)
- Elyo Suez, coal combustion in thermal power stations, production of heated water, (no.57)
- EDF, coal combustion in thermal power stations, production of electricity, population study, 2007 (no.69)
- Novacarb, coal combustion in thermal power stations, production of energy for supplying a carbonate production unit (no.54)

- SNET, coal combustion in thermal power stations, generic study, 2008 (no.79)
- Solvay-Carbonate France, coal combustion in thermal power stations, production of energy for supplying a carbonate production unit, Smart Subatech (no.14)
- Storaenso, coal combustion in thermal power stations, production of energy for supplying a paper mill, Algade, 2007 (no.58)

If the specific threshold of 1Bq/g were applied for the ^{210}Pb in case of any imbalance in the ^{238}U chain, the Metz electricity factory dossier (2007, no.53) would not be exempt. No dossier drafted for this professional activity category shows any dose greater than 1 mSv/ year for the workers. Dossiers 15, 16, 24, 27, 28, 29, 30, 79 do not show any measurements of the NORM materials' specific activity.

2 Treatment of tin, copper, titanium, niobium, bismuth and thorium ores

Treatment of titanium ore, international bibliography [14]

To produce titanium oxide, two processes are used: sulphuric or chlorinated processes. For these two processes, the radioactivity of the titanium ores (slag, rutile, ilmenite) does not concentrate in the products, co-products, liquid or gaseous effluents, but in the solid wastes from production, in particular the tartar that forms in the equipment. The concentrations of radionuclides in the processes are weak during the use of slag, unlike the concentrations noted during the use of ilmenite. Radioprotection measures may be necessary for the workers; given the effective implementation of these measures, the doses received by the workers should not exceed 1 mSv/ year. The chlorinated process involves three main stages: titanium tetrachloride (TiCl_4) is produced by chlorination, cooled down (for separation of solids and the TiCl_4), then oxidised to produce titanium oxide (TiO_2). The radionuclides concentrate in the installations linked to the chlorination, in particular in the wastes produced by the neutralisation of the solids resulting from separation.

The sulphuric process is more complex. The ore reacts with the sulphuric acid, which forms black liquor which is cleared then crystallised. The hydrolysis allows a hydrated titanium oxide to be obtained, which is then calcined to obtain the finished product. The radionuclides concentrate in the form of deposits or tartar, mainly on the crystallisation and hydrolysis installations and in the filters.

2.1 French situation

The MEEDM does not provide specific data on the ore treating installations. According to the producers and trade unions that were consulted (see below), the treatment of copper, bismuth and thorium ores no longer takes place in France.

According to Imerys Ceramics France, the only French company mining tin and niobium (as a secondary activity at a site dedicated to the extraction of kaolinized granite) is Imerys Ceramics France (previously Société Kaolins de Beauvoir). The concentrated tin, tantalum and niobium produced in the form of sand are enriched by natural radionuclides due to its gravimetry extraction.

The French Aluminium Association makes reference to four French sites belonging to the sole operator in the market, Rio Tinto Alcan. The treatment of the aluminium ore is carried out in France only at the Gardanne site, which uses imported bauxite (sedimentary rock) for the production of alumina. The Dunkerque, St Jean de Maurienne and Lannemezan sites use metallurgical alumina (only the St Jean de Maurienne site partly recovers the alumina produced in

Gardanne, the others import the alumina) to produce aluminium by electrolysis or technical alumina for various industrial uses. The old Auzat site is closed.

According to Millenium Inorganic Chemicals (MIC), the treatment of titanium ore is carried out at two French production sites: Tioxide Europe in Calais uses slag, and MIC in Thann-Ochsenfeld uses rutile and ilmenite; these raw materials have different radiological compositions, the slag being enriched in titanium dioxide and less radioactive than the ilmenite. Tioxide Europe produces titanium oxide, mainly used as pigment; as well as the titanium oxide, Millenium Chemicals produces titanium oxychloride, also used as pigment or in the electronics industry. At the Thann-Ochsenfeld site, enhanced natural radioactivity wastes is produced during an acid reaction of the ore, and stored. Millenium Chemicals also had a production site in Le Havre, which closed in May 2008, where the radioactivity problem was identified.

The treatment of the monazite took place at the Rhodia site in La Rochelle in order to extract the thorium; these activities are no longer carried out (see §8).

2.2 List of dossiers received

Endorsed by the regulation:

- Millennium Chemicals Lyondell - Le Havre, Utilisation de scories et d'ilménite pour la fabrication d'oxyde de titane (*Use of scoria and ilmenite for producing titanium oxide*), 2005 (no.3)
- Imerys Ceramics France (ex SKB), extraction de kaolin (silicate d'alumine hydraté), (*Extraction of kaolin – hydrated alumina silicate*) Algade, 2003 (no.5)
- Millennium Chemicals Lyondell – Thann and Oschenfeld, Production d'oxyde de titane et de tétrachlorure de titane (*Production of titanium oxide and titanium tetrachloride*), 2004 (no.7)
- Tioxide Europe, traitement de minerai de titane (*Treatment of titanium ore*), Hunstman, 2007 (no.44)
- Alcan Rio Tinto, Gardanne site, traitement de minerai de bauxite pour production d'alumine (*Treatment of bauxite ore for production of alumina*), Algade, 2007 (no.75)

Not covered by the regulation:

- SOKA, extraction de kaolin (silicate d'alumine hydraté), (*Extraction of kaolin – hydrated alumina silicate*) Norisko environment, 2006 (no.6)

2.3 Characterisation of materials

	²³⁸ U	²²⁶ Ra	²¹⁴ Pb	²¹⁰ Pb	²³² Th	²²⁸ Ac	²³⁵ U	⁴⁰ K
SKB: raw material kaolin (IRSN estimation)	0.07	-	-	-	0.005	-	-	-
SKB: solid tantalum tin concentrate	17	32	-	7.1	0.28	-	1.3	0.041.1 0 ⁻³
Alcan Gardanne: bauxite (raw material)	0.07 et 0.18	-	-	-	0.09 et 0.13	-	0.05 and 0.1	0.1 and 0.2
Alcan Gardanne: bauxaline (wastes)	0.17 et 0.20	-	-	-	0.34 et 0.49	-	0.05 and 0.08	0.13 and 0.30
Alcan Gardanne: autoclave tartar	0.21 to 0.55	-	-	-	0.16 et 0.36	-	0.05 and 0.03	0.03 and 0.14
Millenium Chemicals Thann: Ilmenite RGC	-	0.1	-	-	-	-	<0.00 6	0.04
Millenium Chemicals Thann: slag	-	<0.00 6	-	-	-	-	<0.00 3	<0.01
Tioxyde Europe: finished product	-	<0.00 41	<0.00 14	-	-	<0.00 13	-	-
Tioxyde Europe: Slag	-	<0.04	-	-	0.048	0.009	-	0.155
Millenium Chemicals Le Havre: tartar (wastes)	<11.5 1	251.2	252.2	37.42	493.7	543.4	<0.3	<2.04

Table 5: specific activities Bq/g, dossiers 3, 5, 7, 44, 75

The biggest specific activities are shown up in the wastes produced by the chemical treatment of titanium mineral, namely the rutile.

2.4 Workers' exposure

Description of the processes

The treatment of the kaolin mineral (or the kaolinised granite) is done firstly by cleaning, then by mechanical separation of the different components of the brute mineral. At Imerys Ceramics France (ICF, dossier no.5), three products result from the treatment: kaolin, sand and the tin-tantalum concentrate (concentrating the natural radioactivity of the ore), absent from the production of SOKA (dossier no.6). This concentrate is produced in the form of black sand.

The treatment of the aluminium ore (bauxite) at the Gardanne site is done through reaction of the ore with sodium bicarbonate after fine grinding. The liquid then obtained undergoes a series of operations before being precipitated in hydrated form (dilution, settling, cleaning). The last phase of this process (filtration, calcination) involves giving the alumina physical-chemical characteristics adapted to its various uses. Each year the Gardanne site produces around 650,000 tonnes of aluminium from bauxite (sedimentary rock) with the resulting production residue being the bauxaline which will eventually be used for other purposes, in particular as an intermediary layer at the wastes storage centre. The practice of dumping this residue in the sea should cease in 2016.

The treatment of the titanium ore (ilmenite, rutile and slag) also calls for industrial processes whose main transformation stage involves a chemical reaction, as described above. At Thann-Ochsenfeld, the production of titanium oxide is done by sulphuric means; the ore's natural

radioactivity concentrates mainly at the installations for the filtration and hydrolysis of the black liquor and installations for the production of titanium tetrachloride. Lower levels of concentration are also observed at the piping, valves, pumps... The dose rates measured on these various installations range from 0.53 $\mu\text{Sv}/\text{hour}$ to 11.9 $\mu\text{Sv}/\text{hour}$, and can vary over time for the same installation. When maintenance work is being carried out, radioactive wastes is generated (equipment and tartar). The nearby Ochsenfeld site stores the wastes that are low in radioactivity in anticipation of a dedicated removal channel. The other wastes are cleared in the class 1 storage centre. At the now closed Le Havre site, Millenium Chemicals also produced titanium oxide; its production generated enhanced natural radioactivity wastes (see Table 5).

Tioxyde Europe also uses the sulphurous process. The radioactivity concentrations observed at Millenium Chemicals are not cited by Tioxyde Europe, which uses slag (naturally less radioactive than ilmenite).

Dose evaluation

For the treatment of tin ore (dossier no.5), the most exposed workplaces are those that are positioned near the tin-tantalum concentrate whose specific activity is around 10Bq/g of ^{238}U and ^{226}Ra (see. §2.3 of this annexe). The maximum dose received by an ICF employee (laboratory) is 1.4 mSv for 1600 hours of work, mainly due to the dose rate in this location (0.4 to 0.71 $\mu\text{Sv}/\text{hour}$) as well as the alpha volumic activity of the dust in the air (16 mBq/m³ of air). Close by to the tin-tantalum concentrate, the dose rate is 10 $\mu\text{Sv}/\text{hour}$.

The IRSN notes in its note of 11th July 2007 that the calculation hypotheses are considered as too conservative (duration of exposure equal to annual working time, taking into account the radon in the dose estimations, volumic activities equal to the detection threshold), which probably leads to an excessive dose assessment for the workplaces analysed.

For the treatment of aluminium (dossier no.75), the gamma cartography of the installations shows higher dose rate levels at the press filter (filter cake park), the bauxite stock and contact with the cleaning tartar in the autoclave, at the level of those found in the regions of France where natural radioactivity is higher than in the Gardanne region (100 c/s at 2m from the bauxite stock, maximum found at the site at 180 c/s at contact with the "filter cake" stock). The dose rates measured at the installations range from between 40 nSv/hour (reference point) and 100 nSv/hour for the washers (90 nSv/hour for the filter cake). The alpha volumic activity of the dust in the air is at the most equal to 9mBq/m³ in the bauxite unloading area (the reference point level being 0.5mBq/m³).

The workplaces used for the dose evaluations are linked to the proximity with the three potential source terms: bauxite, autoclave area and the press filter area. A reference exposure scenario and a scenario linked to the presence on site are also studied. The external radiation exposure pathways, radon and radioactive dust inhalation are evaluated and show effective added doses that range from between 0.06 mSv/year and 0.03 mSv/year (for 1600 hours of work). The most exposed workplace is the "unloading train" and is situated in the bauxite unloading area.

For the treatment of titanium ore, Millenium Inorganic Chemicals (MIC) in Thann carried out various studies and series of measurements in order to evaluate the doses received by the workers. An initial evaluation was carried out between August 2004 and January 2005: those exposed wore an individual alpha dosimeter for three periods of two months. The dose evaluations carried out using these measurements showed that the workers were exposed to between 0 and 1.19 mSv for 1600 hours of work. It is the risk linked to external exposure that seems to be pre-dominant, followed by the risk of radon inhalation. Internal exposure due to dust inhalation is often deemed to be zero, as the measurements are below the detection threshold. The workplaces evaluated are linked to monitoring the installations' black and white

parts (doses between 0 and 0.04 mSv/year), the maintenance of the installations (doses between 0.30 and 1.19) and the intervention of an external company for carrying out maintenance work (0.07 and 0.09 mSv/year). The most exposed workplaces is linked to the intervention of an electrician for maintenance in a controlled area (1.19 mSv/year), then to the agent which makes the maintenance of the chlorinators (1.00 mSv/year); for these two workplaces, the pre-dominant risk is that of external exposure.

A zoning of installations was carried out by MIC based on dose rate values; fixed monitoring devices (Algade) were installed on the site (in particular in supervised and controlled areas) in order to monitor the risks of gamma radiation exposure as well as the risks of radon and dust inhalation. With regard to dust inhalation risks, one sole result is greater than the detection limit of the measurement method used: for the radon risk (220 and 222), the values are about one hundred nJ/m³ (measurement of potential alpha energy due to short life decay products) for each of the isotopes.

An individual dosimetric follow-up on the workers who had to work in the supervised or controlled areas is carried out on-site. This equated to a total of 119 individuals in 2009, employees of MIC. The employees of external companies working in these areas must also be equipped as such, at the request of MIC: the results of the passive and operational dosimeters show that the value of 1 mSv/year is not exceeded. Workplace studies will be carried out by MIC in order to include the risks linked to dust and radon; the definition of the workplaces does, however, seem tricky due to the multiple operations carried out in different areas with no fixed schedules.

Dose evaluations at the workplaces (external and internal exposure) were also carried out for the Le Havre site in 2005. The dose rate levels in agent change areas varied between 0.07 and 1.5 µSv/year, with certain hot points showing a dose rate that could reach up to 20 µSv/hour in case of contact. The alpha volume activities in dust in the grinding areas (work areas of those agents responsible for the supply of coal mills) were between 4.7 and 15.1 mBq/m³ of air (the maximum value of 28 mBq/m³ is found in the ilmenite storage building). The exposure scenario used for evaluating the doses combines the dose rate value from the background noise and an average of the alpha volume activities in dust, for an exposure period of 1600 hours per year. The calculated annual dose (external exposure and dust inhalation) is 0.62 mSv/year. The measurements of radons carried out on-site were not included in the dose calculation. With regard to the storage area for wastes in barrels, Algade mentions a dose rate of 2.2 µSv/hour and a very high level of specific activity of wastes in its report (internal exposure risk if they are released into the air), which could easily lead to 1 mSv/hour being exceeded.

Tioxyde Europe has not carried out an evaluation on the doses received by the workers.

The summary of effective added doses for the workers is presented in paragraph 3.3.2 in the body of the report.

Measures for reducing exposure

The distance of the source term from the workers as well as its limitation in quantity was used by Imerys Ceramics France (ICF), particularly in the laboratory. The laboratory technicians are subject to a dosimetric follow-up and have individual protection equipment available. Following the inspection on 10th March 2009, the ICF were requested to implement the requirements of the Labour Code in accordance with article R.4457-13 of the code.

At Millenium Inorganic Chemicals (MIC), the implementation of the zoning, the individual dosimetric follow-up of the workers for external exposure, the acknowledgement of the radiological risk in the prevention plans passed with the outside companies concerned, as well as the monitoring of radon, dust and gamma radiation exposures in the supervised and controlled areas by fixed measurement devices allows the risk linked to the NORM materials on these installations to be assessed. The implementation of measures to reduce exposure for the employees is carried out for the posts showing the highest levels of risks of exposure to the NORMs (implementation in the tanks) by limiting the time of exposure and the wearing of individual protection equipment (filtering cartridge mask, gloves, overalls).

2.5 Exposure for the public

Among the studies cited in §2.2 of this annexe, only five evaluate the dose received by the public. The IRSN estimates that in 70% of the studies, the approach taken by the industrial party is the correct one: external exposure and internal exposure by dust inhalation were, on the whole, well evaluated; only exposure caused by radon was not really examined. The effective added doses excluding radon range between 80 $\mu\text{Sv}/\text{year}$ and 1330 $\mu\text{Sv}/\text{year}$. The population group receiving a dose of 1.33 $\mu\text{Sv}/\text{year}$ corresponds to the study lead by Millenium Chemicals for the Thann and Ochsenfeld sites. The IRSN draws attention to the upper bound nature of this value. It was established based on the assumption of 7000h/ year of presence in the vicinity of the piping circulating the effluents at the treatment station. Nevertheless, the IRSN underlines that the dose rate measured is 0.31nGy/hour while the natural background noise was estimated at 0.12nGy/hour by the industrial party. The industrial party also specifies that additional measurements demonstrate the significant influence of this piping.

By not taking into account the effective dose presented in the study lead by Millenium Chemicals for the Thann and Ochsenfeld sites, the effective added doses presented vary between 80 $\mu\text{Sv}/\text{year}$ and 140 $\mu\text{Sv}/\text{year}$. The IRSN underlines that these doses are weak. Internal exposure is the pre-dominant means of exposure. These results are consistent with those published in the literature, in particular those published by UNSCEAR [15] which shows that in some cases the effective dose received by the public living in the vicinity of the installations can be 100 $\mu\text{Sv}/\text{year}$.

2.6 Quality of the studies received

No study on the treatment of copper, niobium, bismuth or thorium ores has been received. As a result, only the installations for the treatment of tin, aluminium and titanium ores are studied in this analysis (which includes study no.6 as well as no.71 and no.74, see §13.2).

With regard to the standard operation of the installation, the description of the processes is deemed to be generally satisfactory and enables the workplaces to be identified. The external exposure has been well evaluated. With regard to exposure by dust inhalation, this pathway of exposure has not been examined in around 30% of cases. Nevertheless, where it has been examined, it has been well evaluated. Exposure caused by radon is generally well examined and measured and the IRSN underlines that the measurements carried out show generally weak concentrations of radon. All the calculated effective individual doses are added individual effective doses and for half of the workplaces do not take into account the dose caused by the radon. Nevertheless, they are based on duration of exposure that is not specific to the workplace. In order to evaluate an individual effective dose received by the workers in the most realistic way possible, the IRSN deems it desirable to use durations of exposure that are adapted to the installation.

The IRSN believes that maintenance and dismantling of the installations must be taken into account and described in the evaluations in accordance with the Order of 25th May 2005.

2.7 Result

According to the French Aluminium Association, only the Gardanne site processes the aluminium ore in France. According to Millenium Chemicals, the only two sites that are still active in terms of titanium ore treatment are MIC in Thann and Tioxyde Europe in Calais. According to the ICF, only the Kaolin site in Beauvoir processes tin ore in France. As such, the studies received relating to these areas of activity seem to cover the entire production.

Workers' exposure to enhanced natural radioactivity in the industries of titanium and tin ore treatment is liable to exceeding 1 mSv/year if no protection measure is put in place. With regard to the treatment of aluminium ore at the Gardanne production site, workers' exposure to enhanced natural radioactivity is less than 1 mSv/year. The implementation of simple radioprotection measures in order to reduce the dose received by the workers (reduction of working time, distancing the source of exposure from the workplace) seem easily achievable, in the manner of the options used by the ICF due to the mobile nature of the natural source of radiation. For MIC, the reduction of the dose received is more tricky to put in place due to the presence of NORMs in the installations themselves, that are, by definition, not mobile. The possibility of requesting the application of the Labour Code in accordance with article R.4457-13 must, therefore, be retained.

The definition of the zoning on the installations seems to be trickier due to a risk of internal contamination. Integration of the dose by dust inhalation in the definition of zoning, the variation in the dose rate values over time (depending on production and the cleaning carried out on the equipment, for example) may lead to an under-estimation or an over-estimation of the surface area of areas considered as supervised or even controlled. The risk linked to the radon must be seized by the volume activity of the air, apart from the definition of regulated areas, in order to not include it in the dosimetric evaluations.

The application of exemption thresholds as defined in reference [5] and in the paragraph "Notion of exemption for natural sources of radiation" would lead to the exemption of the following document:

- Rio Tinto Alcan, Gardanne site, traitement de minerai de bauxite pour production d'alumine (*treatment of bauxite ore for production of alumina*), Algade, 2007 (no.75)

Among the dossiers received for this professional activity category, the Huntsman Tioxyde (no.44) et Rio Tinto Alcan (no.75) dossiers do not show any doses greater than 1 mSv/year for the workers. Dossier no.6 does not give any measurements of the specific activity of the NORM materials.

3 Production of refractory ceramics and glassmaking, foundry, steel industry and metallurgy using refractory ceramics

3.1 French situation

Refractory ceramics owes its natural radioactivity to the presence of various raw materials: kaolin, alumina, bauxite, zircon, monazite or clay, for example. It is mainly the percentage of zircon in the ceramic that causes its natural radioactivity to vary. Due to their heat resistance, the refractory ceramics (and on a larger scale the refractory products) are mainly used as a compound in internal walls of ovens, crucibles or other appliances subject to high temperatures. The cement works,

steel industry, foundry, paper mill, metallurgy and glass making sectors are the main consumers of these materials.

Masonry work on ovens or crucible requires the use of specialist staff; the specialist companies are CTIO, the EML group (Prevel, Thermio, Banette), Ferdeck & Fumitherm (non-exhaustive list). SEPR is the main producer of refractory ceramics in Europe: some companies are specialists in the valorisation of refractory materials (notably Valoref and Recumat).

The dossiers received in application of the regulation relate mainly to the use of refractory ceramics as masonry, glassmaking, oven, and steel industry parts, as well as the producers or recyclers of these ceramics. The metallurgy and steel industry sector was able to meet the requirements of the Order of 25th May 2005.

According to the MEEDM figures, there are 84 specialist sites in the glass industry in France. There are six companies that specialise in industrial heating and 26 suppliers of refractory materials in zircon, bauxite and zirconium oxide or brick blocks in bauxite or zircon (Kompas database).

3.2 List of dossiers received

Endorsed by the regulation:

- PCC France, precision steel industry of lost wax, IRSN, 2007 (no.9)
- Sanden Manufacturing, aluminium foundry, Algade, 2006, (no.11)
- Federation of trade union chambers in the glass industry (FCSIV), use of refractory ceramics for internal walls in ovens, Algade, 2007 (no.17)
 - Duralex International France (no.18)
 - Eurofloat, glassmakings, (no.31)
 - Arc International Cookware SAS, glassmakings, (no.32)
 - Saint-Gobain - ISOVER France, glassmakings, (no.33)
 - OI Manufacturing France, glassmakings, (no.35)
 - Saint-Gobain Emballage, glassmakings, (no.37)
 - Saint-Gobain Emballage, glassmakings, (no.38)
 - Saint-Gobain Emballage, glassmakings, (no.39)
 - Saint-Gobain Emballage, glassmakings, (no.40)
 - Tourres et Cie Saverglass, glassmakings, (no.41)
 - INTERPANE Glass France S.A.S., glassmakings, (no.42 and no. 55)
 - Saint-Gobain Desjonqueres, glassmakings, (no.43)
 - Saint-Gobain Emballage, glassmakings, (no.45)
 - Saint Gobain Vetrotex, glassmakings, (no.49)
 - SAVERGLASS, glassmakings, (no.50)
 - OI Manufacturing France, glassmakings, (no.51)
 - AGC Glass unlimited, glassmakings, (no.56)
 - Euroglass, glassmakings, (no.61)
 - Saint-Gobain Glass, glassmakings, (no.63)
 - Bormioli Rocco, glassmakings, (no.70)
- Société de Traitements Chimiques des Métaux, foundry, Apave, 2007 (no.34)
- Le Bronze industriel, foundry(no.46)
- Valoref, receipt, separation and recycling of refractory ceramics, Algade, 2007 (no.47)
- Valoref, demolition of a glass oven, Algade, 2008 (no.47)
- FerroAtlantica - PEM, steelworks, 2007 (no.48)
- Société de Traitements Chimiques des Métaux, foundry, Apave, 2007 (no.62)

- CTIF, welders generic study, 2006 (no.64)
 - o Montupet, foundry, 2007 (no.23)
 - o SAFEM, foundry (no.60)
- Rockwool France, Use of bauxite for production of rockwool, Algade, 2008 (no.71)
- SAPA Profilés Puget, foundry, Apave, 2006 (no.72)
- Aluminium Dunkerque, use of refractory bricks in foundry - steel industry, Algade, 2008 (no.74)
- SEPR Le Pontet, production refractory ceramics, 2008 (no.78)

Not covered by the regulation:

- Fonderie et ateliers du Bélier, foundry using zircon cement, CTIF, 2007 (no.25)
- Daussan, production of refractory products (cement and pulverulent powder), Algade, 2007 (no.52)
- Ferro Couleurs France, use of refractory products, Algade, 2007 (no.66)
- Terreal, manufacturing of refractory ceramics, IRSN, 2008 (no.68)

The generic study of the glass industry, carried out on five different glassworks, was used by 20 French glass workers (according to the 84 MEEDM figures¹)

Outwith regulation, the dossiers submitted by Fonderie et ateliers du Bélier (no.25), Daussan (no.52), Ferro Couleurs France (no.66) and Terreal (no.68) show no particular features with regard to enhanced natural radioactivity. Only Ferro Couleurs France uses zircon (see §5 of this annexe) for foundries using zircon. Vermont S.A.'s response to the letter from ASN (dossier no.26) has not been included in this summary. The steel industry and metallurgy sectors have provided little response to the Order of 25th May 2005.

3.3 Characterisation of materials

Some products are characterised by a measurement of the dose rate or c/s^2 . The measured dose rates at contact of refractory bricks are included in a range of values ranging from 230 nSv/h to 1400 nSv/h (800c/s). This maximum value reaches 800 nSv/h at 1 metre. The measurements at contact with the ovens in service vary between 30c/s and 1000c/s (for particular items made from zircon).

The measurements of the specific activities of refractory ceramics³ show values between 0.05 and 4Bq/g for the radionuclides belonging to the chain of ²³⁸U, 0.052 to 0.8Bq/g for the radionuclides belonging to the chain of ²³²Th and 0.014 to 0.4Bq/g ²³⁵U; activities variable depending on the sources of supply. The international bibliography mentions values that can reach up to 10Bq/g for refractory ceramics [10]. No measurement contained in the dossiers received has shown such levels in France.

Other products are analysed, in particular the specks on the dust collectors, the chamber sulphates and other combustion residues, likely to concentrate the 210 lead at 1.5 to 2Bq/g due to the thermal treatment, or even several dozen Bq/g at SEPR (see

Table 6).

¹ Public database of installations classified for the protection of the environment: www.installationsclassees.ecologie.gouv.fr

² Dossiers no.17 FCSIV, STCM no.62 and 34

³ Dossiers PCC France no.9, Sanden no.11, FCSIV no.17, Valoref no.47

	²³⁸ U	²³² Th	²³⁵ U	⁴⁰ K	²¹⁰ Pb
Raw material: bauxite	0.1 to 0.5	0.3 to 0.5	-	0.15 to 0.25	-
Raw material: zircon	3.0 to 4.1	0.60 to 0.80	0.19 to 0.30	<2.2	1.8 to 2.8
Raw material: brown corindon	0.4	0.5	-	<0.23	-
Raw material: chamotte	0.35	0.4	-	<0.14	-
Ceramics (PCC France)	0.29 to 0.89	0.052 to 0.14	0.014 to 0.037	0.0095 to 0.011	-
Chamber wastes (FCSIV)	3.12	0.60	<0.12	0.45	-
Chamber sulphates (FCSIV)	0.02	<0.02	<0.05	0.20	-
Steam from purifier (FCSIV)	<0.02	<0.02	<0.02	<0.02	2
Potassium carbonate (FCSIV)	<0.03	<0.05	<0.05	19.7	-
Oven dust (Sanden)	<0.02	<0.02	<0.03	<0.11	-
Oven refractories (Sanden)	0.05	0.16	<0.03	<0.11	-
Refractories (SEPR)	1.1 to 2.7	0.3 to 0.6	0.06 to 0.2	-	0.1 to 0.3
Intermediary product: thermal silica (SEPR)	0.7	0.3	<0.08	-	10.5
Wastes: acidic silica (SEPR)	0.36 (²³⁴ Th)	0.05 (²²⁸ Ac)	<0.06	-	70.3

Table 6: specific activities in Bq/g, dossiers 9, 11, 17, 78

3.4 Workers' exposure

Workplaces related to maintenance of the ovens or management of refractory ceramic wastes would potentially be exposed [10].

Description of the manufacturing process

At SEPR, the production of refractory ceramics, marble and powders (electric fondues) is done using zircon sand, 40,000 tonnes of which is used each year, alumina and other raw materials. The production of ceramics is done melting these materials, the SPER having a park of 8 electric arc fusion furnaces. The finished products are stored on-site before being shipped.

Glass makers, steel industry and foundries have one or several ovens or crucibles whose inside walls are made of refractory materials. Wastes linked to the use of an oven is the wastes from the combustion found on the ground of the oven, as well as the wastes (refractory ceramics) resulting from the maintenance of the oven, whose inside walls lose some of their thickness whilst it is in service. However, this production mode does not lead to any significant concentration of radioactive elements in the used refractory ceramics, which keep their original composition. Only the steam and residue from the combustion can concentrate the ²¹⁰Pb.

The workers' risk of exposure in these industries is linked to the storage of zircon (external exposure), to the grinding and bagging during the production and recycling of the ceramics (internal and external exposure), to the presence of refractory ceramic ovens or when handling wastes resulting from fusion.

The dossiers received identify almost exclusively the risk linked to the presence of zircon in the refractory ceramics. Only Daussan and Terreal analyse the radioactive risk for the production of refractory products not using zircon, which is below 1 mSv/year according to the evaluations by IRSN and Agade.

Dose evaluation

Production of refractory ceramics

Since 1987, the SEPR has carried out several measurement campaigns aimed at evaluating the doses received by the workers due to the use of zircon, by taking into account external exposure, radon inhalation and dust inhalation. The workplaces concerned are linked to oven maintenance, transport and storage of zircon and some finished products made from zircon, supervision of ovens as well as the management of wastes such as dust at the bottom of the chamber and dust resulting from steam filtration installations. In total, 385 workers are potentially exposed to the enhanced natural radioactivity of the zircon. The first campaigns of measurement and dose evaluation of workplaces enabled the identification of the workplaces liable to being exposed to more than 1 mSv/year. The 1996 campaign showed that the highest external exposure values are found when coming into contact with products (storing finished products, assembly of refractory blocks, receipt of bags of zircon, opening zircon silos), exposure to radons was considered negligible, and internal exposure linked to the inhalation of dust was shown to be a risk at three workplaces.

In 2003, 36 out of 385 employees are considered as being potentially exposed, the maximum dose being evaluated at 2.1 mSv/year; exposure to radon is then included in the dose calculation. As the uncertainties over the measurements are rather significant (due to the weak values shown, in particular for the radon and dust compounds), a final study was carried out in 2006-2007 in order to hone the radon measurements by increasing the capacity of the sampling devices (from 4 l/h to 80 l/h) over a sampling period of six months. The results of the measurements show that the radon risk seems to have been over estimated (it goes from 1.5 mSv/year to 0.1 mSv/year). Furthermore, the creation of sealed cabins and the improvement of the ventilation enabled the level of dust inhalation to be reduced for workplaces identified as being at risk. This last campaign of measurements conducted by Algade showed that the workers' exposure was between 0.22 and 0.53 mSv/year (effective added dose for 1600 hours of work). External exposure varies between 0.14 and 0.43 mSv/year; internal exposure (alpha volumic activity of dust in the air) varies between 0.01 and 0.12 mSv/year, and the exposure to radons (222 and 220) between 0.01 and 0.07 mSv/year. The most exposed employees are those who work at the zircon bead production.

Glassmaking, foundry, steel industry and metallurgy using refractory ceramics

In the typical use of glass work refractory ceramics (oven in service or storage of refractory ceramics), it is mainly masonry parts made from zircon that increase the dose rate measured near the oven or in the storage areas for materials made of zircon or potassium. In the oven areas, the average values of the dose rates vary between 80 and 200 nSv/h (maximum value: 700 nSv/h). The highest value (1500 nSv/h) occurs at composition (weighing and dispatch to the oven for raw materials). The highest levels of alpha volumic dust activity are also measured at composition (36 and 75 mBq/m³ of air); away from this area, the vast majority of the measurement results are below the detection limit. With regard to radon, there does not seem to be any significant measurement. The effective added doses received by the workers, including the internal (dust and radon) and external exposure pathways are between 0.07 and 0.57 mSv/year depending on the scenario identified. The chimney engineers and the composition workers are those who are most exposed, due to the inhalation of dust (chimney engineers) and the dose rate (composition worker) (dossier no.17). The assessment of the FCSIV dossier by IRSN [16] shows that the glass worker operators can also intervene during the maintenance and cleaning of the ovens or dust collectors. These interventions, not evaluated by the FCSIV, could lead to doses of 0.5 mSv/year, in addition to the doses evaluated in normal service, therefore possibly exceeding the 1 mSv/year value. The IRSN also underlines the large variability of the contribution of the dose due to dust inhalation; for the composition workers, exposure by dust inhalation may be the main exposure

pathway depending on the site where the dose is evaluated. Furthermore, the FCSIV dossier does not specify if the workers' exposure to zircon is taken into consideration in the submitted dose evaluations.

In steel industry, foundry and steel industry, some refractory ceramics are also made of zircon; their radiological characteristics and the workers' risk of exposure do not differ from the use of refractory ceramics in glassmaking. The measurements carried out (at FerroAtlantica, STCM, SAPA, Rockwool France and Le Bronze industriel) show dose rate values of one hundred nSv/h, or even 1 μ Sv/h in penalising cases (inside the STCM ovens). The alpha volumic activity for dust (measurements carried out at FerroAtlantica, STCM, Rockwool France) vary depending on the production sites and the operations carried out; at FerroAtlantica, the maximum value noted is 9mBq/m³ of air, whereas this figure is 62mBq/m³ of air at the post for the preparation of raw materials at Rockwool France. The radon measurements are generally weak. The evaluations of effective added doses (external exposure and dust inhalation) received by workers are shown to be between 0.06 and 0.49 mSv/year for 1600 hours of work (FerroAtlantica, Rockwool France). STCM evaluates the workers' exposure at 0.6 mSv/year for 600 hours (external exposure only, not deducted from background), despite the dust level measurements varying from 60 to 220mBq/m³ of air.

Rockwool France's specific activity of combustion ash shows an imbalance of the ²³⁸U chain in the form of a concentration in ²¹⁰Pb of 5, 11 and 18Bq/g.

At Aluminium Dunkerque (foundry – steel industry), some refractory bricks exceed the background (300 per second instead of 30). However, the levels of radioactivity are weak (maximum dose rate in atmosphere at 300 nSv/h inside an oven, 420 nSv/h in case of contact with Pomagri, a raw material made from potassium) and the refractory bricks (and not refractory ceramics) do not seem to contain any zircon; the alpha volumic activity for dust is significant in the penalising case of an oven demolition site: it is evaluated at 112mBq/m³ of air. Depending on the exposure scenarios, the effective added doses received by the workers is between 0.07 and 0.18 mSv (external exposure and dust inhalation) for 1600 hours of work per year. For the example of the oven demolition site, the doses evaluated are 13 and 21 μ Sv for 20 hours of work (mainly internal exposure by dust inhalation).

At Montupet and Sanden, the dose rate measurements carried out in the agent development areas do not show any significant increase in relation to background noise (0.1 μ Sv/h). Only a product made from potassium has an enhanced natural radioactivity due to the presence of ⁴⁰K. At Sanden, the volume activity in radon is lower than 50Bq/m³, and the alpha volumic activity for dust is lower than 1mBq/m³ of air. Nevertheless, given a value of 1mBq/m³ of air, exposure for the workers would be 36 μ Sv/year.

Workplace	Hours of work	Effective added dose	Ways of being exposed that were studied
Oven operator (working near oven)	1600 h	0.27 mSv/year	External radiation exposure, EAP equivalent dose, equivalent dose in dust
Maintenance worker (working on the oven)	1600 h	0,3 mSv/year	External radiation exposure, EAP equivalent dose, equivalent dose in dust
Chimney engineer (oven repair)	1600 h	0.57 mSv/year	External radiation exposure, EAP equivalent dose, equivalent dose in dust
Composition worker (mixing raw materials)	1600 h	0. 54 mSv/year	External radiation exposure, EAP equivalent dose, equivalent dose in dust
Stock controller (near the stock of raw materials)	1600 h	0. 12 mSv/year	External radiation exposure, EAP equivalent dose, equivalent dose in dust

Table 7: dose evaluations provided by FCSIV

Oven repair and maintenance

The oven maintenance work may be sub-contracted to external companies, or occasionally carried out by foundry or glass works employees. At Rockwool France (dossier no.71), PEM (dossier no.48) and Arc International (dossier no.32), the workplace of “chimney engineer” was subject to a dose evaluation for the internal and external exposure compounds. The first two sites indicated that an chimney engineer received a dose of 0.26 mSv/year for 100 hours of work (external exposure and dust inhalation). Arc International evaluates the exposure time of their chimney engineers at 800 hours of work per year, i.e 0.38 mSv/year based on figures from the FCSIV study. At Aluminium Dunkerque, the doses received when working at the demolition site are 21 µSv for 20 hours of work, which could lead to exposure greater than 1 mSv/year for an individual engaged in permanent employment at a demolition site.

Valoref offers sorting and removal services for refractory wastes resulting from demolitions or oven maintenance. The level of recovery of the wastes can thus reach 60%. For a 9 day long maintenance operation, where 7,000 tonnes of wastes is sorted, Valoref studied the risk linked to the enhanced natural radioactivity of products made from zincon, by providing site dosimeters and individual dosimeters for the measurement of the dose rate and the alpha volumic activity for dust. All workplaces are considered: site manager near the refractory (1420 hours), the wastes sorter manually working at a conveyer belt where the wastes is moistened (620 hours), the “sulphate” workplaces involving removing dust and sulphates from the bottom of the chamber (160 hours), the vehicle drivers carrying out the demolition of the oven (320 hours), and the worker assisting the vehicle drivers (320 hours). The effective added doses vary from 0.09 to 0.29 mSv/year. The most exposed workplaces are those of the foreman (mainly external exposure) and the sulphate collectors. For the sulphate collectors, it is the internal exposure to dust that is damaging (0.19 mSv/year); the alpha volumic activity values for air range up to 92.6mBq/m³ of air (²³⁸U and ²³²Th).

Recycling of refractory ceramics

Valoref (recovery and reuse of refractory products) studied the impact of their recycling operations of refractory ceramics containing zircon for their employees at the Bollène site. The most exposed workplaces are linked to those involving the grinding and sorting of the materials, given the importance of the “proximity to end source / hours of work” relationship in the dose evaluations. The study carried out by Algade in 2000 showed effective added doses of between 0.1 mSv/year (quality control) and 1.9 mSv/year (sorting-prebreaking) . After having honed these measures with a second campaign in 2003 (increased volumes of sampling for the radon measurement), the second evaluation showed effective added doses of between 0.04 mSv/year (loading / unloading of products) and 0.59 mSv/year at the “bagging” workplace (placing a product that has been finely ground to 0 to 0.5mm in a big-bag). The dose evaluations take into

account the following means of exposure: radon inhalation, dust inhalation and external radiation exposure.

The inspection carried out on 27th March 2008¹ on these two sites in the presence of Algade enabled the employees' working conditions to be verified and allowed for an effective implementation of collective protections against the risk of inhaling radioactive particles (sprayers on the sorting chain, dust collectors).

The dust and sulphates in the chamber are recovered as final wastes by specialist companies.

The summary of effective added doses for workers is presented in paragraph 3.3.3 of the body of the report.

3.5 Exposure for the public

34 studies evaluate the exposure of the people living in the vicinity of the refractory ceramic production installations and the glassmaking, foundry, steel industry and metallurgy activities using refractory ceramics. Of the 34 studies, only six evaluate the dose received by the public.

The means of exposure were well evaluated. Where some means of exposure were not examined, this is explained. Exposure due to radons is treated in a more heterogeneous manner. It is only considered in one single dossier, i.e. six population groups. These calculations indicate that exposure to radons is significant in some cases.

The effective added doses excluding radon range from 10 $\mu\text{Sv}/\text{year}$ to 600 $\mu\text{Sv}/\text{year}$. Statistically, no means of exposure appears as pre-dominant in terms of dose. With regard to the effective dose of 600 $\mu\text{Sv}/\text{year}$ evaluated by the Société Européenne des Produits Réfractaires (SEPR) of Le Pontet, the IRSN underlines that this value is rather pessimistic given that the industrial party used a dose rate measured at a location that is not accessible for the public (within the confines of the installation and near the installation's guardhouse) and an exposure time of 7000 hours per year. The IRSN notes four other values greater than 150 $\mu\text{Sv}/\text{year}$ and corresponding to the study submitted by Valoref of Bollène. They all correspond to a pessimistic calculation given that the industrial party used a "residence" style exposure scenario (exposure duration of 6300 hours per year or 7000 hours per year) while there are no homes situated in the vicinity of the installations. With the exception of these values, the effective added doses submitted range between 10 $\mu\text{Sv}/\text{year}$ and 140 $\mu\text{Sv}/\text{year}$. These results are consistent with those published in the literature, in particular those published by UNSCEAR [15].

The summary of the effective added doses for the public is given in paragraph 3.4.3 of the body of the report.

Furthermore, of the studies received, the generic study on glassmaking submitted by the FCSIV was subject to an in-depth analysis by the IRSN from which the following point arose: given the results of the measurements carried out on the site and in the installations, the absence of radiologically affected liquid or solid wastes, containment of materials containing natural radionuclides, limited time for storage on site for such solid wastes and weak doses liable to be received due to inhaling rejected dust in gaseous effluents, there is not expected to be any significant radiological impact on the public due to the glassmaking activities.

¹ See report of 27th March 2008 inspection

3.6 Quality of studies received

40 studies evaluate the exposure of workers at the refractory ceramics production installations as well as the glassmaking, foundry, steel industry and metallurgy activities using refractory ceramics. Three of these studies are used as reference points: a generic study on glassmaking, a generic study on foundry and a study carried out on a lead foundry installation using refractory ceramics. The generic study on glassmaking submitted by the FCSIV was subject to an in-depth analysis by the IRSN, summarised in part under §**Erreur ! Source du renvoi introuvable.** of this annexe. The studies drawing on the reference studies but not demonstrating the relevance of the results of the reference study to their installation were not used. As such, 18 studies and 73 workplaces were used.

With regard to the standard operation of the installation, the IRSN underlines the importance of the description of the processes for the identification of the exposed work workplaces and believes that the studies should be improved on this point. The means of exposure were generally well evaluated. Nevertheless, the IRSN believes that, for around 10% of the workplaces, internal exposure by dust inhalation was neglected with no satisfactory explanation. The calculated effective individual added doses are, for most workplaces, effective individual added doses that do not take into account doses caused by radons. 80% of them are based on a duration of exposure that is not specific to the workplace. In order to evaluate an effective individual dose received by the workers in the most realistic way possible, the IRSN proposes to use durations of exposure that are adapted to the installation. Furthermore, the measurements carried out show weak radon concentrations.

The IRSN believes that the maintenance and dismantling of the installations must be taken into account and described in the evaluations in accordance with the Order of 25th May 2005. The IRSN selected the effective individual added doses excluding radons for which either the external and internal exposures were used in the evaluation or, if one of the means of exposure was not used, it was deemed to be insignificant by the IRSN. With the exception of one workplace, the effective individual added doses do not exceed the limit of 1 mSv/year. This is consistent with the maximum effective individual dose published by the AIEA [14].

3.7 Result

The use of refractory ceramics as materials for making oven doors is not likely to involve a dose greater than 1 mSv/year for the workers, due to the ceramics' weak level of radioactivity, especially as they do not contain any zircon, and in the absence of any operator working in the immediate vicinity of the oven, except in the case where the operators take part in the dismantling of a production oven.

The production or recycling of refractory ceramics made from zircon is likely to lead to doses greater than 1 mSv/year, in particular due to the inhalation of dust, if no protection measure is put in place (fogging of sorting chains and crushing units, for example).

However, it is mainly the repair and demolition of ovens containing refractory ceramics made from zircon that induce the highest individual doses, if this work is carried out by the same person throughout the whole year.

Furthermore, products other than the refractory ceramics may contain enhanced natural radioactivity due to the presence of zircon.

Nevertheless, a difficulty exists in the measurement of the alpha volumic activity for dust and radons. Taking into account the detection limit value for the dose calculations (instead of a zero

value and in the absence of a sufficiently accurate measurement) may lead to an overestimation of the received doses (FCSIV, Valoref and SEPR dossiers).

The implementation of simple protection measures may be studied for the workers specialised in oven masonry (chimney engineers) and for the workers of companies recycling or producing these products in order to reduce the doses received. However, if these employees are carrying out these activities on a full time basis, individual protection must be worn, justified by drafting risk analyses. The industrial party should also periodically review, or in the event of a change in their installations, the dose evaluations or the risk analysis. Drafting a guide of good practices for the benefit of these workers, distributed by the professional organisations, could lead to an improvement in the practices. However, wearing a mask is often made compulsory due to the risk of dust inhalation (without considering radioprotection).

Applying exemption thresholds as defined in reference [5] and the “Notion of exemption for natural sources of radiation” paragraph would lead to the exemption of the following dossier:

- Aluminium Dunkerque, utilisation de briques réfractaires en fonderie – sidérurgie (*use of refractory bricks in foundry – steel industry*), Algade, 2008 (no.76)

Only the first documents drafted by Valoref (no.47) and SEPR (no.78) (not taken into account in this §3) show doses greater than 1 mSv/year for the workers. The dossiers submitted by the companies specialised in the masonry of ovens, or that of Valoref for a demolition site, show that the workers can receive over 1 mSv/year if they regularly work in the working conditions analysed for carrying out the studies. Dossiers 18, 31, 32, 33, 34, 35, 37, 38, 39, 40, 41, 42, 43, 45, 46, 49, 50, 51, 55, 56, 60, 61, 62, 63, 64, 70, 72 do not show any specific activity measurements of NORM materials.

4 Production or use of compounds containing thorium

International bibliography

The doses received by the workers at a particular site due to storing TIG electrodes (among other products) would be around 1.9 µSv for 1700 hours of work [14].

4.1 French situation

Thorium 232 is used as an additive in certain products, including:

- Steel industry electrodes ;
- Optics;
- Magnesium/thorium alloys used in aeronautics.

Thorium enhances the alloys’ resistance to heat (steel industry electrodes, aeronautics). At the Thales Group, adding thorium is carried out for camera optics or pods imported from England, and used on vehicles or planes. TIG steel industry electrodes are no longer produced in France, but are stocked by distributors (for example Air Liquide Weldline).

4.2 List of dossiers received

Endorsed by the regulation:

- Montupet, fonderie, utilisation d'une électrode de soudure TIG au thorium (*foundry, use of a TIG thorium steel industry electrode*), 2007 (no.23) ;
- Satori, atelier de maintenance de carters d'aéronautique (*maintenance site for aeronautical cases*), ITFP, 2008 (no.80) ;
- Thales Optronique S.A. (TOSA), 2009 (no.81).
- Rhodia, 2007, no.36, see §18.2

4.3 Characterisation of materials

Thoriated tungsten steel industry electrodes contain a few percent Thorium 232 (74Bq/g of thorium 232 for the WT20s), which increases their longevity and improves the electric arc's striking. According to a 2001 document from the Regional Health Insurance Centre (CRAM) (Centre region), the WT20 model would contain 275mg of Thorium for an activity of 1.13MBq of ²³²Th. Montupet measured a dose rate at contact of the electrode of 0.2 µSv/h.

According to the study carried out by Satori, the "ATAR" cases from the F1 and Super Etendar inspections contain a thoriated magnesium alloy of 4%. No measurement of the specific activity of these alloys has been carried out; the dose rate at 5cm of the casing is 15 µSv/h.

At the Thales Group, the largest thorium optic measurements 650cm² and can contain up to 1.5g of thoriated tetra fluoride ThF₄.

Table no.8 below shows the specific activities submitted by Rhodia in dossier no.36.

Material	²³² Th	²²⁸ Ra	²²⁸ Th	²³⁵ U	²²⁷ Ac	²³⁸ U	²³⁰ Th	²²⁶ Ra	²¹⁰ Pb	²³⁴ U	²³¹ Pa	⁴⁰ K
Brute thorium hydroxide, 2005	720	720	720	10	10	100	100	40	40	100	10	-
Dry RRAs, 2005 (radiferous residues)	143	909	997	0,2	10	5	20	25	26	5	0.3	-
Dry RSBs, 2005 (general solid residue)	48	42	40	0,3	0,15	6	6	3	3	6	0.3	-
Thorium site (thorium oxide or nitrate)	1636 - 3022	1251 - 0	1091 - 3022	-	0 - 0	0 - 0	234 - 432	0 - 0	0 - 0	0 - 0	0 - 0	-
MES type 1	2.8	4.5	5.2	0.2	1.8	5.2	5.2	2.5	2.5	5.2	0.2	-
MES type 2	1.6	2.2	2.3	0.1	1.5	1.8	1.8	0.8	0.8	1.8	0.1	-

Table 8: specific activity of materials for the site at Rhodia, La Rochelle (dossier no.36)

4.4 Workers' exposure

Estimations of the workers' exposure caused by the use of electrodes present some very different conclusions: these range from a negligible risk to a risk of over 6 mSv/year [10].

At Montupet, the electrode is used in a hermetic piece of equipment, and the dust linked to the use of the electrode is recovered in a filter, itself collected by the supplier. As the equipment is hermetic, workers are only exposed when handling the electrode to place it in the sharpening or steel industry assembly. The annual dose received by external radiation exposure is evaluated at 3.4 μ Sv. The TIG steel industry electrode distributors stock the products waiting to be shipped; no evaluation of the radiological impact linked to the storage has been carried out in France.

At Satori, the risk of exposure for staff is linked to the presence of cases in the maintenance workshop and to the grinding carried out on these parts. The alpha volumic activity of dust in the air is evaluated at 3.19 Bq/m³, and the dose rate between two cases spaced around 1m apart is 3.5 μ Sv/h. For 500 hours of work without protection equipment, the dose received would be around 81.75 mSv/year (1.75 mSv/year due to external exposure and 80 mSv/year due to internal exposure). Maintenance of the cases is carried out at a dedicated site. Individual protection equipment (chemical cartridge respirators) is worn by the employees in order to reduce the dose linked to inhalation of grinding dust containing thorium 232. The dosimetric follow-up of the employees is done by chest and wrist passive dosimetrics, as well as by radio toxicological analyses. At a minimum, improvements are to be made to the inhalation system of the site and the relevance of the radio toxicological analyses, which have, so far, been carried out for tritium and, therefore, not relevant; supplements are to be supplied, in particular with regard to the risk analysis and the study of workplaces which has not been carried out in order to evaluate the efficiency of wearing the mask. The application of the Labour Code on this site was subject to an inspection by the ASN on 21/06/2009.

TOSA estimates the dose rate near an optic of 650 cm² containing 2470 Bq of ²³²Th, by comparing the optic to an isolated source, at 30 cm, to be 2.47 μ Sv/h. The evaluation of doses received by the workers for maintenance work carried out by the industrial party (for fitters and repair technicians), does not allow for an opinion to be given on the effective annual dose received by the operators.

The Rhodia site used monazite from 1946 to 1994. Since 1994, the concentrates of rare earth have been imported from China and used directly by the site; the production of brute thorium hydroxide between 1970 and 1987, considered by Rhodia to be a recoverable material, is linked to the use of monazite. In 2007, the site held 186 tonnes of radiferous residue awaiting removal, as well as "general purpose solid residue" (RSB), produced between 1988 and 1993 and low in radioactivity, of which 61,000 tonnes were used as filling material in the La Pallice industrial area with the agreement of the authorities (see dossier no.36). The remains of the RSB (8,023 tonnes) are expected to be removed as wastes that is very low in radioactivity (40%) and radiferous wastes (60%).

The production of thorium oxide is done using existing stock of a thorium nitrate solution; this nitrate is precipitated, filtered, then burned at 900°C before being sieved and then put into metal casks. The effluents resulting from the filtration are processed in the radioactive effluent treatment plant and produce radiferous residue.

The production of “mantle” thorium nitrate is also done using a thorium nitrate solution. The heating, crystallisation, draining and drying processes are carried out successively and allow a dry product to be obtained and contained in barrels. The effluents resulting from the draining process are recycled in the process. The production of compounds containing rare earth is not detailed in the dossier submitted by Rhodia.

Rhodia carried out an evaluation of the doses received by those workers considered to be the most exposed. Three such workplaces were identified by Rhodia: the thorium workshop, the treatment workshop for radioactive effluents as well as maintenance work. In 2005, the maximum dose at the thorium workshop was estimated at 63 mSv/year for 1300 hours of work, external exposure and internal exposure (radon 220) included, then re-evaluated in 2007 at 42 mSv/year. This dose evaluation was made while taking into account the wearing of individual protection equipment (in particular a supplied air hood). In its study, Rhodia mentions that the dosimetric follow-up of the workers, which was carried out throughout the year, allowed this post to be stopped as soon as the dose received reached 15 mSv/year, internal exposure (radon) and external exposure included. Given the new requirements of the Labour Code, the production of thorium was stopped in May 2007. Following an inspection from the ASN in December 2007 and structural adjustments requested by the ASN in January 2008 based on this inspection, this post can be re-activated provided that Rhodia meets its commitments by implementing the relevant structural adjustments as requested.

For the effluent treatment workshop workplace, the dose estimated by Alcade for 80 hours of annual work is 0.34 mSv; the dose is solely linked to external exposure, the radon and dust inhalation measurements give results of zero. With regard to the maintenance work, the creation of the improvement site for the storage of HBT_h was taken as an example; in total, ten people received between 1 and 6 mSv for duration of the treatment operation of about one year.

These three dose evaluations given in dossier no.36 do not provide a good idea of the risk linked to the use of compounds made from thorium; nor do they represent the follow-up carried out by the company on the questions of staff exposure. For the management of radioprotection at the site, Rhodia draws on the requirements of the Labour Code that are applicable to the installations subject to authorisation under the Public Health Code (nuclear activities); 66 Rhodia employees undertook an individual dosimetric follow-up, and 19 employees of external companies were subject to the same requirements (figure varies depending on the year). A person responsible for radioactivity is appointed, means for measuring radioactivity are put in place and measures for the reduction of exposure are taken, in particular at the thorium post: wearing of individual protection equipment and reduction in hours of work. The dosimetric report carried out over the period from April 2007 to March 2008 shows the exposure of five individuals to doses greater than 1 mSv/year, including three individuals employed by external companies (25 individuals for the dosimetric report of 2006).

The regulation on enhanced natural radioactivity is not applicable to the brute thorium hydroxide production sector, as the raw materials are used for their radioactive properties. This may also apply to the production of thorium oxide and nitrate as these compounds are re-used for their radioactive properties. The “treatment of rare earth” part not used for the production of thorium is subject to the requirements of the Order, but has not been taken into account.

4.5 Exposure for the public

Only the study submitted by Rhodia (no.36) evaluates the exposure and the dose received by the people living in the vicinity of the installations for the production or use of compounds containing thorium. External exposure and exposure due to radons were well evaluated. For the

internal exposure via dust inhalation, the IRSN believes that, for certain exposure scenarios used by the industrial party, for example in a children's adventure playground, this means of exposure should have been examined. The industrial party should complete its dossier on this point. The effective added doses excluding radon vary between 12 $\mu\text{Sv}/\text{year}$ and 350 $\mu\text{Sv}/\text{year}$.

The summary of effective added doses for the public is given in paragraph 3.4.4 of the body of the report.

4.6 Quality of studies received

With regard to the three studies received (Satori, TOSA, and Rhodia for the thorium posts only, see. §18.2), the description of the processes is deemed to be, on the whole, satisfactory. The external exposure is well evaluated. With regard to internal exposure by dust inhalation, this means is often neglected by the industrial parties with no solid explanation. There is little examination or measurement of exposure caused by radons. Nevertheless, the IRSN underlines that the measurement carried out shows a weak radon concentration. The effective individual doses calculated for all the posts are individual added effective doses and, for the majority of workplaces, doses not taking into account the dose caused by radons.

The IRSN believes that the maintenance and dismantling of the installations must be taken into account and described in the evaluations in accordance with the Order of 25th May 2005. The IRSN chose individual effective added doses excluding radons for which either the external and internal exposures were used in the evaluation or, if one of the means of exposure was not used, it was deemed by the IRSN to be negligible. The individual effective added doses vary between 1.3×10^{-4} mSv/year and 81.7 mSv/year: the value of 1 mSv/year is exceeded for two workplaces which relate to the production of compounds containing thorium or the fabrication of parts containing thorium. These high doses are, nevertheless, consistent with the data published by the AIEA [17] which specifies that the dose received by the workers at installations producing compounds containing thorium may, in some cases, exceed 20 mSv/year.

4.7 Result

The use of compounds containing thorium may lead to significant doses, particularly in the aeronautical industry, where maintenance work is carried out on parts containing thorium. The grinding may lead to doses linked to internal exposure of around ten mSv for only a few hundred hours of work per year: individual and collective protection is, therefore, a necessity in order to limit the dose received and to not exceed the regulatory limits.

The application possibility of the Labour Code in accordance with article R.4457-13 of this must be kept for these industries, in particular the optimisation of the radioprotection and dosimetric follow-up of the workers. The dosimetric follow-up of the internal exposure may be carried out in accordance with notice IRSN/DRPH/2009-153 cited in reference [18].

The use of thorium steel industry electrodes does not appear to lead to doses greater than 1 mSv/year when the steel industry equipment is hermetic and collects the dust generated.

The application of the exemption thresholds as defined in reference [5] and in the "Notion of exemption for natural sources of radiation" would lead to the following dossiers not being exempt:

- Montupet, fonderie, utilisation d'une électrode de soudure TIG au thorium (*Montupet, foundry, use of a thorium TIG steel industry electrode*), 2007 (n°.23);
- Thales Optronique S.A. (TOSA), 2009 (n°.81).
- Rhodia, 2007, n°.36, see §18.2

Only the dossiers drafted by Montupet (n°.23) and TOSA (n°.81) do not show any doses greater than 1 mSv/year for the workers. Dossier no.80 does not have any results of measurements of the specific activity of magnesium-thorium alloys.

5 The production of zircon and baddeleyite, and the foundry and metallurgy using zircon and baddeleyite

International bibliography

The exposure of workers to enhanced natural radioactivity in zircon powder, ceramic or tile production factories is due to the presence of zircon, a mineral that is naturally rich in radionuclides (see §15.3. of this annexe). Zircon sand or powder is produced by wet or dry grinding of the ore. Zircon grinding leads to external exposure due to the storage of the materials, but also internal exposure due to dust inhalation.

For a presence of 2000 hours per year, the exposure of workers in the zircon powder grinding production factories would be between 0.65 and 3.32 mSv/year. In production factories for tiles or fritted products, exposures vary between 0 and 1.41 mSv/year for the same length of time; the internal doses are almost zero, except when in proximity to the zircon silo (0.32 mSv/year).

The highest doses are linked to external exposure at the zircon storage centre, or the inhalation of dust during the grinding or bagging processes. These dose evaluations are based on hazardous exposure scenarios in terms of working hours [14].

The production of zircon (zirconium oxide) by chemical reaction is liable to producing enhanced natural radioactivity wastes whose specific activities may be close to 5000 Bq/g [14].

5.1 French situation

The element Zr is zirconium, zircon being the chemical combination of zirconium, silica and oxygen ($ZrSiO_2$, concentration in Zr of around 40%). The baddeleyite is comprised of zirconium and oxygen only (ZrO_2 , concentration in Zr of around 70%). Other minerals contain zirconium, some at higher concentrations than the zircon itself. Baddeleyite seems to be the ore with the highest concentration of zirconium. Zircon contains, on average 1 to 5 Bq/g of the elements of the ^{238}U chain.

Zircon has several uses in industry. In France, Cezus (subsidiary of Areva) uses zircon ores to produce a zirconium sponge used in the nuclear industry.

Zircon is also used in different forms for its abrasive or refractory properties: the lost wax precision foundries use the zircon sand as a compound in their grinding; glassmakings and foundries...use it as a compound for refractory ceramics. As such, the foundry and metallurgy processes using zircon are affected by section 3 and 5 of the Order.

To a lesser extent, zirconium is used in disk brake pads, or in prostheses in bio ceramics, for example. As such, Diatomic uses 4 tonnes of zircon per year; 50% is used for the production of dental prostheses and 50 % is used as a component of micro ceramics (electronic).

Some French industrial parties are specialised in the transformation of zircon: Imerys (grain and powder zircon), CMMP (zircon sand) (non-exhaustive list). Four zirconium providers were identified using the Kompass database.

5.2 List of documents received

Endorsed by the regulation:

- Snecma: utilisation de farine de zircon en fonderie (fonderie de précision à cire perdue) (*use of zircon flour in foundry - lost wax precision foundry*), May 2006 (n°.2)
- Cezus: Production de zirconium (*Production of zirconium*), June 2007 and March 2006 (n°.4)
- Gestion des déchets de fonderie de précision à cire perdue (*Management of lost wax precision foundry waste*), 2001, IPSN (n°.8)
- PCC France, fonderie de précision à cire perdue (*lost wax precision foundry*), IRSN, 2007 (n°.9)
- Foseco, utilisation de farine et de sables de zircon (*use of zircon flour and zircon sand*), 2007 (n°.20)
- Unifrax France, utilisation d'oxyde de zirconium (*use of zirconium oxide*), Algade, 2004 (n°.21)
- CTIF, étude générique fondeurs (*foundry worker generic study*), 2006 (n°.64)
 - Fonderie et ateliers du Bélier, fonderie utilisant du sable de zircon (*foundry using zircon sand*), CTIF, 2007 (n°.25)
- Alcan, fonderie (*foundry*), Algade, 2007 (n°.59)
- Ferro Couleurs France, utilisation de zircon pour la fabrication d'émaux (*use of zircon for the production of enamel*), Algade, 2007 (n°.66)
- CMMP, transformation mécanique de sable de zircon (*mechanical transformation of zircon sand*), Algade, 2007 (n°.67)
- SEPR Le Pontet, production de céramiques réfractaires (*production of refractory ceramics*), Algade, 2008 (n°.78)

Outwith the professional activity category:

- Valoref, réception, tri et recyclage de céramiques réfractaires (*receipt, sorting and recycling of refractory ceramics*), Algade, 2007 (n°.47)
- Valoref, chantier de démolition d'un four de verrerie (*glasswork oven demolition site*), 2008 (n°.47)

5.3 Characterisation of materials

The specific activities or measurements of dose rates carried out on the materials vary depending on their quality. The dose rate measured in case of contact with a stock of 1.7 tonnes of zircon flour is 2 µSv/h, 0.35 µSv/h at 1 metre.

	²³² Th	²³⁵ U	²³⁸ U	²²⁶ Ra
Dry material, chlorination wastes (Cezus)	14.1 (average)	1.4 (average)	29.2 (average)	116.7 (average)
Dry material, sublimation wastes (Cezus)	10.0 (average)	14.6 (average)	318.6 (average)	49.4 (average)
Zircon flour (PCC France)	0.460	0.088	3.10	-
Coating bath (PCC France)	0.330	0.066	2.50	-
Zircon ore (Foseco)	0.68	0.16	3.06	3.77
Zircon flour (Ferro Couleurs)	0.7	0.2	4.0	-
Zirconium oxide (Ferro Couleurs)	<0.02	<0.02	<0.05	-

Table 9: specific activities in Bq/g, dossiers 4, 9, 20, 66

5.4 Workers' exposure

Production of zirconium sponges

By reaction with the zircon mineral, Cezus produces hafnium metal, magnesium chloride, zirconium oxide, silicon tetrachloride and zirconium sponges (main production). The main wastes generated by the process is wastes from emptying the "chlorinator" and the "sublimator" ovens (radiferous wastes), mud from the effluent treatment centre and the liquid effluent wastes. The production concept is broken down into several processes, and the major process concerns the production of enhanced natural radioactivity wastes and the existence of radioactivity concentration points in the installations and the carbo-chlorination / sublimation (taking place first of all in the process). The wastes dose rates recorded in the vicinity of the installation range from 1 to 8 $\mu\text{Sv/h}$; with regard to the wastes, the output dose measured at the racking stage is 7.5 $\mu\text{Sv/h}$ and 22 $\mu\text{Sv/h}$ in the building used for their management. The concentration of the radioactivity is linked to the warehouses and scaling recorded in the installations.

The risk analysis carried out by Algade in 2007 (without considering the wearing of individual protection equipment) lead to the determination of the supervised and controlled areas based on the Order of 15th May 2006¹, taking into consideration the risks of exposure to gamma radiation, radons and dust. The supervised areas are linked to the presence of zircon (storage and unloading areas), radioactivity concentration points at the carbo-chlorination installations and the management of the material or wastes (other than radiferous) used at these installations. The controlled areas are situated at the chlorinator and sublimator ovens, radiferous wastes treatment installations (temporary unloading area, racking area and storage building) or at the installations for handling the materials produced by these installations. These areas were defined based on the results obtained using fixed post measuring stations, individual alpha dosimeters (individual samplers), or even additional ponctual measurements.

The evaluation of doses received by the workers (2004) was carried out using individual alpha dosimeters (individual samplers) which were worn by workers over 12 one month periods (risk of exposure to gamma radiation, radons, dust). The posts studied were those linked to intervention in supervised or controlled areas; as such, 20 posts were evaluated, for both Cezus employees as well as employees from external companies carrying out maintenance work, for example. For 1700 hours of work, the doses received by the Cezus employees range from 0.4 to 3.8 mSv; for the external companies, the doses range from 0.8 to 3.5 mSv (not including exposure to radioactivity naturally occurring in the environment).

The dosimetric monitoring (radons, gamma radiation and dust) carried out in 2007-2008 over 12 consecutive months and for 33 workers (Cezus and external companies) shows that 20 workers had an annual effective dose of between 1 and 6 mSv/year. The radon risk is identified in the radiferous wastes management areas (due to their specific activity in radium 226); whereas the gamma risk and dust is identified in the "carbo-chlorination" building. The dosimetric surveillance of the Cezus workers and those of the external companies is carried out around the clock.

Foundry and metallurgy using zircon

The lost wax precision foundries use zircon flour or sand to make the moulds; at the exit of the oven, the moulds are broken, and the shells containing zircon are recovered. Zircon can also be used as a raw material in foundry or metallurgy in order to make materials from zircon, such as

¹ Order of 15th May 2006 on conditions of delimitation and marking of monitored and controlled areas and areas especially regulated or forbidden due to the exposure to ionizing radiation, as well as enforced hygiene, safety and maintenance rules

corundum for example. The employees potentially exposed are those who are in contact with or in the vicinity of the compounds made from zircon (shop, storage areas...) or use it directly. The processes do not lead to the concentration of the raw material's natural radioactivity: the wastes shows equal or lower levels of specific activity, except in the case of thermal treatment. In this case, the wastes resulting from the dust collectors or dust at the bottom of the chamber may show specific activities in ^{210}Pb that are higher than those of the primary material. In practice, the workers' exposure may exceed 1 mSv/year: the presence of zircon stocks gradually increases external radiation exposure, which is around 0.3 to 0.4 $\mu\text{Sv/h}$ at 1m of the zircon stock. However, it is the internal exposure that can significantly increase the workers' effective added dose. PCC France evaluates the most exposed workplace at 0.767 mSv for 1645 hours (not including radon) in the coating workshop (mainly external exposure) and Foseco at 0.90 mSv for 2000 hours (mainly external exposure) in the material storage hanger. The measurements of the alpha volumic activity for dust in the air at PCC France do not show any levels that exceed the detection thresholds. The grinding processes of materials containing zircon, at CMMP or Alcan for example, are liable to significantly increase the alpha volumic activity of dust in the air and, as a result, increase workers' internal exposure; at Alcan, the alpha volumic activity measurements for dust in the air in the proximity of the corundum grinding are around one hundred mBq/m³ of air, and around ten mBq/m³ of air at CMMP. Both evaluate doses greater than 1 mSv/year for their workers.

For lost wax precision foundries, only the study carried out by the IRSN at Snecma Gennevilliers shows a dose of 7.88 mSv/year in internal exposure at the post for the production of moulds made from zircon (coating workshop).

The summary of effective added doses for workers is given in paragraph 3.3.5 of the body of the report.

5.5 Exposure for the public

Five studies evaluate the exposure for people living in the vicinity of the zircon and baddeleyite production installations, and the foundry and metallurgy using zircon and baddeleyite. Of these five studies, only three evaluate the dose received by the public. The IRSN notes that, with the exception of the ingestion for which the corresponding exposure may be considered as weak, all the means of exposure have been evaluated. The effective added doses not including radons ranges from 4 $\mu\text{Sv/year}$ to 160 $\mu\text{Sv/year}$. The predominant means of exposure is external exposure.

These results are consistent with those published in the literature; in particular the results published by UNSCEAR [15].

Foundry and metallurgy using zircon

The exposure of the public could be linked to the concentration of ^{210}Pb or ^{210}Po in the particles let out into the atmosphere, due to the thermal treatment undergone by the moulds in zircon. The presence of electrostatic filters limits the emissions into the atmosphere. The public's means of transferring doses and risks of exposure for the foundries and metallurgies are comparable to those for the glassmaking industry (see §**Erreur ! Source du renvoi introuvable.** of this annexe).

Production of zircon

The transformation of zircon by grinding can lead to the increase in alpha volumic activity of the air around the site, or to deposits on the ground when raw materials, wastes or finished products containing zircon are being handled. Around the edges of the site, the presence of zircon stocks may lead to an increase in dose rates.

The summary of effective added doses for the workers is given in paragraph 3.4.5 of the body of the report.

5.6 Quality of studies received

11 studies evaluate the exposure of the workers at zircon production installations and the foundry and metallurgy processes using zircon. Of the 11 studies, one is a generic study for foundry activities. The analysis draws on 11 studies and 42 workplaces have been taken into account.

With regard to the standard operation of the installation, the IRSN underlines the importance of the description of the processes for the identification of workplaces exposed and believes that the studies should be improved on this point. The means of exposure were, on the whole, well evaluated. Nevertheless, the IRSN believes that, for 20% of the workplaces, internal exposure by dust inhalation was neglected with no satisfactory explanation and believes that volumic activity measurements of dust or the amount of dust collected are necessary. The calculated effective individual doses are individual effective added doses and half of these refer to posts that do not take into account the dose caused by radons. Three quarters of the doses are based on duration of exposure that is not specific to the workplace. In order to evaluate an effective individual dose received by the workers in the most realistic way possible, the IRSN believes that durations of exposure that adapted to the installations should be used. Furthermore, the measurements carried out show generally weak radon concentrations.

The IRSN believes that the maintenance and dismantling of installations must be taken into account and described in the evaluations in accordance with the Order of 25th May 2005. The IRSN chose the effective individual added doses not including radons for which either the external and internal exposures were used in the evaluation or, if one of the means of exposure was not used, it was deemed by the IRSN to be negligible. For $\frac{3}{4}$ of the workplaces, the effective individual added dose does not exceed the limit of 1 mSv/year. For eight workplaces, the effective added dose does exceed the limit of 1 mSv/year. These eight posts correspond to two studies for which a maximal and hypothetical duration of exposure was used (1600 hours of work per year). The IRSN believes that, for these workplaces, an evaluation based on realistic durations of exposure should be used.

In addition, the IRSN underlines that an effective individual dose of 2 mSv/year is consistent with the data published by the AIEA which shows, for the production of zircon via a thermal process, a maximum annual effective dose of 3.1 mSv/year [14].

5.7 Result

The exposure of the workers in the foundries, metallurgies and mechanical transformation (grinding) factories using zircon may exceed 1 mSv/year, due to dust inhalation or the presence of the zircon storage area near the workplaces. The implementation of exposure reduction measures (positioning adapted to zircon stocks, wearing individual protection equipment, hovering away the dust...) may enable the exposure level to below 1 mSv/year depending on the individual case. As with the implementation or production of ceramic refractories (see §3 of this annexe), the implementation of simple protection measures may be studied for the workers specialised in oven or crucible masonry and for the workers of companies recycling or producing these products, in order to reduce the doses received. However, if these employees are carrying out the activity on a full-time basis, individual protection must be worn, which is justified by the risk analysis. The industrial party should periodically review the dose evaluations or risk analysis.

This should also be done if any changes are made to the installations. The production of a good practices guide for these workers, distributed by the professional organisations, could lead to the practices being improved. Nevertheless, wearing the mask is often compulsory due to the risk of dust inhalation (not considering radioprotection).

With regard to the Cezus site, the exposure reduction measures are not enough to reduce workers exposure below 1 mSv/year, and the requirements of the Labour Code set out in accordance with article R.4457-13 are applicable; these must be retained.

No dossiers received would be exempted under the application of the thresholds as defined in reference [5] and the "Notion of exemption for natural sources of radiation" paragraph. The dossiers drafted by the IPSN (no.8), PCC France (no.9), Foseco (no.20), Unifrax France (no.21), CTIF and Fonderies et Ateliers du Bélier (no.64 and no.25), Alcan (no.59), Ferro Couleurs France (no.66), SEPR (no.78) and CMMP (no.67) show no doses greater than 1 mSv/for the workers.

Dossiers 2 and 25 do not show any specific activity measurements of NORM materials.

6 The production of phosphate fertilisers and the production of phosphoric acid

In the international bibliography, the data available on the issue mainly concern the production of phosphoric acid and associated radiferous wastes, as well as the production of phosphogypsum whose concentration in radium 226 is around 0.5 to 0.7Bq/g.

6.1 French situation

The production of phosphate fertiliser requires the use of potash ore, phosphate, sulphuric and phosphoric acid. The production of phosphoric acid by reaction with the phosphate ore and sulphuric acid is at the source of the wastes that is highly concentrated in radium 226 (radium sulphates), resulting from piping, filters... [8]; this production is no longer carried out in France.

The phosphate fertiliser production installations are less affected as the processes used are not the same as for the production of phosphoric acid, and the phosphoric acid used in France today is imported from producing countries, most notably North African countries.

According to the Kompass database, there are 31 phosphate fertiliser suppliers (phosphate fertiliser, made from ammonia phosphate, superphosphates).

6.2 List of documents received

Endorsed by the regulation:

- Timac, St-Malo, production d'engrais phosphatés, (*production of phosphate fertiliser*) Algade, 2007 (no.22) – Roullier Group
- Fertinagro, Misson, production d'engrais phosphatés, (*production of phosphate fertiliser*) Algade, 2007 (no.65)
- Sud Fertilisants, Sète, production d'engrais phosphatés, (*production of phosphate fertiliser*) (n°73) – Roullier Group
- Interfertil, Le Tréport, production d'engrais phosphatés (*production of phosphate fertiliser*), Algade, 2007 (no.76) – Roullier Group

- Interfertil, Tarnos, production d'engrais phosphatés (superphosphates triples) (*production of phosphate fertiliser- triple superphosphates*), Algade, 2007 (no.77) – Roullier Group

6.3 Characterisation of materials

Specific activities	²³⁸ U	²³⁵ U	²³² Th	⁴⁰ K
Phosphate ore 1 (interfertil)	1.2	0.07	0.03	<0.4
Phosphate ore 2 (Tarmac)	1.2	<0.1	<0.1	<0.1
Phosphate ore 3 (Fertinagro)	0.45	<0.09	0.04	<0.29
Potassium ore 1 (Fertinagro)	<0.16	<0.09	<0.02	15.12
Potassium ore 2 (Interfertil)	<0.1	<0.1	<0.1	14.1
Superphosphate (Fertinagro)	0.27	<0.10	0.02	<0.21
Phosphoric acid (Interfertil)	1.6	<0.1	<0.1	<0.1
NPK Fertiliser (Interfertil)	0.5	<0.1	<0.1	4

Table 10: specific activities in Bq/g, dossiers 22, 65, 73, 76, 77

6.4 Workers' exposure

Description of processes

In the phosphate fertiliser production installations, the presence of radionuclides is linked to the use of potash and phosphate ores. The materials with the highest doses rate are potash (0.90 µSv/h at contact) and phosphate (0.30 to 0.55 µSv/h at contact). The transformation is done in the following stages: grinding, acid attack then granulation before being put into big bags. The superphosphate has specific activities of 0.1Bq/g for radionuclides ²³⁸U, ²²⁶Ra, ²³⁵U, ²²⁸Ra and ⁴⁰K. Finished products, and more specifically, the NPK fertiliser (Nitrogen, Phosphate and Potassium) may show specific activities in ⁴⁰K of Bq/g (3.6 to 4Bq/g for NPK fertiliser).

Dose evaluation

For the Fertinagro installations at Misson, the evaluation of doses received by the workers is based on the dose rate measurements and alpha volumic activity of the air (dust) carried out in the areas where workers are operating: granulation, production of superphosphate, finished products in bulk, packaging in big bags and storage of materials. One sole scenario is used, considering the presence of a worker in these different areas for 1600 hours per year. The workplaces linked to the maintenance of the installations are not specifically evaluated, in the absence of appropriate measurements. The dose rate varies from 0.07 µSv/h and 0.20 µSv/h. The values of the alpha volumic activity of the dust at the workplace vary from 2.9 to 15mBq/m³ of air (the "natural background noise" is estimated at 8mBq/m³ of air). Considering 1600 working hours per year, external exposure (averaged) is evaluated at 0.096 mSv/year plus the local background noise and the internal exposure at 0.244 mSv/year (taking into account the maximum measured value, including background). With regard to the radon, the measurement made over one day shows a value of 50Bq/m³ of air.

For the Interfertil installations, the evaluation of the doses received by the workers is based on the measurements carried out in the areas where the Tarnos factory workers operate: granulation, bagging and storage of materials, outside area adjacent to the mechanical site. The dose evaluations take into account the external exposure (added in relation to the natural background), the internal exposure linked to the radon and dust. For 1600 working hours per year, the external exposure is estimated at 0.092 mSv (not including natural background), exposure to short life decay products to the radon is estimated at 0.023 mSv/year (values averaged then background noise deducted), and 0 mSv/year for the inhalation of long life radioactive dust (measurement less than or equal to natural background). The scenario of workers' exposure is identical to that

used for the Fertinagro installations. This study is undertaken for the Interfert factories based in Sète (French *department* no. 34), Tonnay Charente (17) and Le Tréport (76). In relation to natural background the dose rate measurements carried out at Timac did not show any rise in dose rates in the areas where the agents operate. Only the measurements of alpha volumic activity (dust) between 2.9 and 13.8mBq/m³ of air showed an increase in relation to the natural background noise (evaluated at 1mBq/m³ of air); the effective added doses received by the workers are evaluated at 206 µSv/year based on 1600 hours of exposure with an alpha volumic activity value of 13.8mBq/m³ of air.

The exposure scenarios used in these various dossiers, show doses that range from 0.0115 to 0.340 mSv/year. For these phosphate fertiliser production factories, the gamma cartography of the installations does not show any concentration of radioactivity in the wastes, sub-products or on the installations, contrary to what is stated in the literature for phosphoric acid production installations.

6.5 Exposure for the public

Five studies evaluate the exposure of the people living in the vicinity of the phosphoric acid and phosphate fertiliser production installations. Of the five studies, only three evaluate the dose received by the public. Of these three studies, two do not show any doses specific to their installation, but a transposition of the results of the third study. The IRSN notes that, with the exception of the ingestion for which the corresponding exposure can be considered as weak, all the means of exposure were evaluated. The effective added dose not including radon is 25 µSv/year. This value is consistent with those published in the literature, particularly the values published by UNSCEAR [15].

The measurement of the radioactivity of the industrial water of the Misson site shows a specific activity in ⁴⁰K of 13.53Bq/l. Opposite the Tarnos site, the Adour water has an activity of 1.78Bq/l for an activity of less than 1Bq/l of industrial waters. No information is given with regard to the outlet and treatment used for this industrial water.

6.6 Quality of the studies received

Five studies evaluate the exposure of workers in phosphate fertiliser production installations. There is no study on the production of phosphoric acid, as this activity has been delocalised. The IRSN underlines that one of the five studies is used as a reference point by other industrial parties on this sector. Due to the limited number of studies received, the IRSN underlines that the data is insufficient for drawing conclusions on the exposure of workers in this sector.

With regard to the standard operation of the installation, the description of the procedures given in the six studies is not deemed to be satisfactory and does not enable the identification of the workplaces that are most exposed. The IRSN underlines the importance of a precise description of the workplaces given the identification of the exposed workplaces and believes that the studies should be improved on this point. For the workplaces identified, the means of exposure were well evaluated. The effective individual doses calculated are effective individual added doses for all the workplaces, but not one is estimated based on duration of exposure that is specific to the workplace. In order to evaluate an individual effective dose received by the workers in the most realistic way possible, the IRSN believes that durations of exposure adapted to the installation should be used. In addition, the measurements carried out show weak radon concentrations.

The IRSN believes that the maintenance and dismantling of the installations must be taken into account and described in the evaluations in accordance with the Order of 25th May 2005. The

IRSN chose the individual effective added doses not including radons for which either the external and internal exposures were used or, if one of the means of exposure was not used, this was deemed by the IRSN to be negligible. The effective individual added doses range from 0 mSv/year to 0.1 mSv/year. IRSN underlines the fact that these doses are consistent with the data published by AIEA: up to 0.8 mSv/year for the production of fertiliser [14] and 0.3 mSv/year for a maximum activity of 1500Bq/kg in the fertiliser [17].

For all the workplaces evaluated by the IRSN, internal exposure by dust inhalation is the predominant means of exposure.

6.7 Result

The phosphate fertiliser production installations do not appear to lead to any significant exposure for the workers when the production of phosphoric acid is not taking place on the site; the previous phosphoric acid production installations must, however, be monitored on two issues: exposure for the public and protection of the environment linked to the storage of NORM wastes, the radioprotection of the workers responsible for the dismantling of the installations, packaging, sorting, transportation or return of wastes.

No dossier would be exempt under the application of the exemption thresholds as defined in reference [5] and in the “Notion of exemption for natural sources of radiation” paragraph. No dossier shows a dose greater than 1 mSv/year for the workers. Dossier no.73 does not show any specific activity measurements for the NORM materials.

7 Treatment titanium dioxide

Tioxyde Europe produces titanium oxide pigments, a material which it extracts from titanium ore, the slag. In Thann, Millenium Chemicals produces titanium oxide and titanium oxychloride (mainly pigments) also from titanium ore. These companies are, therefore, affected by the Order of 25th May 2005 in two aspects: treatment of titanium ore and treatment of titanium oxide. As the titanium found in the ore is in the form of TiO₂ (titanium dioxide), the industries carrying out the treatment of the titanium ore are the same as those that carry out the treatment of the titanium dioxide.

No other French company is affected by this sector, which endorses the titanium dioxide treatment industrial installations that produce titanium oxide pigments [10].

Only the list of dossiers received will, therefore, be cited for this professional activity category, as paragraph 2 already deals with this issue.

7.1 List of dossiers received

Endorsed by the regulation:

- Millennium Chemicals Lyondell - Le Havre, Utilisation de scories et ilménites pour fabrication d’oxyde de titane (*Use of scoria and ilmenites for producing titanium oxide*), 2005 (no.3)
- Millennium Chemicals Lyondell – Thann and Oschenfeld, Production d’oxyde de titane et de tétrachlorure de titane (*Production of titanium oxide and titanium tetrachloride*), 2004 (no.7)
- Tioxyde Europe, traitement de minerai de titane (*Treatment of titanium ore*), Hunstman, 2007 (no.44)

8 Treatment of rare earth and production of pigments containing rare earths

8.1 French situation

Cerium, lanthanum, yttrium and promethium are examples of metals that belong to the group of rare earth. These metals are present in different ores, notably in monazite, which also contains thorium.

Rare earth is used in different chemical forms for various purposes. For example, the use of rare earth oxides as pigments, or the incorporation of cerium in alloys for fire stones, production of magnets etc...

The Rhodia Electronics & Catalysis site is specialised in the treatment of rare earth, production which also leads to the production of compounds containing thorium. The co-products thorium oxide and thorium nitrate enable the production of products requiring the use of thorium, not necessarily used for their radioactive purposes (see section no.4, “production or use of compounds containing thorium”). The rare earths are used for several purposes: catalysts for exhaust pipes, flat screens, low energy bulbs, high precision optics, stamping bank notes, medical imaging etc... It should be noted that the treatment of rare earth carried out at the Rhodia site has also led to the production of compounds used for their radioactive properties: to cite just one example, this is the case for brute thorium hydroxide (see §8.4); as a result, the site does not seem solely subject to the regulatory requirements linked to the enhanced natural radioactivity.

The PEM factory at Château Feuillet produces, as a secondary activity, “silicon rare earth compounds”, whose radiological characterisation shows dose rates of 2000 nSv/h (500 nSv/h at 1 m).

The Thann site (MIC) used to carry out the treatment of monazite.

No dossier has been received on the production of pigment containing rare earth.

8.2 List of dossiers

- Rhodia Electronics & Catalysis, traitement de terres rares (*treatment of rare earth*), 2007 (no.36)
- FerroAtlantica - PEM, stockage et utilisation de terres rares dans les alliages (*storage and use of rare earth in alloys*), 2007 (no.48)

The Rhodia dossier is analysed in §4 of this annexe, except for the “quality of studies” aspect, where the posts linked to the handling of rare earth are also included in the evaluation.

8.3 Characterisation of materials

Site	Material	²³² Th	²²⁸ Ra	²²⁸ Th	²³⁵ U	²²⁷ Ac	²³⁸ U	²³⁰ Th	²²⁶ Ra	²¹⁰ Pb	²³⁴ U	²³¹ Pa	⁴⁰ K
PEM	FeSiTR 1	-	1,22	-	< 0.06	-	0.46		<0.050	-	-	-	<0.001

Table 11: specific activities in Bq/g, dossiers 36, 48

8.4 Workers' exposure

Description of processes

At the PEM factory, the production of silicon rare earth (SiTR) is carried out using a FeSiTR compound.

Evaluation of doses

At PEM, the areas for the storage, bagging and crushing of FeSiTR are radiologically marked. On contact with the product, there is a dose rate of 2000 nSv/h; at the crushing and bagging, high values of air alpha volumic activity are produced (319 and 105mBq/m³ respectively). The use of rare earth leads to an effective dose of 0.06 mSv/year for 16 hours of work per year, as this compound is used to a lesser extent by PEM.

8.5 Exposure for the public

Two studies evaluate the exposure and dose received by the people living in the vicinity of the installations for the treatment of rare earth and the production of pigments containing rare earth.

External exposure and exposure due to radons were well evaluated. For internal exposure caused by dust inhalation, the IRSN believes that, for some exposure scenarios used by the industrial operator, for example the children's adventure playground, this means of exposure should have been examined. The industrial operator should complete their dossier on this issue. The effective added doses not including radon range from 12 µSv/year to 350 µSv/year. With the exception of the effective dose of 120 µSv/year, all values relate to the study submitted by [18].

The summary of effective added doses for the public is given in paragraph 3.4.8 of the body of the report.

8.6 Quality of the studies received

Two studies evaluate the exposure of the workers at the installation for the treatment of rare earth and the production of pigments containing rare earth.

Due to the limited number of studies received, the IRSN underlines that the data is not sufficient enough to enable a conclusion to be drawn on the exposure of workers in this professional activity sector.

With regard to the standard operation of the installation, the description of the processes presented is only deemed to be satisfactory for one single study and does not, therefore, enable the most exposed workplaces to be identified. All the means of exposure were well evaluated. All the effective individual doses calculated are individual added effective doses that do not take into consideration the dose caused by radon and are generally based on a duration of exposure that is specific to the workplace. In addition, the measurements carried out show weak radon concentrations.

The IRSN estimates that the maintenance and dismantling of the installations must be taken into account and described in the evaluations in accordance with the Order of 25 May 2005.

The IRSN chose the effective individual added doses not including radons for which either the external and internal exposures were used in the evaluation or, if one of the means of exposure was not used, this was deemed by the IRSN to be negligible. The effective individual added doses range between 0.06 mSv/year and 0.3 mSv/year. The IRSN underlines that these doses are lower

than the data published by the AIEA which shows 1 mSv/year to 8 mSv/year on average for the extraction of rare earth from monazite [17].

8.7 Result

With regard to the Cezus site (treatment of zircon ore, see. §5.6 of this annexe), the requirements of the Labour Code outlined in article R.4457-13 are applicable for the Rhodia site. However, some installations of the site are liable to being used or have used the materials for their radioactive properties, which is not covered by the Order of 25 May 2005. The exposure of the workers to enhanced natural radioactivity (thorium 232) is greater than 1 mSv/year for certain workplaces, and the production sector for the treatment of rare earth must be evaluated in terms of radiological risk.

No dossier would be exempted under the application of the thresholds as defined in reference [5] and the “Notion of exemption for natural sources of radiation” paragraph. Only the dossier drafted by Rhodia (no.36) shows doses greater than 1 mSv/year.

9 Treatment of underground water by filtration for the production of water for human consumption and mineral water

9.1 French situation

There are several underground water filtration installations for producing water for human consumption: the main companies in this sector are Veolia Eau, Saur and Lyonnaise des Eaux.

9.2 List of dossiers

- Européenne d’Embouteillage, extraction d’eau destinée à la consommation humaine (*extraction of water for human consumption*), Onectra, 2007 (no.10)

9.3 Characterisation of materials

	²²⁶ Ra	²¹⁴ Pb	²¹⁴ Bi	²¹⁰ Pb	²²⁸ Ac	²¹² Pb	²¹² Bi	⁴⁰ K
Resin 1	11	3.7	3.7	0.3	0.096	0.082	0.082	1
Resin 2	12	6.5	6.5	0.24	0.1	0.088	0.088	1
Reference resin	-	-	-	-	<0.0678	<0.127	<0.127	3.85

Table 12: specific activities in Bq/g, dossier no. 10

9.4 Workers’ exposure

Description of processes

Various processes allow the filtration of the underground water for human consumption. The main processes that the ASTEE¹ is aware of are filtration by sand, active coal or resin. The water pumped out from water catch systems situated nearby is channelled to the buildings housing the filtration installations. The international bibliography on the issue mentions the radon degassing at the filtration installations and the concentration of radionuclides in the filters. The presence of staff at the filtration installations could lead to exposure at levels of radon volume activity greater than 400Bq/m³.

At the Donnery site (l’Européenne d’Embouteillage), the use of an ion exchange resin separator to remove the iron and magnesia from the source water concentrates the radionuclides. After

¹ Association Scientifique et Technique pour l’Eau et l’Environnement

around six years of use, the resin specific activity is 10Bq/g in radium 226. The filtration processes are automated, are carried out in an area designated for this purpose and inside hermetic installations.

St-Yorre (Salaise site, Isère) treats the water using sand rich in manganese in order to remove the nitrates; this process also concentrates the radium 226 and the decay products of the thorium 232, respectively, in the amounts of 5 and 3Bq/g; the dose rate measured at contact of the used sand is 3.5 $\mu\text{Sv/h}$ (analysis report following a detection portal warning).

In their study submitted in application of the Order of 25th May 2005, l'Européenne d'Embouteillage studied the maintenance posts, the only posts susceptible to coming into contact with the ion exchange resin separators. The dose evaluations take into account external exposure only, and show a dose of 110 $\mu\text{Sv/year}$, giving a pessimistic consideration of the accumulation of tasks related to the maintenance by the one same worker. As the water filtration and filter cleaning is automated, maintenance work is carried out very infrequently. Requests for supplements were sent to l'Européenne d'Embouteillage for the evaluation of the radon exposure pathway. With regard to internal exposure, the company studied it under abnormal situations, given the resins' constant humidity which greatly limits exposure by dust inhalation during the maintenance of filters (by definition, the resin captures the particles present in the water).

9.5 Quality of the studies received

The IRSN underlines that the data is not sufficient to allow conclusions to be drawn on the exposure of workers in this professional activity sector.

With regard to the standard operation of the installation, the description of the processes was deemed satisfactory, but, with no explanation, no dose evaluation was carried out on all the workplaces. Effective individual doses were calculated for all the workplaces, but they do not take into account all the possible means of exposure. Therefore, the IRSN believes that the doses presented underestimate the dose received by the workers.

The IRSN believes that the maintenance and dismantling work at the installations must be taken into account and described in the evaluations in accordance with the Order of 25th May 2005.

For the two workplaces studied, there was no evaluation on all the pathways of exposure. Therefore, no effective individual dose was upheld by IRSN in this analysis.

9.6 Result

The concentration of the radioactivity in the underwater treatment filtration installations leads to concentrating, notably, radium 226; workers may become exposed when carrying out maintenance or cleaning, or as a result of the radon degassing at these installations. We await further information and no final report can be drawn at this stage. The risk is rather linked to the radon presence at the installations. The management of the filter wastes is also a point that should be monitored.

No study was received on the exposure of the people living in the vicinity of the installations for the treatment of underground water by filtration.

L'Européenne d'Embouteillage would not be exempt under the application of the thresholds as defined in reference [5] and the "Notion of exemption for natural sources of radiation" paragraph. The dossier does not show any dose greater than 1 mSv/year.

10 Spas.

10.1 French situation

According to the CNETH (National Council of Spas), there are currently 101 spas in France, whose legal framework is formed by the therapeutic guidance given by the Health Minister [19].

With regard to exposure to natural radioactivity, the spas are also regulated by the Order of 22nd July 2004¹ taken in application of article R.1333-15 of the Public Health Code. As such, they must carry out radon measurements. The Order of 25th May 2005 endorses the production of NORM as well as exposure linked to radons (see annexe 3 of the Order).

10.2 List of dossiers

- Bourbonne-les-Bains, IRSN, 2003 (13)

10.3 Characterisation of materials

The Bourbonne-les-Bains study only provides radon measurements. The radon 222 volume activity ranges from 200 to 3630Bq/m³.

10.4 Workers' exposure

The dossier drafted by the IRSN in 2003 at the Bourbonne-les-Bains spas aims to characterise the radon associated risk for workers at the establishment.

With regard to the enhanced natural radioactivity, no French data is available. However, it is possible that the channels, filters or pumping equipment concentrate the water's natural radioactivity (notably the radium 226), as is the case for example at the paper mill filtration installations, oil and gas extraction installations or the water treatment installations.

10.5 Quality of the studies received

The IRSN underlines that the data is not sufficient to draw conclusions on the exposure of workers in this professional activity sector.

With regard to the standard operation of the installation, the description of the processes was deemed to be satisfactory. Exposure due to radons is the only means of exposure examined, measured and evaluated in this study. The IRSN underlines that the measurements carried out show high radon concentrations: 88% of the measurements are greater than 400Bq/m³. Exposure reduction measures are, therefore, necessary. As no evaluation for the means of exposure other than that caused by radons has been carried out, no individual effective added dose was evaluated.

The IRSN believes that the maintenance and assembly processes of the installations must be taken into account and described in the evaluations in accordance with the Order of May 2005. For all workplaces, only exposure caused by radons was evaluated: no effective individual dose has, therefore, been upheld in this analysis.

10.6 Result

¹ Order of 22 July 2004 on modalities for the management of radon related risk in places open to the public

The data supplied is incomplete and does not allow any final report to be drawn on the workers' exposure.

No study on exposure of the people living in the vicinity of the spas has been received.

11 Sectors not affected by the Order of 25th May 2005

11.1 Extraction of oil and gas

The oil and gas extraction installations can concentrate the natural radioactivity of the mineral deposits in the piping, pumps, separators... The production of salts containing radioactive elements is aided in the shafts where the injection and / or production of water occurs. This is particularly the case for shafts connected to mineral deposits near the stripping and that have a favourable geology. In France, the production sites in the south west meet the aforementioned requirements. Total Exploration & Production France discovered this phenomenon in the work-over sites (replacement of tubes used for extraction, the tubing) in 1997 and 2003. In addition to these sites, Total identified that the problem of radioactivity could be found at the installations during normal exploitation at points which were conducive to the build up of tartar and / or solid materials: valves, filters, purging areas (contamination of soil or piles of purged materials), separators and storage of solid materials extracted from the separators [20]. The dose rates measured at contact of certain wastes (mud from separators) at a work-over site in 2008 ranged up to 40 $\mu\text{Sv/h}$, for specific activities for mud from 2 to 40Bq/g. On an international level, the issue of the production of enhanced natural radioactivity wastes in oil and gas treatment or extraction installations is documented [21].

Based on the radiometric cartography of the gas production sites connected to the Lacq, Meillon and Vic-Bilh fields (2005) and the Lacq refinery site (2006), TEPF notes the presence of NORM in the production lines near the shaft heads, at the bottom of the separators, in the liquid and gas pipes, as well as in the soil due to the discharge of deposits, production water or storage not adapted to the tubing. The cartography of the TEPF installations of the Parisian basin shows that there is no RNR problem in this area.

Workers' exposure is mainly linked to the cleaning and maintenance of the installations as well as the management of the resulting NORM wastes.

The application of the exemption thresholds as defined in reference [5] and in the "Notion of exemption for natural sources of radiation" paragraph would lead to not exempting these industries, given the dose rates observed. Neither the ASN nor the IRSN have dose evaluations for the workers or the public carried out by the industrial parties.

11.2 Geothermal Science

The geothermal science sector is identified in the report from the Robin des Bois association as being a producer of NORM [8]. A visit of the GEIE Kutzenhausen geothermal science site held on 2nd December 2008 showed the presence of NORM on the extraction surface installations of water drawn from several thousand metres deep, despite the site's recent opening. The concentration of natural radioactivity at work seems to be the same as in the case of oil and gas extraction: the natural radioactivity concentrates in the bends, valves, filters... in the piping. The specific activity of the filters analysed is around 10Bq/g for the ^{226}Ra and 167Bq/g for the ^{210}Pb for example.

The application of the exemption thresholds as defined in reference [5] and in the “Notion of exemption for natural sources of radiation” paragraph would lead to not exempting these industries, given the dose rates observed. Neither the ASN nor the IRSN have dose evaluations for the workers or the public carried out by the industrial operators.

11.3 Papermill industry

The paper mill sector, identified in the study by the Robin des Bois association [8], may also be at the source of the production of NORM depending on the production processes used.

At Tembec in Tarascon, the use of a bleaching process without chlorine (ECF process, Elementary Chlorine Free) lead to pushing barium sulphate and radium sulphate into the piping and the web filter of the first stage of treatment of bleaching the paper pulp. This phenomenon is identified by Tembec at the factories using this process. The dose rate measurements at contact of the installations range from local background noise (<100 nSv/h) to 4.5 µSv/h.

According to Tembec, the chlorine based process does not appear to concentrate the natural radioactivity.

The application of the exemption thresholds as defined in reference [5] and in the “Notion of exemption for natural sources of radiation” paragraph would very likely lead to not exempting these industries, given the dose rates observed. Neither the ASN nor the IRSN have dose evaluations for the workers or the public carried out by the industrial parties.

11.4 Treatment of ores

At SOKA, after cleaning and removal of the sand by cycloning, the drying by filter-press of the pre-treated kaolin granite ore allows the desired kaolin to be obtained; it is the webs and sub-webs of the filters that concentrate and fix the natural radioactivity of the ore at 20Bq/g for the ²³⁸U chain (see §2.3 of this annexe). Workers' exposure is less than 1 mSv/year.

The application of the exemption thresholds as defined in reference [5] and in the “Notion of exemption for natural sources of radiation” paragraph would lead to not exempting these industries.

11.5 Result

The geothermal science, oil and gas extraction and paper mill sectors could be included in the French regulation on enhanced natural radioactivity, which today is not the case. With regard to the treatment of ores, not enough data is available to be able to give an assessment of their integration to regulation.

Annexe 4: Detailed synthesis of mass activity measurements

The IRSN listed the specific activities presented in the studies submitted by the industrial operators. As such, of the 79 studies received, 35 show specific activity measurements for the materials, i.e. around 400 samples analysed mainly by spectrometry γ and over 3,500 results of measurements. The radionuclides measured are ^{40}K and those of the ^{235}U , ^{238}U and ^{232}Th chains. 47% of the measurements relate to radionuclides from the ^{238}U chain, 28% to those from the ^{232}Th chain, only 15% to those from the ^{235}U chain and 9% to ^{40}K . Figure 1 shows the numbers of results less than and those above the detection limit for potassium 40 and the three aforementioned chains.

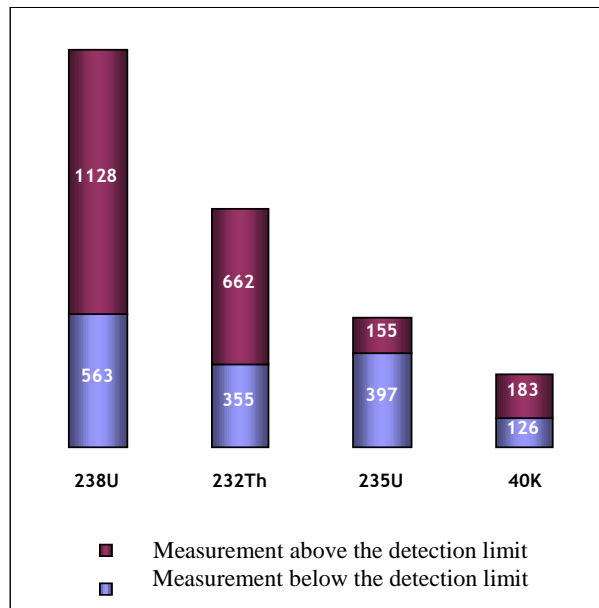
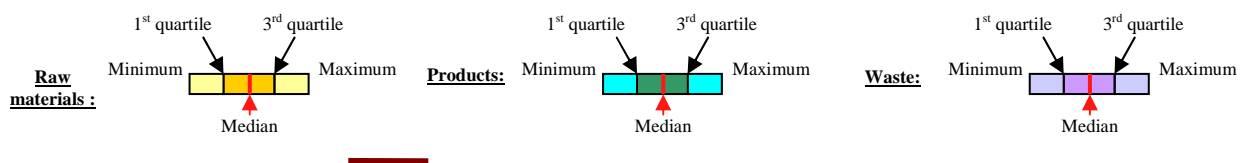


Figure 1: Distribution of measurements of ^{40}K and the ^{238}U , ^{232}Th and ^{235}U chains

Figures 10 to 15 show the range of specific activities for the ^{40}K and some radionuclides of the main groups of the ^{238}U and ^{232}Th chains.



The number in brackets relates to the number of samples with a specific activity above the detection limit.

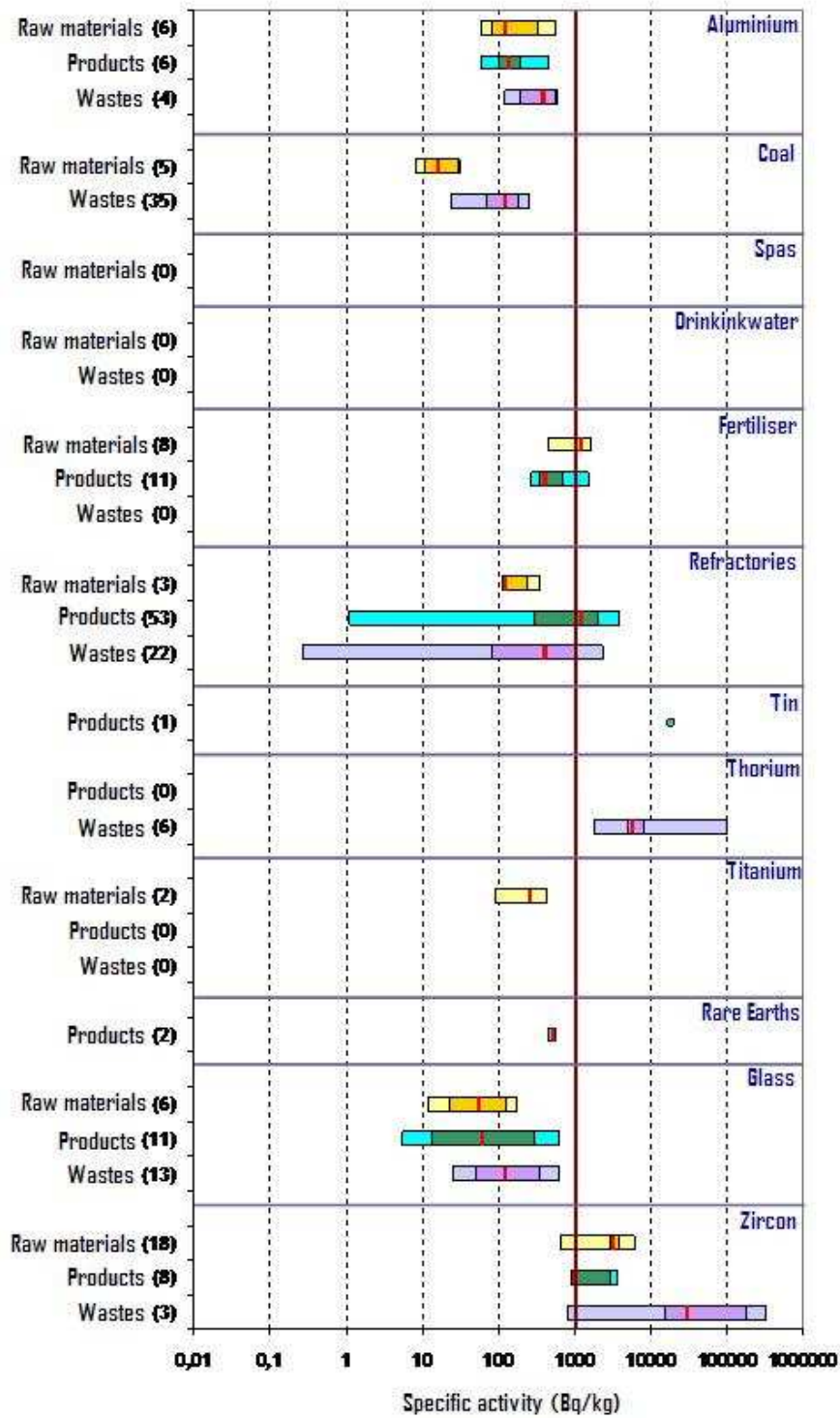


Figure 2: Specific activities for the ²³⁸U (Bq/kg) chain

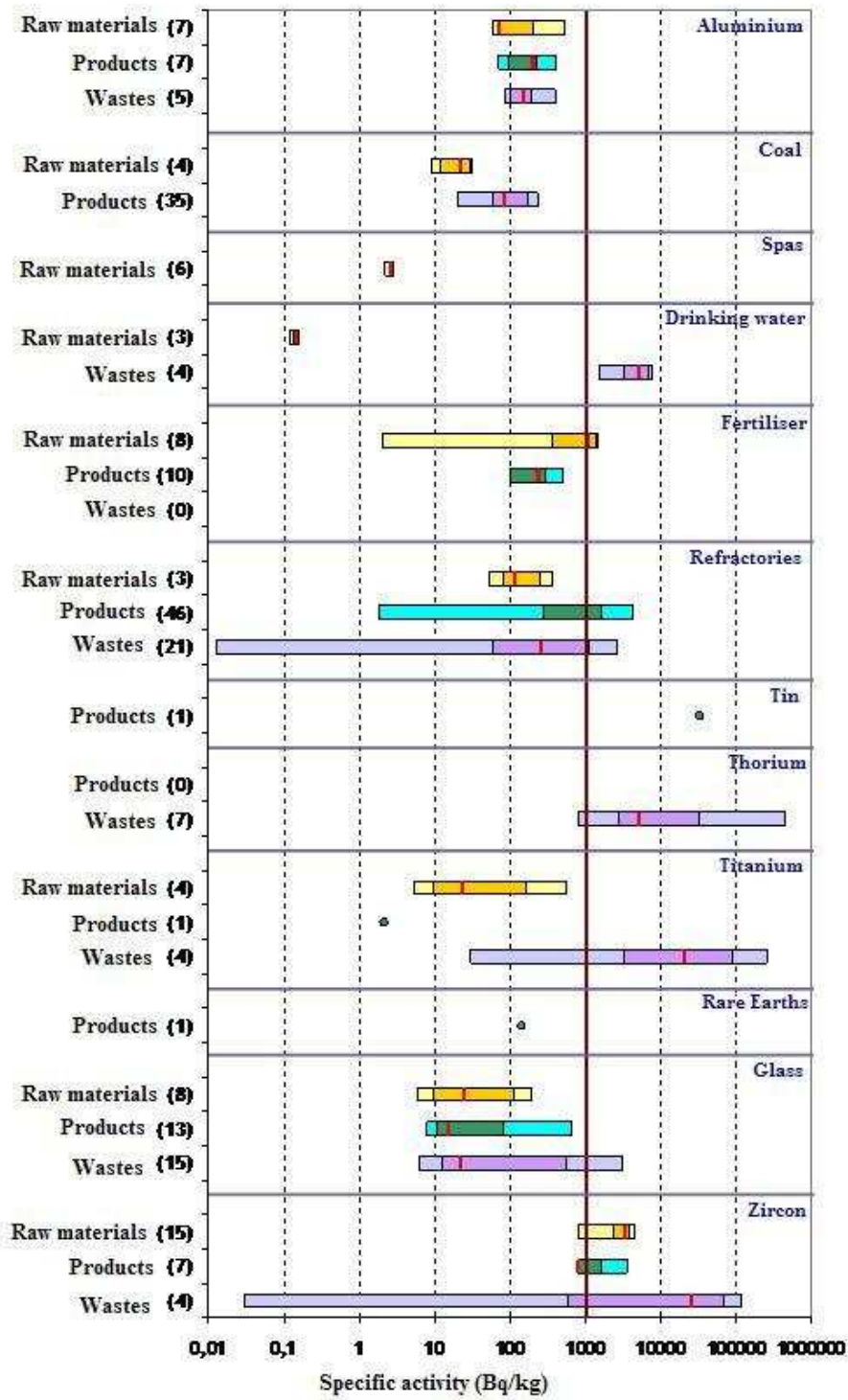


Figure 3: Specific activities for the ²²⁶Ra group of the ²³⁸U group (Bq/kg)

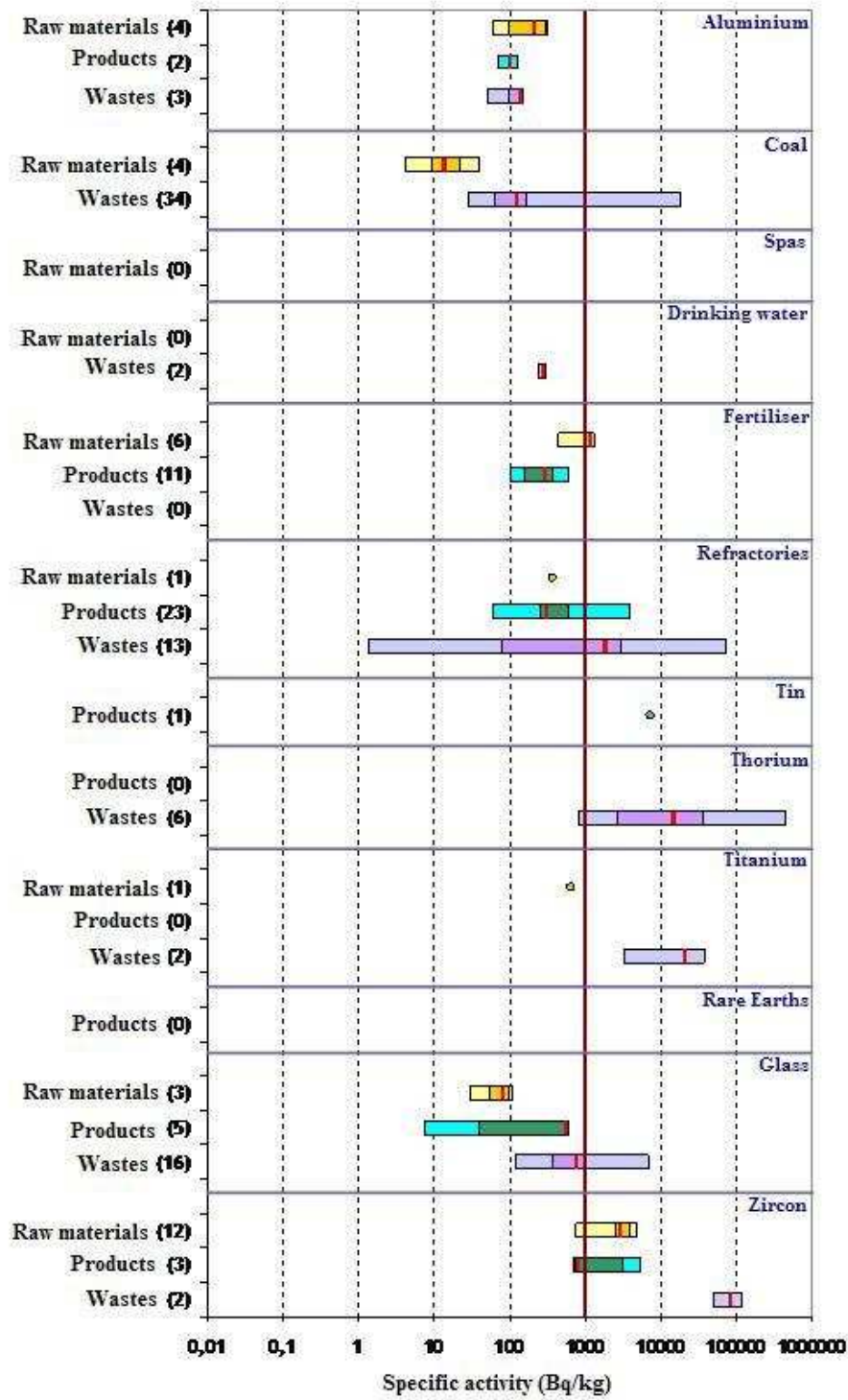


Figure 4: Specific activities for the ^{210}Pb group of the ^{238}U group (Bq/kg)

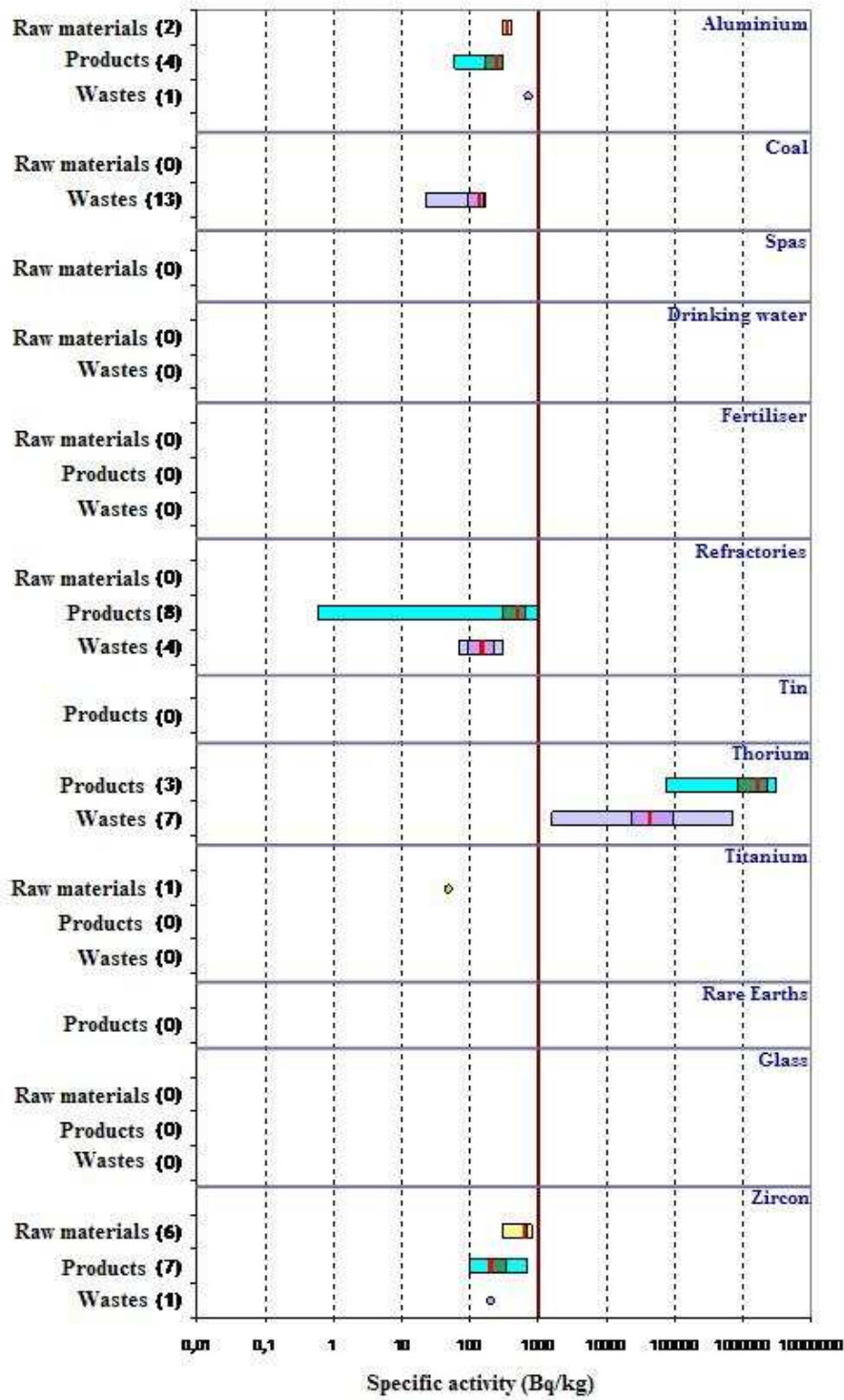


Figure 5: Specific activities for the ²³²Th chain (Bq/kg)

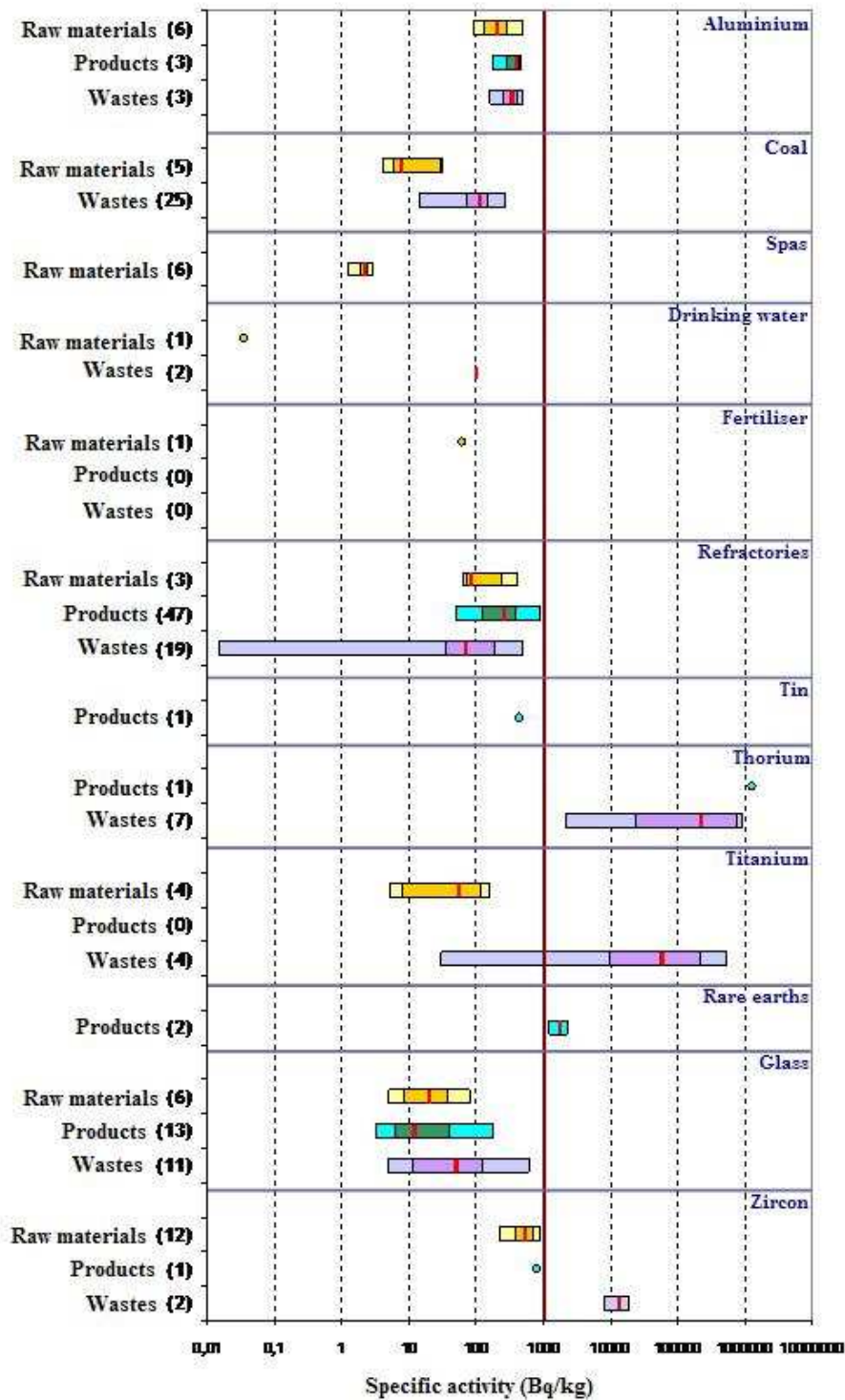


Figure 6: Specific activities for the ^{228}Ra group of the ^{232}Th group (Bq/kg)

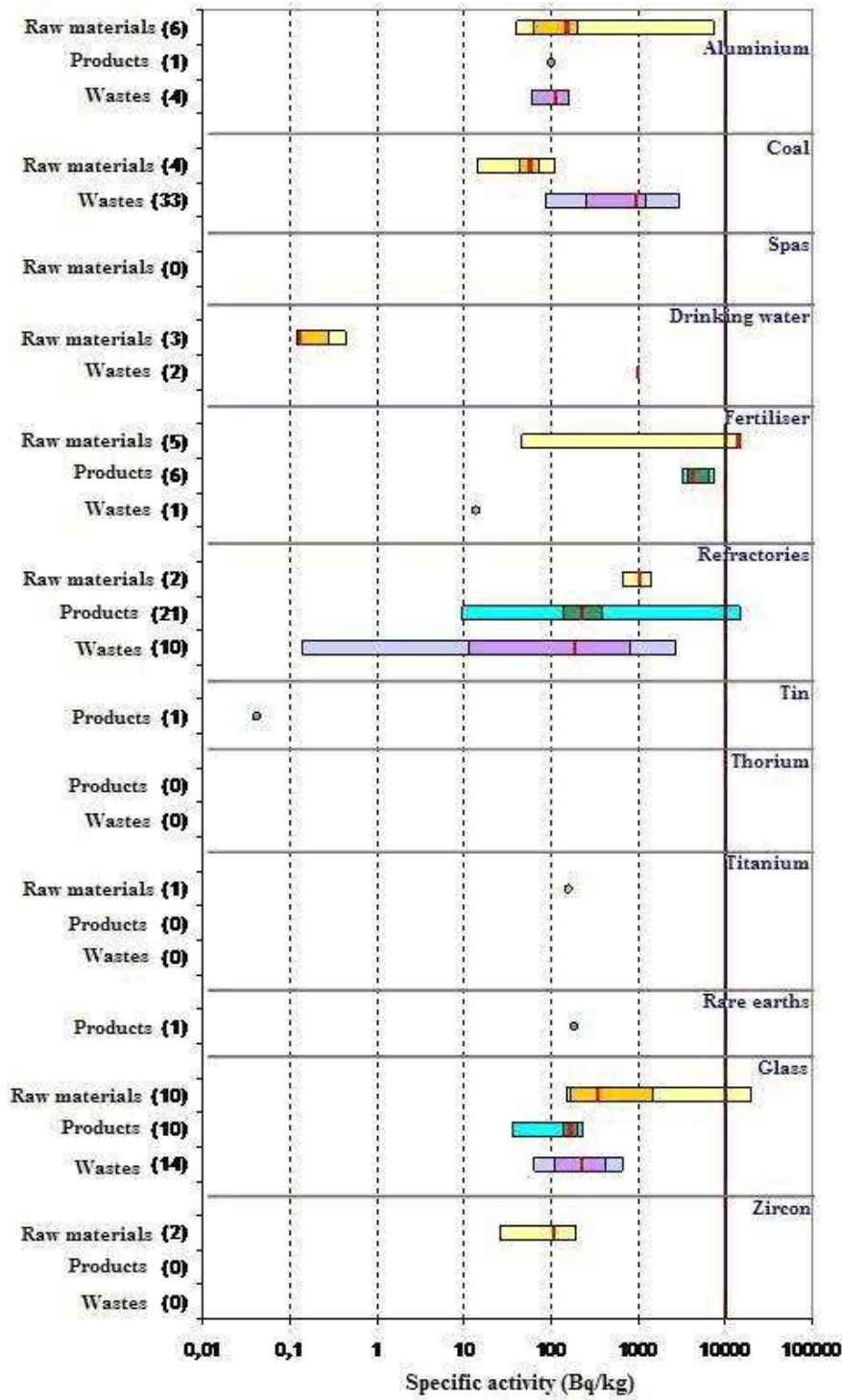


Figure 7: Specific activity of the ⁴⁰K (Bq/kg)

Annexe 5: Bibliography

- [1] Guide méthodologique pour l'acceptation de déchets présentant une radioactivité naturelle dans les installations classées d'élimination, DEI/SARG/2006-009, 18 July 2006
- [2] Notice IRSN/DRPH/2009-115 on the drafting of the report on the application of the Order of 25 May 2005 on the "quality of studies received" and "exposure of the public" and related report IRSN/DRPH/SER/2009-11 of 22 June 2009
- [3] RP 122, Part II, Application of the concept of exemption and clearance to natural radiation sources, European Commission, 2001
- [4] Application of the concepts of exclusion, exemption and clearance, Safety Guide RS-G-1.7, AIEA
- [5] European Commission Services considerations with regard to natural radiation sources in BSS Directive, 16/01/2009
- [6] RP88, Recommendations for the implementation of title VII of the European basic safety standards directive concerning significant increase in exposure due to natural radiation sources, European Commission, 1997
- [7] Bilan sur la gestion des déchets contenant de la radioactivité naturelle renforcée, Autorité de sûreté nucléaire, 2009
- [8] La radioactivité naturelle technologiquement renforcée, Robin des Bois association, December 2005
- [9] Notice IRSN/DRPH/2009-161 on the first version of the report on the application of the Order of 25th May 2005 submitted by the ASN to the IRSN on 6/07/2009
- [10] Revue bibliographique de l'impact radiologique des installations susceptibles d'engendrer une exposition aux rayonnements naturels renforcée par un procédé industriel, DGSNR, July 2004
- [11] Hazardous accumulation of radioactive lead on the water wall tubes in coal fired boilers, W.M.M Huijbregts, M.P. De Jong, and C.W.M. Timmermans, Anti corrosion Methods and Materials Volume 47, No.5, 2000
- [12] Radioactivité naturelle renforcée – Analyse radiologique des cendres du foyer de la chaudière et du gypse produit par l'installation de désulfuration (IDD), EDF, 25 March 2009
- [13] National Radiological Protection Board (NRPB), Radiological Impact on the UK Population of Industries which Use or Produce Materials Containing Enhanced Levels of Naturally Occurring Radionuclides. Part I: Coal-Fired Electricity Generation, 2001
- [14] Naturally Occurring Radioactive Material (NORM V), proceedings of an international symposium, Seville, Spain, 19-22 March 2007, AIEA
- [15] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Sources and effects of ionizing radiation, Volume I: Sources, 2000
- [16] Notice IRSN/DRPH/2009-78 on the study submitted by the FCSIV in application of the Order of 25 May 2005
- [17] International Atomic Energy Agency (IAEA), Assessing the need for radiation protection measurements in work involving mineral and raw materials, Safety reports series no.49, 2006
- [18] Notice IRSN/DRPH/2009-153, 6 August 2009 on the studies carried out by Rhodia in application of the Order of 25 May 2005
- [19] Conseil National des Exploitants Thermaux, official site of French hydrotherapy, www.cneth.org
- [20] Rapport de visite d'une installation de production de gaz (puits) - Total Exploration Production France (TEPF) – ASN/Division Bordeaux, June 2008
- [21] Safety report series n°34, Radiation Protection and the Management of Radioactive Wastes in the Oil and Gas Industry, IAEA
- [22] Evaluation de l'exposition aux rayonnements ionisants naturels liée aux activités industrielles non nucléaires en France, Mémoire CNAM, Aline Maigret, 12 February 2009

[23] Radioactivité naturelle technologiquement renforcée – les cendres de charbon et les phosphogypses, January 2009

Annexe 5: list of dossiers

1. Electricité de France (EDF) / Société nationale d'électricité et de thermique (SNET),
 - Evaluation des expositions radiologiques associées aux cendres volantes produites par les centrales thermiques à charbon en France – Première phase : exposition des travailleurs (*Evaluation of radiological exposure linked to flying ash produced by coal fired power stations in France – First Stage: workers' exposure*), May 2003
 - Summary letters EDF/D4017/03/226/RSH/MP of 26th May 2003 and EDF/D5540/MYR/CS/16/06 12 April 2006
2. SNECMA, Etude de danger sur l'exposition au zircon (*study on danger of exposure to zircon*), May 2006
3. Millennium Chemicals Lyondell, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides des chaînes naturelles de l'uranium et du thorium (*Study of radioprotection problems linked to the use of products containing radionuclides from natural chains of uranium and thorium*), 11/05/2005
4. AREVA CEZUS,
 - Estimation des doses efficaces reçues par les populations voisines du site de CEZUS (*Estimation of effective doses received by people living in the vicinity of the CEZUS site*), 15/12/2005
 - Etude des ambiances radiologiques aux postes de travail (*Study of radiological atmospheres at workplaces*) – Dosimetric monitoring of staff from 11/12/2002 to 7/01/2004 and 25/02/2004
5. Denain–Anzin Minéraux DAM Kaolins de Beauvoir,
 - Note technique DAM Beauvoir: Exposition aux rayonnements ionisants d'origine naturelle (*DAM Beauvoir technical note: Exposure to ionizing radiations from natural sources*), 18/01/2006
 - Etude de la situation dosimétriques des travailleurs (*Study of the workers' dosimetric situation*): Evaluation from 17th April to 17th July 2002, Algade Study 2002, 4/09/2002
 - Etude de la situation dosimétrique des fonctions « conducteur de laverie » et « technicienne de laboratoire » (*Study of the dosimetric situation for the "laundrette operator" and laboratory technician" positions*): Evaluation from 2nd June to 19th December 2003, Algade Study 2003, 9/02/2004
 - Inspection Report SGS 1-12-05, 5/12/2005
6. SOKA, Société Kaolinière Armoricaïne, Dossier Radioactivité naturelle renforcée: Vérification de l'exposition des salariés au poste de travail et des populations du 12/06/2006 au 9/10/2006 (*Enhanced natural radioactivity dossier: Verification of the exposure of employees at their workplaces and exposure of the public from 12/06/2006 to 9/10/2006*), Norisko Report no.A3877620/0601, 2/03/2007
7. Millennium Chemicals in Thann and Ochsenfeld (68)
 - 16/01/2004 dossier

- 21st January 2008 dossier
- 8. Industrie de fonderie, Etude relative au devenir des déchets présentant une très faible radioactivité produits par l'industrie de fonderie de précision à modèle perdu (*Foundry industry, Study on what happens to waste that is produced by the lost model precision foundry industry and has a very low level of radioactivity*), technical report no.01/0017, 31/01/2001
- 9. Fonderie PCC France, Etude de l'exposition aux rayonnements ionisants, Partie 1: exposition des travailleurs (*study on exposure to ionizing radiation, Part 1: workers' exposure*), report IRSN/DEI/SIAR No. 07/0338, 18/04/2007
- 10. L'Européenne d'Embouteillage,
 - Mesure radiologique sur le site de L'Européenne d'Embouteillage, rapport de fin d'intervention (*Radiological measurement at the Européenne d'Embouteillage site, post-intervention report*) No.2613/RFI/03/0180/163/0, 2/10/2006
 - Etude d'impact sur les travailleurs de la mise en œuvre de matières premières contenant naturellement des radionucléides non utilisés en raison de leur propriété (*Study on the impact on workers of the use of raw materials naturally containing radionuclides not used due to their properties*) no.2613/NT/06/0377/0, 20/07/2007
- 11. SANDEN Manufacturing Europe SAS, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection linked to the use of products containing natural radionuclides*) In application of the parliamentary Order of 25 May 2005 – reports from 27/06/2006, 20/06/2006, 17/10/2006
- 12. UFIP (French Union of Petroleum Industries), radioactivité naturelle liée à l'activité pétrolière en France (*natural radioactivity related to the petroleum industry in France*), report 58 953, November 2005
- 13. Bourbonne-les-Bains thermal facility, Le radon dans les bâtiments de l'établissement thermal de Bourbonne-les-Bains, Dépistage et investigations complémentaires (*Radon in buildings at the Bourbonne-les-Bains thermal facility, tracing and additional investigations*), report IRSN/DEI/SARG No. 03/03, 26/11/2003
- 14. SOLVAY-CARBONATE-France, Activités professionnelles mettant en œuvre des matières premières contenant naturellement des radionucléides (*industrial activities using raw materials naturally containing radionuclides*), analysis report No. 06/376/C, 14/06/2006
- 15. Déshydratation installations, Evaluation des expositions aux rayonnements ionisants liées à l'exploitation d'installations de déshydratation (*Evaluation of exposure to ionizing radiation related to the exploitation of dehydration installations*), April 2007, CEPN
- 16. SUN DESHY - Soudron and Francheville factories, Evaluation des doses associées à la production de mâchefers dans les installations de déshydratation de fourrages verts (*Evaluation of the doses linked to the production of clinkers in fodder dehydration installations*) – summary of the CEPN study, "Evaluation des expositions aux rayonnements ionisants liées à l'exploitation d'installations de déshydratation" (*Evaluation of exposure to ionizing radiation related to the exploitation of dehydration installations*) April 2007, 21/05/2007

17. Fédération des chambres syndicales de l'industrie du verre (FCSIV), Etude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*Generic study on the problems of radioprotection linked to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
18. Duralex International France, La Chapelle Saint Mesmin et Rives de Giers, Courier DURALEX from 20/06/2007 and FCSIV study: Etude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*Generic study on the problems of radioprotection linked to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
19. Electricité de France, Radioactivité naturelle des cendres de charbon - étude d'évaluation des doses reçues par les travailleurs des centrales thermiques charbon (*Natural radioactivity of coal ash – evaluation study of doses received by workers in coal power stations*), Study note E381/002831/EP/ENV, 10/05/2007 and CENDRES Project – Evaluation des risques d'exposition potentielle aux rayonnements naturels aux postes de travail des Centres de production thermique de BLENOD et La MAXE (*Evaluation of potential risks of exposure to natural radiation at workplaces at the BLENOD and Le MAXE thermal production centres*), HP 1E/06/023/B, November 2006
20. FOSECO, Etude destinée à évaluer les expositions aux rayonnements ionisants d'origine naturelle (*Study aimed at evaluating exposure to ionizing radiation from natural sources*), courrier SG/SQ/21/2007/PL, 25/05/2007
21. UNIFRAX France – Lorette factory, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides des chaînes naturelles de l'uranium et du thorium (*Study of problems of radioprotection relating to the use of products containing radionuclides from natural chains of uranium and thorium*) – reports from 24/05/2004, 25/05/2004, 16/09/2004
22. TIMAC, Saint Malo, Usine du quai intérieur et usine de la zone industrielle, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels (*Internal quay factory and industrial park factory, Study of problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005 – Reports from 17/04/2007, 18/04/2007, 19/04/2007, reference No. TIMA 60/0/ 2/04/ 07 V1/LL, 24/05/2007
23. Montupet, Diors, Etude destinée à mesurer les expositions aux rayons ionisants d'origine naturelle induits par les installations (*study aimed at measuring the exposure of ionizing rays from natural sources caused by the installations*), Montupet courrier reference YA/DM/IC/c/MONTUPET061127, 1/06/2007 and study carried out by the CTIF « la radioactivité en fonderie, sources et exposition des personnes, mesures de prévention » (*"radioactivity in foundry, sources and exposure of individuals, preventative measures"*), October 2006
24. Prodéva, Vatry, Evaluation des doses associées à la production de mâchefers dans les installations de déshydratation de fourrages verts et synthèse de l'étude CEPN

- « Evaluation des expositions aux rayonnements ionisants liées à l'exploitation d'installations de déshydratation » (*Evaluation of the doses linked to the production of clinkers in fodder dehydration installations and summary of the CEPN study, "Evaluation of exposure to ionizing radiation related to the exploitation of dehydration installations"*) April 2007, 21/05/2007
25. Fonderie et Ateliers du Bélier, Vêrac, Exposition aux rayonnements ionisants d'origine naturelle – Site de FAB à Vêrac (*Exposure to ionizing radiation from natural sources – FAB site, Vêrac*), Study CTIF / D2A 5634, May 2007
26. Vermont S.A., Montieramey, Courier ref. FL/MCB 8095, 28/06/2007
27. Cristal Union, Bazancourt, Evaluation des doses associées à la production de mâchefers dans les installations de déshydratation de fourrages verts et synthèse de l'étude CEPN "Evaluation des expositions aux rayonnements ionisants liées à l'exploitation d'installations de déshydratation" (*Evaluation of the doses linked to the production of clinkers in fodder dehydration installations and summary of the CEPN study, "Evaluation of exposure to ionizing radiation related to the exploitation of dehydration installations"*) April 2007, 15/05/2007
28. Euro luz, Pauvres, Evaluation des doses associées à la production de mâchefers dans les installations de déshydratation de fourrages verts et synthèse de l'étude CEPN "Evaluation des expositions aux rayonnements ionisants liées à l'exploitation d'installations de déshydratation" (*Evaluation of the doses linked to the production of clinkers in fodder dehydration installations and summary of the CEPN study, "Evaluation of exposure to ionizing radiation related to the exploitation of dehydration installations"*) April 2007, 26/06/2007
29. Alfaluz, 5 factories: Recy, Saint Remy, Pontfaverger, Sept saulx, Lavannes, Evaluation des doses associées à la production de mâchefers dans les installations de déshydratation de fourrages verts et synthèse de l'étude CEPN "Evaluation des expositions aux rayonnements ionisants liées à l'exploitation d'installations de déshydratation" (*Evaluation of the doses linked to the production of clinkers in fodder dehydration installations and summary of the CEPN study, "Evaluation of exposure to ionizing radiation related to the exploitation of dehydration installations"*) April 2007, 4/05/2007
30. Capdéa, 3 usines: Assencières, Aulnay, Marigny le Châtel, Evaluation des doses associées à la production de mâchefers dans les installations de déshydratation de fourrages verts et synthèse de l'étude CEPN "Evaluation des expositions aux rayonnements ionisants liées à l'exploitation d'installations de déshydratation" (*Evaluation of the doses linked to the production of clinkers in fodder dehydration installations and summary of the CEPN study, "Evaluation of exposure to ionizing radiation related to the exploitation of dehydration installations"*) April 2007, 9/05/2007
31. EUROFLOAT, Salaise-sur-Sanne, Etude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*Generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007, 1/06/2007), Courier from 18/06/2007

32. Arc International Cookware SAS, Châteauroux, Etude sur l'exposition des travailleurs à la radioactivité naturelle, Juin 2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*Study on the exposure of workers to natural radioactivity, June 2007 and generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
33. Saint-Gobain - ISOVER France, Chalon-sur-Saône, Courier from 21/06/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
34. Société de Traitements Chimiques des Métaux (STCM), Bazoches les Gallerandes, Etude destinée à mesurer les expositions aux rayonnements ionisants d'origine naturelle et à estimer les doses auxquelles la population est susceptible d'être soumise du fait de STCM, (*Study aimed at measuring exposure to ionizing radiation from natural source and estimating the doses to which the public is likely to be subjected due to the STCM*) October 2006
35. OI Manufacturing France, Veauche, Courier ref. JP/RM/0712d, 27/06/2007 and étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
36. Rhodia Electronics & Catalysis, La Rochelle, Etude faite par le site Rhodia Electronics & Catalysis dans le cadre de l'arrêté du 25 mai 2005, relative aux activités professionnelles mettant en œuvre des matières premières contenant naturellement des radionucléides non utilisés en raison de leurs propriétés radioactives (*Study carried out by the Rhodia Electronics & Catalysis site under the Order of 25th May 2005 on industrial activities using raw materials naturally containing radionuclides not used due to their radioactive properties*), Ref. HSE/GB/CD, 020/07, 18/06/2007
37. Saint-Gobain Emballage – Verrerie d'Epervain/Oiry, Courier ref. 07/PMF/029, 4/07/2007, étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007, Summary of the study and conclusions, recommendations for the facility
38. Saint-Gobain Emballage, St Romain le Puy Facility, Summary of the study and conclusions, recommendations for the facility, Courier from 27/06/2007, et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007

39. Saint-Gobain Emballage, Verrerie de Chalon sur Saône, Summary of the study and conclusions, recommendations for the facility, Courier ref. GF/MNF/062/107, 4/07/2007, et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
40. Saint-Gobain Emballage, Lagnieu Glassworks, Summary of the study and conclusions, recommendations for the facility, Courier ref. TTh/gv, 5/07/2007, et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
41. Tourres et Cie Saverglass, Le Havre, Courier ref. L VDE/JAA No.07/14, 5/07/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
42. INTERPANE Glass France S.A.S., Seingbouse, Courier from 3/07/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
43. Saint-Gobain Desjonqueres, Mers-les-Bains, Resume of the study and conclusions, recommendations for the facility, Courier from 16/07/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
44. HUNTSMAN Tioxide Europe S.A.S., Calais, Study carried out in accordance with article 2 of the additional prefectural Order DAECS/PE/BIC-CT No 2007-57, 27 February 2007, Ref. SHE/CG/AA, 31/05/2007
45. Saint-Gobain Emballage, Cuffies, Vauxrot Glassworks, Summary of the study and conclusions, recommendations for the facility, 11/07/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
46. Le bronze industriel, Suippes, Study report: Radioactivité naturelle renforcée, Mesures et prélèvements sur le terrain le 22/06/2007 (*Enhanced natural radioactivity, measurements and samples on the ground on 22/06/2007*), report No. Re 7-01, 19/07/2007

47. Valoref, Bollène
 - Impact de l'utilisation de déchets réfractaires sur les travailleurs et sur l'environnement (milieu naturel et population) (*Impact on workers and the environment of the use of refractory waste (natural landscape and populated areas)*), 29/06/2007
 - Chantier de démolition de four (*Oven demolition site*), Algade, 2009
48. Ferro Atlantica / FerroPem, Aigueblanche, Château-Feuillet factory, Etudes des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels (*Studies on problems of radioprotection related to products containing natural radionuclides*), interventions carried out by Algade on 17/05/2006, 18/05/2006, 12/06/2007 and 13/06/2007, report No. PEM60-02-06 07 V1FS, 10/07/2007
49. Saint Gobain Vetrotex, Chambéry, Courier from 24/07/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
50. SAVERGLASS, Feuquières, Courier from 16/07/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
51. OI Manufacturing France, Labégude, Courier from 12/09/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
52. Daussan, Woippy, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, Reports from 20/02/2007 and 21/02/2007, ref No. daus 60/0/ 2/02/ 07 V1/FS, 30/04/2007
53. U.E.M. Metz electricity factory, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, Reports from 22/05/2007, 23/05/2007 and 24/05/2007, report No UEMZ 60/0/ 2/05/ 07 V1/SB, 5/07/2007
54. Novacarb, Laneuville-devant-Nancy, Courier Ref. VJ/BH/HSQE 2007/129, 12/10/2007 et rapport relatif à l'étude de l'impact potentiel sur les travailleurs de la radioactivité naturelle contenue dans des produits de combustion (*report on the study of the potential impact on workers of the natural radioactivity contained in combustion products*), SMART/Subatec report No. RC2007/68, 30/03/2007

55. Interpane, Seingbouse, Courier from 8/11/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
56. AGC Glass unlimited, Bousois, Courier from 17/12/2007 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
57. Elyo Suez, Installations at Bagnolet, Massy, Vaulx-en-Velin and Besançon, Evaluation de l'exposition des travailleurs aux rayonnements ionisants des cendres issues de la combustion du charbon en centrale de production thermique (*Evaluation of the exposure of workers to ionizing radiation from ash from the combustion of coal in thermal power stations*), 3/10/2007
58. Storaenso, Corbehem, Courier from 8/02/2008 et étude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, Reports from 18/09/2007 and 19/09/2007, report No. STEC 60/0/ 2/09/ 07 V1/SB, 5/11/2007
59. ALCAN, Beyrede, Courier from 23/02/2007 et étude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25 May 2005, Intervention from Algade on 7/09/2006 and 8/09/2006, report No. ALCA 64/0/ 2/09/ 06 V1/FS, 19/02/2007
60. SAFEM, L'Isle d'Espagnac, Courier Ref MG/BP/7192, 21/12/2006 and study carried out by CTIF: la radioactivité en fonderie, sources et exposition des personnes, mesures de prévention (*radioactivity in foundry, sources and exposure for individuals, prevention measures*), October 2006
61. Euroglass, Hamburg, Courier from 25/01/2008 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
62. Société de Traitements Chimiques des Métaux (STCM), Toulouse, Etude destinée à mesurer les expositions aux rayonnements ionisants d'origine naturelle et à estimer les doses auxquelles la population est susceptible d'être soumise du fait de STCM (*Study aimed at measuring exposure to ionizing radiation from natural source and estimating the doses to which the public is likely to be subjected due to the STCM*), October 2006
63. Saint-Gobain Glass, Aniche factory, Courier from 9/1/2008

64. CTIF, Etude générique - La radioactivité en fonderie, sources et exposition des personnes, mesures de prévention (*Generic study – Radioactivity in foundry, sources and exposure of individuals, preventative measures*), October 2006
65. Fertinagro, Misson, Courier from 14/12/2007 et étude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, Report from 3/07/2007, report No. FERT 60/0/2/07/ 07 V1/LL, 10/12/2007
66. Ferro Couleurs France, Limoges, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, report carried out between 6th September and 15th Novembre 2007, report N° FERR 60/0/ 2/11/ 07 V1/SB, from 4/02/2008
67. CMMP, Saint Quentin, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, Intervention carried out by Algade between February 2007 and September 2007, report No. CMMP 61/02/09/ 07 V1/SB, 4/02/2008
68. TERREAL, Saint Amans Sault, Exposition à la radioactivité naturelle renforcée sur le site de TERREAL à Saint-Amans-Sault (81) (*Exposure to enhanced natural radioactivity at the TERREAL site, Saint-Amans-Sault (81)*), report IRSN/DEI/SIAR No.08/0022, 7/02/2008
69. EDF, Etude générique - Radioactivité naturelle des cendres de charbon, Etude de l'exposition de la population aux rayonnements ionisants d'origine naturelle (*Generic study – Natural radioactivity of coal ash, Study on exposure of the public to ionizing radiation from natural sources*), T AF 0 000 PPPP NE X 2126 Index A, 4/04/2007
70. Bormioli Rocco, Masnières, Courier from 20/03/2008 et étude générique des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels dans les activités de verrerie (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*) (October 2006 – February 2007), 1/06/2007
71. Rockwool France, Saint Eloy-Les-Mines, Courier from 15/04/2008 et étude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*generic study of the problems of radioprotection related to the use of products containing natural radionuclides in glassmaking*), Intervention carried out by Algade on 15/06/2007 and 16/10/2007, report No. ROCK 60/0 2/10 07 V1/FS, 26/03/2008
72. SAPA Profilés Puget, Puget sur Argens, Report APAVE No.2705115, 12/10/2006
73. Sud Fertilisants, Sète, Courier from 19/09/2007 et étude des risques radiologiques liés à la radioactivité naturelle (*study on the radiological risks linked to natural radioactivity*), in application of the parliamentary order of 25th May 2005, Sud Fertilisants, 30/08/2007

74. Aluminium Dunkerque, Loon-Plage, Courier from 15/07/2008 et étude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, Intervention carried out by Algade on 26/02/2008 and 27/02/2008, report No. ALCA 69/0 2/02 08 V1-FS, 16/06/2008
75. ALCAN Gardanne, Courier from 27/08/2007 et étude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, Intervention carried out by Algade on 20/12/2006, 15/03/2007 & 16/03/2007, report No. ALCA 63/03 07 V2/FS, 22/08/2007
76. Interfertil, Le Tréport, Courier from 12/12/2007 et étude des risques radiologiques liés à la radioactivité naturelle (*study of radiological risks related to natural radioactivity*), in application of the parliamentary Order of 25th May 2005, 27/11/2007
77. Interfertil, Tarnos, Etude des problèmes de radioprotection liés à l'utilisation de produits contenant des radionucléides naturels, (*Study on problems of radioprotection related to the use of products containing natural radionuclides*), in application of the parliamentary Order of 25th May 2005, Generic study based on measurements taken at the Tarnos site, report No. INTE 60/0 2/08 07 V1 LL, 22/08/2007
78. Société Européenne des Produits Réfractaires (SEPR), Le Pontet, Impact environnemental associé à l'utilisation du zircon à la SEPR (*Environmental impact linked to the use of zircon at the SEPR*), August 2008
79. Société nationale d'électricité et de thermique (SNET), Hornaing, Courier SNET/no.60-FH/FL, 3rd October 2008 and study, « Evaluation des risques d'exposition potentielle aux rayonnements naturels aux poste de travail de la centrale thermique d'Hornaing » (*"Evaluation of potential risks of exposure to natural radiation at workplaces in the Hornaing power station"*), September 2008
80. SATORI, Courier from 14/11/2008 and technical note no. 0810/060 of ITPF on l'exposition professionnelle lie à la radioactivité naturelle – Evaluation des doses reçues dans l'atelier CARTERS ATAR (*industrial exposure related to natural radioactivity -Evaluation of doses received in the CARTERS ATAR site*), 10/10/2008
81. Thales Optronic, use of compounds containing Thorium (thorium optics), « dossier d'étude sur l'exposition aux rayonnements ionisants d'origine naturelle » (*"dossier study on exposure to ionizing radiation of natural sources"*), April 2009