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PRACTICAL IMPLICATIONS OF THE ADOPTION OF EXEMPTION VALUES IN TRANSPORT

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SUMMARY

IAEA Safety Series 6, 1985 Edition (amended 1990) states that "Radioactive material shall mean any material having a specific activity greater than 70kBq/kg". The 1996 Transport Regulations now defines radioactive material as any material with specific activity and total activity greater than radionuclide specific values given in the Regulations. The values of activity concentrations range from about 1 to 10^7 Bq/g (most of the values being in the range of 1 to 100 Bq/g) and the total activity from 10^3 to 10^{10} Bq. As these values are radionuclide dependent and generally lower than 70 Bq/g, their implementation for transport practices may give rise to changes in the present management of transport as well as measurement procedures. However, the 70 Bq/g value was generally understood to apply to all radionuclides present in a radioactive material while the new radionuclide specific values are for parent radionuclides and include the contribution from daughter radionuclides.

In this context, the aim of this report is to present the evaluation of the main impacts arising from the implementation of the new exemption regulation. This evaluation is performed within the framework of a project funded by the European Commission involving different teams from France, United Kingdom and Germany. For this evaluation, the following steps were developed on the basis of the different national contexts:

- Analysis of the exemption concept in the national transport regulation
- Identification of the transport practices affected by the modification of the regulations
- Evaluation of the practical implication for selected practices

Special attention is given to transport practices involving natural radionuclides in different European countries, as well as material originating from the decommissioning of nuclear installations.

With regard to the 1996 edition of the IAEA Transport Regulations, it appears that with few exceptions the new exemption criteria are unlikely to impose greater or lesser constraints for

radionuclides and consumer products and materials containing naturally occurring radionuclides than that imposed by the previous Transport Regulations. These transport exemption values are identical to those adopted in the Euratom Concil Directive (EC/96/29), although for the transport of materials containing natural radionuclides not intended to be processed for use of these radionuclides a factor 10 is used.

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1. INTRODUCTION

The definition of exemption criteria was given in IAEA Safety Series 6, 1985 Edition (amended 1990) and stated that "Radioactive material shall mean any material having a specific activity greater than 70kBq/kg". On the basis of radiological concern and for the purpose of homogeneity with the IAEA Basic Safety Standards, the 1996 Transport Regulations now define radioactive material as any material with a specific activity concentration per unit mass and total activity per consignment greater than radionuclide dependent values given in the Regulations.

As these values are radionuclide dependent and rather low, their implementation for transport practices may necessitate an update of the present management of transport as well as the procedures of measurement. This report presents the results of a joint research project (France, United Kingdom and Germany) funded by the European Commission DG XVII. It aims at analysing the main impacts of the implementation of the new exemption regulation. For this purpose, the following steps have been considered:

1. Analysis of the exemption concept in the national transport regulation
2. Identification of the transport practices concerned with the new regulation in France, UK and Germany
3. Preliminary determination of the practical implications for the selected practices

2. THE EXEMPTION CONCEPT IN THE TRANSPORT REGULATIONS

The principles and methods for establishing exemption values have been published by the European Commission DG XI (Radiation Protection 65) and endorsed by the International Atomic Energy Agency (Basic Safety Standards). These documents contain radionuclide-specific activity and activity concentration values, below which reporting is not required for all practices, as the risk involved in handling these radionuclides is considered so small as not to warrant a system of control and supervision by the competent autority.

Concerning the transport of radioactive materials (RAM), the basic radiological dose criteria of the International Basic Safety Standards for Protection Against Ionizing Radiation (BSS) and for the Safety of Radiation Sources (Safety Series No. 115) (including an individual dose of 10 μSv per year and a collective dose of 1 man.Sv per year) were endorsed for the revision of the IAEA Transport Regulations.

Nevertheless the BSS approach, which leads to radionuclide-specific exemption values, is not compatible with a single specific activity value such as the 70 kBq/kg used in the current transport regulations. Therefore a first study, performed under contract to the EC DG XI, was conducted in order to examine the relevance of the BSS exemption criteria to the transport practices. As far as no specific transport scenarios have been considered in the methodology used by the BSS, this study took into account relevant transport scenarios for selected radionuclides in order to derive specific exemption values using the same basic radiological dose criteria.

Because of the general agreement between the transport specific exemption values and those of the BSS, it was considered reasonable to adopt, in the 1996 Edition of the Transport Regulations, the BSS exemption values below which the transport regulations would not apply (Figure 1). Special rules have been adopted for the transport of materials containing natural radionuclides not intended to be processed for use of these radionuclides: in that case, a factor of ten is applied to the exemption activity concentration value.

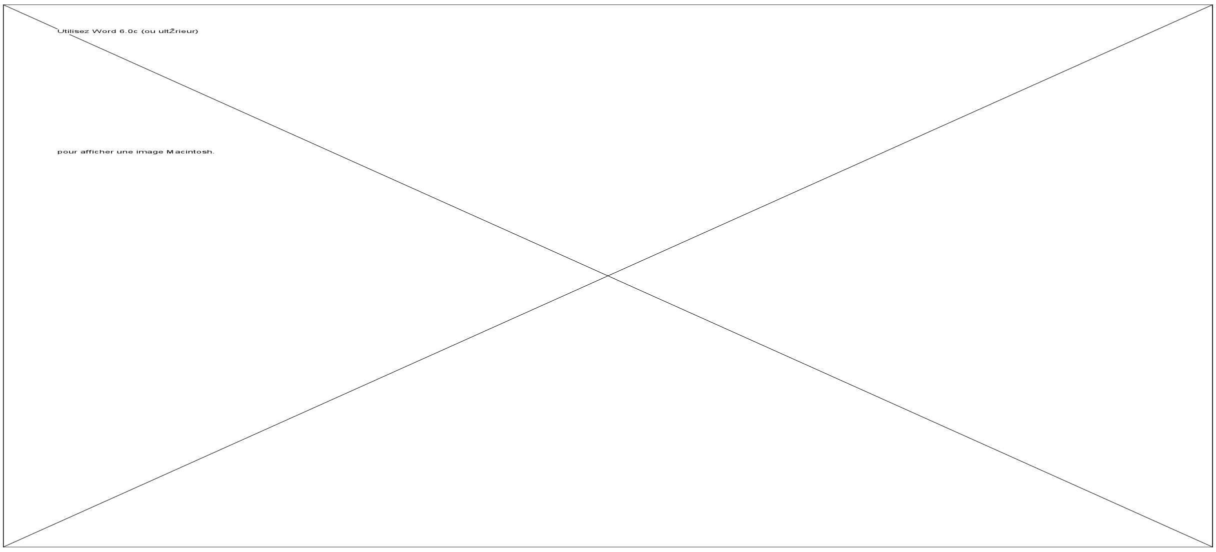

Figure 1. Exemption values for selected radionuclides versus 70 Bq/g

3. REGULATORY FRAMEWORK AND CONTROL

According to the present national regulatory framework, it appears that the level of concern for the application, the monitoring and the controls varies depending on the practices and countries.

3.1 General provisions

The existing International Transport Regulations and, consequently, the nationally applicable Regulations demand any material having a specific activity per unit mass in excess of 70 Bq/g be subject to the safety requirements of the Regulations. Explicitly excluded from the safety requirements of the national and international Regulations are according to § 2009 ADR:

a) transport of limited quantities of hazardous material carried by private individuals, if the material is properly packaged and exclusively used for private or household purposes or for leisure life or sport activities, e.g. thoriated gas mantles.

b) transport of limited quantities of hazardous material forming an integral part of machinery or consumer products.

c) transport of wrecked vehicles carrying hazardous cargo provided that all precautionary measures are taken to assure a completely safe transport.

We note, that the items and materials referred to under a) and b) exempt a broad variety of consumer products containing limited quantities of radioactive material and carried or used occasionally or periodically by private individuals from the safety requirements of the Regulations, e.g. timepieces, fluorescent lamp starters, electronic tubes, smoke detectors etc. The exemption provisions provided for by § 2009, however, may not apply to transport of RAM by commercial shippers or carriers, if these items and materials are carried in larger volumes.

3.2 National provisions

3.2.1 France

Since 1997, the executive role of the French competent authority, whatever the mode of radioactive transport, is carried out by the Direction de la Sûreté des Installations Nucléaires (DSIN) with the technical support of the Institut de Protection et de Sûreté Nucléaire (IPSN). These organisations allow consistency between all the nuclear practices, including transport, especially to ensure compliance with the relevant legislation.

The current IAEA transport regulations and international modal regulations are implemented in the French domestic legislation for ground transport by the recent decrees dated Dec. 5, 1996 («ADR») and Dec. 1996 («RID») which include further requirements concerning, in particular, consignors declarations and transport documents. In addition, the French nuclear companies have implemented their own dedicated requirements including specific notifications prior shipment.

3.2.2 United Kingdom

The main licensing body for radioactive materials in the UK is the Environment Agency (EA), which administers and enforces the requirements of the Radioactive Substances Act, 1993. This Act requires registration for the use and storage of radioactive materials and authorisation for its disposal. Exemption orders made under this act are currently under review. The EA is also the Competent Authority for a number of EC Directives on the shipment of radioactive substances and sealed sources between EU Member States, and shipments of radioactive wastes into, out of, and within England and Wales to ensure that appropriate disposal arrangements are in place before the shipment of the material or waste. Occupational exposure to ionising radiation is regulated by the Health and Safety Executive (HSE) under the Health and Safety at Work Act, 1974, and the Ionising Radiation Regulations, 1985. Both the EA and HSE have inspectors that periodically visit premises in which radioactive materials are used to ensure compliance with the relevant legislation.

The UK implements and enforces the european agreements concerning the international carriage of dangerous goods by road and rail. The executive role of the competent authority is carried out by the Radioactive Materials Transport Division of the Department of the Environment, Transport and the Regions. This department is also responsible for introducing and enforcing national legislation for the transport of radioactive materials, which are in accordance with the IAEA regulations.

3.2.3 Germany

In addition to the general exemption provisions with relevance to RAM provided for by the Transport Regulations, other items and materials have been explicitly exempted from the safety requirements of the Regulations on the national level based on provisions codified in the Hazardous Cargo Exemption Ordinance (GGAV). The items and materials exempted from the safety requirements of the regulation for road and rail transports (applies not to air and sea) by virtue of the Hazardous Cargo Exemption Ordinance include the following, provided that these items and materials are not subject to the licensing and notification requirements of the Atomic Energy Law (AtG) and its subordinated regulations:

- Pacemakers
- Radiopharmaceuticals
- Products (e.g. timepieces, dials) for personal use containing radioactive paint
- Thoriated gas mantles
- Thoriated welding rods
- Electric lights and lamp starters containing natural thorium or Krypton 85

The nationally relevant exemption provisions are - in contrast to the „general“ exemption provisions - generally applicable and apply to both private individuals and commercial shippers provided that these items and materials are shipped in limited quantities and other relevant requirements are met. Any other radioactive materials fall in the scope of the Transport Regulations and are subject to the administrative and technical controls, including supervision and enforcement, laid down in the nationally existing decrees and regulations.

4. MATERIALS OF CONCERN

The analysis performed in this project is focused on the transport practices involving the shipment of materials with low specific activities. It could include the transport of food, coal and coal ashes, building materials, thoriated welding rods and gas mantles, fertilisers, pipeline scale, ores, radioactive wastes, radioactive materials used in hospitals, lighting products, smoke detectors and other consumer products.

According to the activity concentrations prevaling in such materials and the associated transport practices, the manufactured products and materials containing radionuclides with relevance to the study can be broadly grouped in:

- building material
- mining and agricultural products
- contaminated/irradiated materials from decommissioning of nuclear fuel cycle facilities and other areas
- other manufactured (consumer) products

Detailed analyses of these different categories are presented in the national annexes. The following paragraphs present the main results of the analyses performed within this project.

4.1 Building material

This category includes clay, sandstone, bricks, concrete and cement. These materials mainly contain the following natural radionuclides: K-40, Ra-226. With respect to the exemption activity concentration limits (respectively 1000 Bq/g and 100 Bq/g), the activity concentrations found in building materials appears to be two orders of magnitude lower. Consequently, the building material would most likely not fall into the scope of the new regulation.

4.2 Mining and agricultural products

The mining and milling products concern the ore industry and the oil and gas extraction industry.

Within the ore industry, the study focused on phosphate, potash, niobium, iron, zircon sand, microlith concentrate, tin process and rare earth such as monazite, bastnaesite. Table 1 presents the maximum values of activity concentration observed in France, United Kingdom and Germany.

Table 1. Maximum activity concentration in ores etc. (Bq/g)

	Phosphate	Tin	Niobium	Zircon sand	Rare earths monazite,bastnaesite	Exemption value
Po-210,	500		500	400	500	100
Pb-210	500		500	400		100
Th-228		15	80	40	3000	10
Th-230			10	74	500	10
Th-232					3000	100
Ra-226					500	100
Ra-228					3200	100
U-234					500	100
U-238					500	100
Pa-231					23	10
Ac-227				3	23	1

(N.B. According to ST-1, §107, "Natural material and ores containing naturally occurring radionuclides which are not intended to be preocessed for use of these radionuclides provides the activity concentration of the material does not exceed 10 times the values" of exemption levels.)

Iron, potash and coal production related activity appear to be not of concern for the new regulation. According to German data, an average of 120 Bq/g of Ra-226 is observed within the microlith concentrate and thus could be affected by the new regulation, but are already affected by the current regulations.

Pipeline scale from the the oil and gas extraction industry presents a significant concentration of radium, and thorium. These figures (Table 2) largely exceed the exemption threshold, and the current definition of radioactive material.

Table 2. Maximum activity concentration in oil and gas extraction (Bq/g)

	Oil and gas extraction	Exemption value
Th-228	200	10
Pb-210	2000	100
Po-210	600	100
Ra-226	2000	100
Ra-228	2000	100

It is important to point out that pipeline scale from oil and gas extraction is already under the scope of the regulations, and thereore subject to normal transport controls. Consequently, the application of radionuclide-specific exemption values will not affect these materials.

4.3 Contaminated/irradiated materials from decommissioning of nuclear fuel cycle

With regard to the nuclear industry in France, the main concern is related to exemption of radioactive materials derived from dismantling and decommissioning of nuclear installations. Also in France, the exemption values do not directly apply to the materials arising from dismantling and decommissioning, they should be considered as upper limits for the clearance levels. In France, the competent authority for the safety of nuclear installations (DSIN) is not favourably disposed towards the use of exemption values for the wastes arising from the dismantling and decommissioning of nuclear sites. A specific methodology has been proposed recently to classify the dismantling wastes according to their spatial origin and the operational history of the area they belong to. Consequently, waste cannot be exempted only on the basis of its total activity or activity concentration. According to preliminary analyses, EDF now envisages the transport of the main dismantling wastes in excepted packages, even if some of them should respect the exemption criteria for transport because it is expected that the activity concentration of most of the dismantling wastes will be about 10 Bq/g.

4.4 Other manufactured (consumer) products

The materials of concern involve thorium compounds (such as thoriated welding electrodes, gas mantles and electric light devices) and smoke detectors. The maximum values observed in France, United Kingdom and Germany are presented in Table 3.

Table 3. Maximum activity concentration in other manufactured products (Bq/g)

	Thoriated welding electrodes (1-4%(ThO_2))	Gas mantles	Electric light devices	Exemption (Bq/g)
Th-228	35 - 140	1700	500	10
Th-232	35 - 140	3600	500	100
Th-230		460		10
Ra-228		2100		100
Kr-85 *			10^6	10^5

* Kr-85 value is not modified by the special rule applying a factor 10 on natural material and ores

For thoriated electrodes: the weight percentage of Th-228 / 232 ranges from 1 % to 4 %. For a 2 % rod, the activity per single rod was assessed as 3120 Bq to be compared with the maximum permissible activity per consignment of 10000 Bq. Due to the exemption level of activity concentration for the thorium (10 Bq/g), the thoriated tungsten welding electrodes (calculated activity concentration from 71 Bq/g up to 280 Bq/g) would come under the scope of the Transport Regulations (current and future).

Concerning thoriated luminous products, the maximum activity observed in Th-228/232 is 10^4 Bq per item (Xenon short arc lamp / mercury vapour short lamp).

For electric light devices, the maximum activity of 5000 Bq per item (metal halide lamps) for Kr-85 has to be compared with 10^4 Bq exemption value per shipment. Analyses on light devices containing thorium or Kr-85 indicate activities that closely approach or exceed both the 1996 activity exemption limits and activity concentration limits. Consequently, practically all shipments of such luminous and related consumer products, especially if shipped in larger volumes , would fall in the regulatory regime of the new 1996 Transport Regulations and the current regulations. It should be pointed out that the 1996 Transport Regulations do not apply to radioactive material in consumer products which have received regulatory approval, following their sale to the end user.

Smoke detectors normally contain a single isotope either Am-241, Pu-238 or Ra-226. According to UK data up to 33.3 kBq of Am-241 can be included in a detector. As one pallet contains 1080 units, the total activity per consignment is about 3.6 10^7 Bq, to be compared with the exemption value of Am-241 per consignment of 10^4 Bq. There is no exemption based on activity content in the previous regulations.

4.5 European traffic of material containing natural occurring radionuclide

In order to evaluate the amount of low-level radioactive materials concerned within the scope of the study, the Eurostat basic statistics were analysed. They provide exhaustive data on import and export for the European Union in 1987.

- About 7 250 000 tons of phosphate were used in Europe, major EC producers being France, Spain and Belgium and Luxembourg.
- The use of niobium metal ores represents 3250 tons and zircon sands 122 tons.

- According to French mine statistics (BRGM), Rhône Poulenc (La Rochelle, France) is the first world-wide producer of separated rare earths (9 kt/year) from Australian and Asiatic ores.
- The annual amount of scale from oil and gas extraction removed and disposed of in the UK is about 200 tonnes and this probably constitutes the major part of this material in the EU.
- With respect to the manufacture and use of thorium, 1 million gas mantles, 16 tons of thoriated glass and 200 000 pieces of thoriated electrodes were manufactured and distributed for sale .

With respect to the amount of material being produced or used, a rough estimation of the related number of shipments can be derived. The phosphate industry leads to some ten thousand potential shipments. Tens to hundreds of transports movements can be expected from the use of Niobium and Zircon sands. Oil and gas scale movements transported as contamination on pipework and plant involve a few hundred shipments annually. On the basis of French data, some tens shipments of rare earth should take place. As thoriated items and gas mantles are non bulky, the related number of transports is difficult to define. With regard to these figures, special attention should be provided to the phosphate industry which gives rise to a significant number of transports.

5. DISCUSSION/CONCLUSION

Investigations have been made during this study of a large number of operations in which low level radioactive materials are transported, either as bulk or as part of articles such as consumer products. These data represent an important collection of information from three Member States and will be of benefit to other studies on the transport of radioactive materials.

The majority of low-level radioactive materials transported in France, UK and Germany will be unaffected by the new exemption requirements in the 1996 edition of the IAEA Transport Regulations. These transport exemption values are identical to those adopted in the Euratom Concil Directive (EC/96/29), although for the transport of materials containing natural radionuclides not intended to be processed for use of these radionuclides a factor 10 is used. The materials transported were either not considered radioactive under the old Regulations and remain so under the new Regulations , or they were within the scope of the old Regulations and remain so in the new ones. Only a few transport operations may be affected by the new Regulations. These include materials containing enhanced quantities of natural occurring thorium and some bulk movements of consumer products. For these materials, the application of the Transport Regulations is believed of not being overly constraining, nevertheless special attention should be given regarding the implementation of a radiation protection programme. If for a specific material of concern it can be demonstrated, that transportation of this material does not involve any appreciable radiological risks, issue of a general exemption order may be taken into consideration for such a material. However, for the ease of international transportation and in the interest of harmonisation, e.g. within the EU Member States, application of an unified approach in issuing an exemption order would be preferable.

REFERENCES

IAEA, **Regulations for the Safe Transport of Radioactive Material,** Safety Standards Series No. ST-1, Vienna, 1996.

IAEA, **Regulations for the Safe Transport of Radioactive Material,** Safety Series N° 6, Edition 1985, Vienna, 1990.

FRANCOIS P., CAREY A., HARVEY M., HUGHES J.S., LOMBARD J., MOBBS S., RAFFESTIN D., SCHNEIDER T. and SHAW K.B., **The Application of Exemption Values to the Transport of Radioactive Materials,** In: Proceedings of the 11th Conference on the Packaging and Transportation of Radioactive Materials (PATRAM'95), Las Vegas, USA, 3-8 December 1995, Vol.1, pp. 462-469.

HARVEY et al., **Principles and Methods for Establishing Concentrations and Quantities (Exemption values) Below which Reporting is not Required in the European Directive,** CEC Report DOC XI-028/93, RP-65, 1993.

PENFOLD J.S.S., DEGRANGE J.P., MOBBS S.F., SCHNEIDER T., **Establishment of Reference Levels for Regulatory Control at Workplaces where Materials are Processed which Contain Enhanced Levels of Naturally occurring Radionuclides,** Report NRPB-M855, 1997.

DEGRANGE J.P., **Preliminary data concerning the transportation of materials which contain enhanced levels of natural radionuclides,** Note CEPN 98/05, Février 1998.

EUROSTAT, **Basic Statistics,** 32nd Edition, 1995.

BRGM, Carte minière de la France au 1/1000 000 ème, 1995.

EUROPEAN COMMISSION, **Study on Consumer Products containing Radioactive Substances in EU Member States,** Radiation Protection 68, Report EUR 15846 EN, 1995.

BECKER D.E., REICHELT A., **Anthropogene Stoffe und Produkte mit natürlichen Radionukliden, Teil I: Überblick über die wichtigsten Expositionspfade,** Bayerisches Staatsministerium fur Landesentwicklung und Umweltfragen, München, August 1991.

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit), **Umweltradioaktivitat und Strahlenbelastung,** Jahresbericht 1993, Bonn 1996.

IAEA, **International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources,** Safety Series N° 115-I, Vienna 1994.

ADR, **European Agreement Concerning the International Carriage of Dangerous Goods by**

Road.

JOURNAL OFFICIEL L159, **Directive 96/29 Euratom du Conseil du 13 mai 1996 fixant les normes de bases relatives à la protection sanitaire de la population et des travailleurs contre les dangers résultant des rayonnements ionisants,** Juin 1996.

ANNEX 1

Practical Implications of the Adoption of the Exemption Criteria embodied in the 1996 Transport Regulations to Transport Practices in France

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1. NUCLEAR INDUSTRY: EXEMPTION ISSUES FOR DECOMMISSIONING-EDF POSITION

1.1 Regulatory context in France

With regards to nuclear industry, the main concern is the dismantling and decommissioning of nuclear installations.Also, the exemption values do not directly applied to the materials arising from dismantling and decommissioning, they have to be considered as upper limits for the clearance levels. In France, the DSIN (the French authority for the nuclear installations safety), is not favourably disposed towards the use of exemption values for the wastes arising from the dismantling and decommissioning of nuclear sites. With preliminary consultations of the main French utilities (COGEMA, CEA, EDF), the DSIN has developed its own methodology for the radwaste disposal. This regulatory context explains why the concept of exemption is not considered very useful - and not really applicable - by the French utilities, and why they are trying to avoid having recourse to it, in the domain of waste transport also. It must be also noted that DSIN has been recently (June 1997) named as the competent authority for the radwaste transport. Consequently, the point of view of the French regulator concerning decommissioning waste disposal will probably be the most constraining feature for the transport of radioactive wastes.

1.2 The methodology envisaged by the French authorities

The DSIN methodology consists in classifying wastes in accordance with the application of both principles of « zoning » (see further) and « waste elimination paths » (deep or surface storage, very low level waste storage and dumps, possible reuse eventually after compaction, melting…).

The zoning is made according to the spatial origin of the waste and the local[1] operational history of the area it belongs to (incidents of contamination, walk area, intermediate storage area…). Two types of zones are distinguished:

- « nuclear waste zones », where it can be found all types of radioactive wastes :

- High level radioactive waste (and wastes containing long lived radionuclides), which would be sent to the deep storage, in the future,
- Intermediate and low level radioactive wastes, which would be send to the Centre de Stockage de l'Aube,
- Very low level radioactive wastes (below about 100 Bq/g), which would be send in the appropriate storage (not yet designed),
- Non radioactive wastes but needing a specific management (for example, due to the operational history of the area they was belonging to), which would be send also, in most cases, in the very low level waste storage.

All these wastes will be submitted, case by case, to a specific radiological impact study before to be turned toward an elimination path or another.

- « conventional waste zones », where it can be found, by definition:

- only non radioactive wastes which will be send to an industrial dump, without any specific procedure.

In conclusion, the concept of « clearance level » does not exist in France and probably will not exist in the near future as unconditional generic values of activity concentration. The French

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1 The zones are not necessarily corresponding to physical separation of areas (e.g. by walls): it can be envisaged to classify some waste arising from one area as « conventional » and others arising from the same area as « nuclear ». Anyway, the DSIN will give the authorisation case by case.

safety authority prefers to make utilities aware of their responsibilities towards the classification of waste. The aim of this approach is to put the emphasis on the case-by-case analysis and nuclear site operational review rather than on the techniques of activity measurement. However in practice, EDF proposals for zoning are made on the basis of the calculation of standard activity spectrum: the value of 1 Bq/g is generally the practical threshold to define an area as « conventional waste zone » (if no significant incident has occurred in the past).

1.3 The transport of low level radioactive waste arising from the decommissioning of a French PWR

EDF wants to optimise the waste management process at a global level. Thus, EDF wishes to reduce as far as possible the number of primary packaging (i. e. without the transport container) and to develop generic packages for transportation and storage (on industrial site and on disposal). One proposal could be the use of big bags or standardised packaging.

A preliminary analysis of transport has been performed concerning dismantling waste devoted to VLLW (very low level waste) disposal. Six types of waste have been considered with their respective radionuclide spectrum (insulation, rubbles, big tanks, pumps and pipes, electric cabinets). For each of them, the following criteria compliance have been examined: exemption (total activity and activity concentration) and excepted packages.

According to the available monitoring system, the 10 Bq/g (figure allowing exemption for mixed radionuclide) has been considered as the reference value. It should be noted that total activity is not a relevant criteria due to the storage management (for technical and economic reasons, there is a need for transporting and storing large quantities of material) and due to the radionuclide of concern (Co-60).

It is expected that in average the activity concentration of the dismantling waste will be about 10 Bq/g. According to this situation, it should be possible to envisage the exemption of these transports. Nevertheless, the present position of EDF consists to envisage the transport of most of the dismantling wastes in excepted packages (especially because the French authority is presently against the unconditional clearance of the wastes from nuclear installations).

2. EXEMPTION ISSUES FOR NATURAL RADIONUCLIDES IN INDUSTRY

This section summarises the industries that could be concerned by the transportation of materials containing natural radionuclides with an activity concentration higher than exemption limits. The natural radionuclides concerned are principally U-238, U-235 and Th-232 together with their decay products.

The information presented is based on a study performed for the European Commission (Establishment of reference levels for regulatory control of workplaces where minerals are processed which contain enhanced levels of naturally occurring radionuclides, J. S. S. Penfold, J. P. Degrange, S. Mobbs and T. Schneider to be published).

At present time all these industrial activities are exempted. In the following tables, only radionuclides with concentration higher than the exemption levels are considered.

2.1 The phosphate industry

The phosphate rock $Ca_5F(PO_4)_3$ is the starting material for the production of all phosphate products. A large part of white phosphorus is converted into phosphoric acid for later use in the manufacture of artificial fertilisers. The process operations are divided in two different stages: the mining and milling of phosphate ore and the manufacture of phosphate products by either the wet or thermal process. The maximum activity concentrations in materials are reported for the thermal process, where most of the uranium (and its decay products) originally contained in the phosphate ore is retained in the slag. Because of high temperature of the process, most of the volatile radionuclides are released to the process air, giving concentrations of 50 to 500 Bq/g of Po-210 and Pb-210 in dust precipitates, as shown in the following table.

Phosphate industry

	Min. (Bq/g)	Max (Bq/g)	Exemption value (Bq/g)
Pb+210	50	500	100
Po210	50	500	100

2.2 Tin process

Of minerals containing tin, Casserite or tinstone is of the greatest commercial importance. The ore is washed and separated to produce a 70% tin concentrated. This concentrate is mixed with charcoal and heated, then the tin is remelted in a second furnace for further purification to obtain 99.9% purity tin. The major use of tin is in alloys with other metals and as a protective coating. The main hazards are with melting slag. typical concentration in tin ore and slag in the UK were 1 Bq/g of U-238 and 0.3 Bq/g and 4 Bq/g in ore and slag respectively for the Th-232 chain. In slag, only Th-228 has a concentration higher than the exemption limit, as shown in the following table, but up to 200 Bq/g of Po-210 has been found in the collected fume of one UK plant.

Tin smelting slag

	Min. (Bq/g)	Max (Bq/g)	Exemption value (Bq/g)
Th+228	0,09	15	10

2.3 Manufacture of rare earths

The most important sources of rare earth elements are monazite and bastnaesite. The higher concentration is find in monazite sand, as it includes $ThPO_4$. The monazite ore concentrate is obtained from suitable sands by gravimetric and electromagnetic sorting. Then lanthanides are precipited using strong acid or alkaline solutions on the concentrate. The bastnaesite ore concentrate is obtained by a wet process. This concentrate is washed with hydrochloric acid and calcined in order to produce a crude oxide containing 90% of lanthanide oxides. As shown in the next table, most of the radionuclides contained in the ore have a concentration higher than the exemption levels. In particular, the Th-232 decay chain is reported to have activities up to 3000 Bq/g in the monazite concentrate.

Rare earth extraction

	Min. (Bq/g)	Max (Bq/g)	Exemption value (Bq/g)
Th232	0,4	3000	100
Ra+228	23	3200	100
Th+228	0,4	3000	10
Th230	3,5	500	10
Ra+226	3,5	500	100
Pb+210	3,5	500	100
Po210	3,5	500	100
Pa231	0,16	23	10
Ac+227	0,16	23	1
U+238	3,5	500	100
U234	3,5	500	100

2.4 Oil and gas extraction industries

In the oil and gas extraction industries, radiological hazards are due to the scale phenomenon occurring with the oil and gas reservoirs formed in the Jurassic era. It is the result of mineral impurities and builds up because of the injection of incompatible water into the well, evaporation in gaseous wells, pressure changes and/or temperature drops. The material is either barium/strontium sulphate or calcium carbonate precipitate. The chemical similarity of radium and barium leads to it selectively co-precipitating in the scale, which leads to concentration of radium isotopes, at levels higher than exemption values, as shown in the following table. The only other radionuclides are short lived Ra-226 and Ra-228 decay products.

Oil and Gas extraction (scales)

	Min. (Bq/g)	Max (Bq/g)	Exemption value (Bq/g)
Ra+228	6,00E-03	360	100
Th+228	2,00E-03	200	10
Ra+226	7,00E-03	1100	100

2.5 Manufacture and use of thorium compounds

Thorium oxide occurs in many minerals. Those with high concentrations include monazite, thorite and thorianite. Thorium is obtained by first concentrating minerals, then decomposing the concentrate to obtain Thorium salts. Thorium is then used as an additive in a number of materials: thoriated tungsten welding electrodes, magnesium-thorium alloys, manufacture of gas mantles. Activity concentration for thoriated tungsten welding electrodes is around 100 Bq/g of Th-232 and Th-228. Concerning the gas mantle storage, the activities can reach 3600 Bq/g of Th-232. Concentration higher than the exemption levels are also reported for Ra-228, Th-228 and Th-230, as presented in the following table.

Thorium products (gas mantle storage)

	Min. (Bq/g)	Max (Bq/g)	Exemption value (Bq/g)
Th232	230	3600	100
Ra+228	28	2100	100
Th+228	160	1700	10
Th230	71	460	10

2.6 Zircon sands and refractory materials

Most of the commercial useful deposits of zircon are in beach sands (Australia, India, Ukraine, Malaysia, USA). Typically, the sand is pre-processed in very large quantities to separate the mineral sands which include monazite and bastnasite. An important use of these zircon sands is in the manufacture of refractory materials. This refractory product manufacturing process gives rise to volatilised Po-210 and Pb-210 from smelting and dust. The activity concentrations reported for zircon sands and refractory materials can reach values higher than the exemption level for Th-228, Th-230 and Ac-227, as shown in the following table and figure.

Zircon

	Min. (Bq/g)	Max (Bq/g)	Exemption value (Bq/g)
Th+228 *	0,2	40	10
Th230 *	0,2	74	10
Pb+210 **	40	400	100
Po210 **	40	400	100
Ac+227 *	0,009	3,4	1

* zircon sands and refractory materials

** Pb/Po precipitate and volatilised Pb/Po

2.7 Niobium ore processing

The niobium ore is processed by melting with sodium or potassium hydroxide, dissolving in hydrochloridric acid and processing with chlorine. The resulting powdered metallic niobium is then further purified by various methods. Niobium is widely used in the manufacture of electronic components, chemical engineering, in nuclear reactors and in aerospace. The values presented in the following table concern the production of ferro-niobium. This process involves high temperature reaction between pyrochlore and aluminium powder. For pyrochlore feedstock, wastes and slag, and vats of material, the reported activity concentrations are in most cases, higher than the exemption values for thorium isotopes, Po-210 and Pb-210.

Ferro-niobium

	Min. (Bq/g)	Max (Bq/g)	Exemption value (Bq/g)
Th+228 *	7	80	10
Th230 *	6	10	10
Pb+210 **	100	500	100

Po210 **	100	500	100

* pyrochlore feedstock, wastes and slag, vats of material

** Pb/Po precipitate and volatilised Pb/Po

3. ECONOMIC DATA

3.1 Introduction

This annex provides basic quantitative economic information for the practices related to work with enhanced levels of naturally occurring nuclides in industries in Europe.

The industries identified as having pathways for occupational exposure from materials with enhanced levels of natural radionuclides and for which economic data have been searched are:

- Phosphate industry
- Processing of metal ores
- Manufacture of rare earths
- Manufacture and use of thorium compounds
- Titanium dioxide pigment industry
- Oil and gas extraction industry

3.2 Phosphate industry

3.2.1 Mining and milling of phosphate ore

According to the 1993 UNSCEAR publication [i], the main producers of phosphate rock in 1982 were China, Morocco, the former Soviet Union, and the United States. The Eurostat basic statistics [ii] give the following production data for 1987:

Phosphate Production in Europe (1987) [ii]

Production (1 000 t) / material	Country	Mining	Recovering	Import.	Stock Decrease	1987 Total
Phosphate	EUR12	-	127	8 162	71	8 360

Phosphate Use in Europe (1987) [ii]

Use (1 000 t) / Material	Country	Consumption	Export.	Stock increase	1987 Total
Phosphate	EUR12	7 251	1 109	-	8 360

A French monograph [iii] gives the following data for the production of phosphate ores by the most important producing countries from 1981 to 1994:

Phosphate ore Production by major producing countries (1981/1994) [iii]

Production (1 000 000 t) / Country	1981	1985	1990	1991	1992	1993	1994	1994
Morocco	19.7	20.7	21.1	17.8	19.2	18.2	19.8	15%
USA	52.6	49.4	45.8	48.4	47.2	35.6	41.6	32%
ex-USSR	26.2	34.3	36.9	28.4	20.7	14.5	10.0	8%
Others	39.8	43.8	52.7	54.1	55.0	51.7	57.6	45%
Total	138.3	148.2	156.5	148.7	142.1	120.0	129.0	100%

The same reference [iii] gives the following data for the importation of phosphate ores from the most important producing countries by the European Community countries from 1981 to 1994:

Phosphate ore Importation from major producing countries by EC countries (1981/1994) [III]

CEC countries Importation (1 000 000 t) / Country	1981	1985	1990	1991	1992	1993	1994	1994
Morocco	9.79	8.88	5.35	4.60	3.59	2.86	3.24	40%
USA	3.04	2.61	2.34	1.80	1.15	0.72	0.69	9%
Israel	1.06	1.61	1.43	1.35	1.23	1.23	1.09	13%
Togo	1.39	1.45	0.74	0.92	0.50	0.05	0.18	2%
Others	2.23	2.19	1.93	1.77	1.92	2.41	2.91	36%
Total	17.5	16.7	11.8	10.4	8.4	7.3	8.1	100%

The same reference [iii] gives the following data for the production of P_2O_5 by the European Community countries from 1981 to 1993:

P_2O_5 production by EC countries (1981/1993) [iii]

CEC countries Production (1 000 t) / Country	1981	1985	1989	1990	1991	1992	1993	1993
Belg./Lux.	530	361	333	362	340	340	318	14%
Denmark	107	151	136	81	75	65	60	3%
France	1300	1023	1025	916	926	726	697	30%
Germany	559	446	307	294	212	187	165	7%
Greece	143	185	198	199	192	168	122	5%
Ireland	37	3	0	0	0	0	0	0%
Italy	395	380	266	427	388	331	252	11%
Netherlands	324	360	378	365	345	287	256	11%
Portugal	94	81	77	63	39	37	30	1%
Spain	371	480	368	293	271	296	365	16%
United Kingdom	346	286	172	128	90	102	81	3%
EUR12	**4206**	**3756**	**3260**	**3128**	**2878**	**2539**	**2346**	**100%**

3.2.2 Fertilizers

The Eurostat basic statistics [ii] give the following production data for 1993:

Phosphated Fertilisers Production in European Countries (1993) [ii]

Production (1 000 t) / Country	1993 Phosphated Fertiliser Production (P2O5)	1993 Phosphated Fertiliser Production (P2O5) %
Belg./Lux.	340	15%
Denmark	65	3%
Germany	224	10%
Greece	117	5%
Spain	181	8%
France	933	42%
Ireland	3	0%
Italy	325	15%
Luxembourg	-	-

Netherlands	287	13%
Portugal	37	2%
United Kingdom	66	3%
EUR12	**2 238**	**100%**

3.3 Processing of metals ores

3.3.1 Niobium

The Eurostat basic statistics [ii] give the following production data for 1987:

Niobium Production in Europe (1987) [ii]

Production (t) / Material	Country	Mining	Recovering	Import.	Stock decrease	1987 Total
Niobium	EUR12	-	31	3 056	672	**3 759**

Niobium Use in Europe (1987) [ii]

Use (t) / Material	Country	Consumption	Export.	Stock increase	1987 Total
Niobium	EUR12	3 254	505	-	**3 759**

3.3.2 Tin

The Eurostat basic statistics [ii] give the following production data for 1987:

Tin Production in Europe (1987) [ii]

Production (t) / Material	Country	Mining	Recovering	Import.	Stock decrease	1987 Total
Tin	EUR12	4 202	14 491	36 966	13 832	**69 491**

Tin Use in Europe (1987) [ii]

Use	Country	Consumption	Export.	Stock	1987

(t) / Material				increase	Total
Tin	EUR12	54 877	14 614	-	**69 491**

The Eurostat basic statistics [ii] give the following production data for 1993:

Tin Production in European Countries (1993) [ii]

Production (1 000 t) / Country	1993 Refined Tin Production (Metal content)	1993 Refined Tin Production (Metal content) %
Belgium.	0.2	4%
Denmark	-	-
Germany	0.1	2%
Greece	0.2	4%
Spain	2.0	36%
France	-	-
Ireland	-	-
Italy	-	-
Luxembourg	-	-
Netherlands	0.2	4%
Portugal	0.1	2%
United Kingdom	2.8	50%
EUR12	**5.6**	**100%**

3.3.3 Zirconium

The Eurostat basic statistics [ii] give the following production data for 1987:

Zirconium Production in Europe (1987) [ii]

Production (t) / Material	Country	Mining	Recovering	Import.	Stock decrease	1987 Total
Zirconium	EUR12	-	-	135	2	**136**

Zirconium Use in Europe (1987) [ii]

Use (t) / Material	Country	Consumption	Export.	Stock increase	1987 Total

Zirconium	EUR12	122	14	-	**136**

3.4 Manufacture of rare earths

Economic data on the manufacture of rare earth materials has not been identified.

3.5 Manufacture and use of thorium

According to a German study [iv], the two European producers of Thorium dioxide are located in Austria (Treibacher) and in France (Rhône-Poulenc in La Rochelle). Dalheimer [v] gives the following data from a special workshop held at the end of 1992 in Germany:

Important applications of Thorium [v]

Material	Annual Quantity
Lighting	
Incandescent Gas Mantles **Discharge Lamps**	1 000 000 pieces -
Optical industry	
Thoriated Glass **Polishing Powder**	16 t -
Special alloys	
Thoriated Tungsten **Welding Electrodes** **Jet Engine**	200 000 pieces -

3.6 Titanium dioxide pigment

The Eurostat basic statistics [ii] give the following production data for 1987:

Titanium Production in Europe (1987) [II]

Production (1 000 t) / Material	Country	Mining	Recovering	Import.	Stock decrease	1987 Total
Titanium	EUR12	-	2	771	17	**790**

Titanium Use in Europe (1987) [ii]

Use (1 000 t) / Material	Country	Consumption	Export.	Stock increase	1987 Total
Titanium	EUR12	558	232	-	**790**

3.7 Oil and gas extraction industry

The French basic statistics [vi] give the following production data for 1973 to 1994:

Crude Oil Production in the UK and Western Europe (1973/1994) [vi]

Crude Oil Production (1 000 000 t) / Country	1973	1979	1985	1991	1992	1993	1994
United Kingdom	0.1	77.9	127.6	91.1	94.3	100.1	126.8
Western Europe	**15.5**	**114.6**	**189.4**	**212.6**	**229.8**	**243.5**	**276.1**

The Eurostat basic statistics [ii] give the following Crude Oil production data for 1993:

Crude Oil Production in European Countries (1993) [ii]

Production (1 000 t) / Country	1993 Crude Oil	1993 Crude Oil %
Belgium	-	-
Denmark	8 285	7%
Germany	3 066	3%
Greece	562	0%
Spain	875	1%
France	2 754	2%
Ireland	-	-
Italy	4584	4%
Luxembourg	-	-
Netherlands	3 285	3%
Portugal	-	-
United Kingdom	95 226	80%
EUR12	**118 637**	**100%**

The French basic statistics [vi] give the following production data for 1973 to 1991:

Natural Gas Production in European Countries (1973/1991) [vi]

Natural Gas Production (1 000 000 tep) / Country	1973	1979	1985	1989	1990	1991	1991
Germany	14	16	12	14	14	14	10%
France	6	7	5	3	3	3	2%
Italy	13	11	12	14	14	14	10%

Netherlands	54	71	61	54	55	62	45%
United Kingdom	24	33	36	37	41	46	33%
EUR12	**111**	**137**	**128**	**128**	**132**	**144**	**100%**

The Eurostat basic statistics [ii] give the following Natural Gas production data for 1989 to 1993:

Natural Gas Production in European Countries (1989/1993) [ii]

Production (1 000 TJ (PCS)) / Country	1989 Natural Gas	1990 Natural Gas	1991 Natural Gas	1992 Natural Gas	1993 Natural Gas	1993 Natural Gas %
Belgium					-	-
Denmark	116	127	161	167	174.8	2%
Germany	546	546	630	638	633.4	9%
Greece					4.4	0%
Spain					27.4	0%
France	121	113	133	130	131.9	2%
Ireland					100.2	1%
Italy	640	653	656	685	764.5	11%
Luxembourg					-	-
Netherlands	2 522	2 541	2 872	2 885	2 914.6	40%
Portugal					-	-
United Kingdom	1 725	1 904	2 119	2 120	2 524.5	35%
EUR12	**5 826**	**6 036**	**6 722**	**6 770**	**7 257.8**	**100%**

References

[i] UNSCEAR 1993, Sources and effects of Ionizing Radiation, New York, UN, Report to the General Assembly, with annexes, 1993.

[ii] Eurostat Basic statistics, 32° edition 1995.

[iii] Despres A., Rieutord P., Rejets de substances radioactives par les industries non nucléaires, Document présenté par la délégation Française au groupe RAD de l'OSPARCOM.

[iv] Reichelt A., Lehmann K-H., Anthropogene Stoffe und Produkte mit natürlichen Radionukliden, Teil II, Strahlungseigenschaften von Roh- und Reststoffen, Literaturrecherche, TÜV Bayern, 1994.

[v] Dalheimer A., Henrichs K., Monitoring of workers occupationally exposed to thorium in Germany, Radiat. Prot. Dosim. Vol 53, Nos 1-4, pp 207-209, 1994.

[vi] Annuaire statistique de la France, Résultats de 1994, Institut national de la statistique et des études économiques, 1996

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ANNEX 2

The potential impact of the exemption criteria embodied in the 1996 IAEA Transport Regulations on the transport of radioactive materials in the United Kingdom.

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1. INTRODUCTION

The latest edition of the IAEA Transport Regulations (ST-1) 1996[1] introduced, for the first time, radionuclide-specific exemption levels of activity and activity concentration. Previous IAEA Regulations[2] had specified an exemption specific activity of 70 Bq/g for all materials. This report covers the transport in the UK of low activities and low specific activity materials, including those with a specific activity per unit mass below 70 Bq/g. The relevance of the new exemption levels to the transport of these materials is investigated.

2. SCOPE

This study is focused on transport practices in the UK involving the shipment of materials with low specific activities and low activities per consignment. It includes the transport of food, coal and coal ash, building materials, thoriated welding rods and gas mantles, fertilisers, pipeline scale, ores, radioactive wastes, radioactive materials used in hospitals, lighting products, smoke detectors and other consumer products.

3. ADMINISTRATION OF CONTROLS

The main licensing body for radioactive materials in the UK is the Environment Agency (EA), which administers and enforces the requirements of the Radioactive Substances Act[3], 1993. This Act requires registration for the use and storage of radioactive materials and authorisation for disposal. A number of Statutory Instruments are currently in force which give exemption from the requirements of the Act. These include an Exemption Order[4] for Substances of Low Activity. These Exemption Orders, which are largely concerned with the keeping and use of radioactive material are currently subject to review. The EA is also the Competent Authority for a number of EC Directives on the shipment of radioactive substances and sealed sources between EU Member States, and shipments of radioactive wastes into, out of, and within England and Wales to ensure that appropriate disposal arrangements are in place before the shipment of the material or waste.

Occupational exposure to ionising radiation is regulated by the Health and Safety Executive (HSE) under the Health and Safety at Work Act[5], 1974, and the Ionising Radiations Regulations[6], 1985. Both the EA and HSE have inspectors that periodically visit premises in which radioactive materials are used to ensure compliance with the relevant legislation.

The UK implements and enforces the principles of the IAEA Transport Regulations in its domestic legislation. The executive role of the Competent Authority is carried out by the Radioactive Materials Transport Division of the Department of the Environment, Transport and the Regions. Exemptions are provided for in transport regulations; for example for road transport 500 smoke detectors are exempt in any one vehicle provided the activity in each detector is less than 40 kBq and the detectors are for domestic use.

4. INFORMATION GATHERING

Published information available on the radioactive content and the transport practices involved with low specific activity materials in the UK is both sparse and fragmented. Information was therefore obtained from the general literature and by directly contacting representative companies in potential areas of interest and requesting information from them. In many instances the information requested was not available in the level of detail required for a comprehensive analysis. However, on each type of use sufficient data was collected so that a conclusion could be drawn on the effect of the exemption criteria.

5. MATERIALS CONSIDERED IN THE STUDY

5.1 Food

The considerable amount of information available on the radioactive content of various foods and beverages indicates that none of these commodities will be affected by the new regulations[1]. For example some of the highest activity concentrations of potassium-40 are found in tea leaves[7], typically ranging up to about 1 Bq/g; which is three orders of magnitude lower than the relevant activity concentration for exemption[1]. Alpha emitters tend to be concentrated in some food stuffs. For example Brazil nuts tend to have elevated concentrations of radium isotopes, and polonium-210 is concentrated in some sea foods. Typically these radionuclides range up to a maximum of about 0.1 Bq/g, which is three orders of magnitude lower than the activity concentration for exemption[1].

5.2 Coal and Coal ash

5.2.1 Coal

Coal is transported in the UK in either 20-25 metric tonne loads by lorry or 30 tonne loads by railway wagon[8]. The radioactive content of some of the isotopes in coal is given in Table 1. Since the values quoted fall well below the activity concentration for exempt materials the transport of coal will be unaffected by the IAEA 1996 Transport Regulations[1].

5.2.2 Coal ash

Coal ash is cleared from coal fired power station furnaces by an automated process. Once cleared from the power station it is either transferred directly to ash lagoons where it is allowed to settle out, buried in landfill sites or sold for construction work, mainly as underfill for road beds. The situation is complicated slightly because in periods of high demand landfill material which has been in place for less than two years may be recovered and sold. Transport of ash to lagoons or landfill is normally over very short distances on private land, so only the ash which is sold on for construction work needs to be assessed in this study. The radioactive content of ash from several power stations is given in Table 2. It is transported to the road construction sites in 20 or 40 metric tonne loads by lorry[8]. The typical maximum consignment would therefore contain some 4.2×10^6 Bq of radium-226 (using Eggborough in Table 2 as the example ash), which exceeds the activity exemption limit. However, the activity concentration in coal ash for both the isotopes quoted fall well below the activity concentration for exempt materials and therefore ash transport will be unaffected by the IAEA 1996 Transport Regulations[1].

Table 1. Radioactive content of coal[9]

Activity Concentration (Bq/g) for					
K-40		Th-232		U-238	
Average	Range	Average	Range	Average	Range

0.05	0.03-0.1	0.02	0.01-0.2	0.02	0.01-0.6

Exemption values quoted in IAEA Transport Regulations[1] 1996:

Activity concentration for exempt material (Bq/g)[A]	1000	100	100
Activity limit for an exempt consignment (Bq)[A]	1×10^7	1×10^5	1×10^5

[A] *Value in regulations multiplied by 10 because material contains natural radiation and is not used for its radioactive properties.*

Table 2. Radioactive content of coal ash from power stations[10]

Ash sample from power station at:-	Concentration (Bq/g)	
	Ra-226	Th-232
Didcot	0.101 ± 0.018	0.063 ± 0.004
Carmarthen Bay	0.072	0.053
Ratcliffe-on-Soar	0.082	0.057
Drax	0.098	0.070
Eggborough	0.105	0.094

Exemption values quoted in IAEA Transport Regulations, 1996:

Activity concentration for exempt material (Bq/g)[A]	100	100
Activity limit for an exempt consignment (Bq)[A]	1×10^5	1×10^5

[A] *Value in regulations multiplied by 10 because material contains natural radiation and is not used for its radioactive properties.*

5.3 Ores, Minerals and Building Materials

5.3.1 China Clay

The specific activities of the radioactive isotopes found in the China clay, which is produced in Devon and Cornwall, are very low (see Table 3). China clay would therefore not fall within the scope of the new IAEA Transport Regulations (ST-1) 1996.

Table 3. Activity concentrations found in different forms of China clay[11]

Sample Type	Activity Concentration (Bq/g)				
	Ac-228	Bi-214	K-40	Pb-214	Ra-226
Cornish Clay	0.096	0.12	0.44	0.13	0.175
Devon Clay	0.073	0.098	0.34	0.1	0.11
Filler Clay*	0.011	0.041	0.77	0.041	0.057

Exemption values quoted in IAEA Transport Regulations (ST-1) 1996:

Activity concentration for exempt material (Bq/g)[A]	100	NL	1000	NL	100
Activity limit for an exempt consignment (Bq)[A]	1×10^5	NL	1×10^7	NL	1×10^5

*transported in bulk outside UK

[A] Value in regulations times 10 because material contains natural radiation and is not used for its radioactive properties.

NL - isotope not listed in IAEA Transport Regulations (ST-1) 1996

5.3.2 Building Materials

Building materials are usually transported by road in the UK on lorries which can carry between 20 and 25 metric tonnes. Some examples of the concentrations of radium-226 and thorium-232 in building materials are given in Table 4. Since these values fall well below the activity concentrations for exempt natural materials it is clear that the bulk transport of these materials will be unaffected by the current IAEA Transport Regulations (ST-1) 1996.

Table 4. Radioactive content of building materials[12]

Material		Specific activity (Bq/g)	
Type	Main constituent	Ra-226	Th-232
SL20 brick	Silica	0.0329 ± 0.0009	0.0148 ± 0.0007
F54 brick	Flint	0.696 ± 0.0016	0.0516 ± 0.0016
Kirton brown brick	Clay	0.0842 ± 0.0027	0.0512 ± 0.0018
Kirton brown brick	Clay	0.0637 ± 0.0019	0.0395 ± 0.0013
Dapple light brick	Clay	0.0774 ± 0.0029	0.0590 ± 0.0019
Otterham second hardstock brick	Clay	0.0311± 0.0006	0.0521 ± 0.0013
Severn valley orange multi-brick	Clay	0.0569 ± 0.0019	0.0360 ± 0.0009
Ibstock red rustic multi-brick	Clay	0.0765 ± 0.0025	0.0510 ± 0.0016
Ludlow crushed granite brick	Granite in matrix	0.0220 ± 0.0005	0.0062 ± 0.0003
Fyfe-stone block	Granite	0.0490 ± 0.0027	0.0547 ± 0.0023
Fyfe-stone block	Granite	0.0500 ± 0.0024	0.0547 ± 0.0024
Insulating block	Pulverised fuel ash	0.0770 ± 0.0020	0.1700 ± 0.0030
Block	Light expanded clay aggregate	0.0924 ± 0.0023	0.0550 ± 0.0012
Block	Light expanded clay aggregate	0.0964 ± 0.0023	0.0585 ± 0.0023
Block	Oil shale	0.0763 ± 0.0019	0.0429 ± 0.0019
Block	Concrete	0.0177 ± 0.0007	0.0421 ± 0.0007

Exemption values quoted in IAEA Transport Regulations (ST-1) 1996:

Activity concentration for exempt material (Bq/g)[A]	100	100
Activity limit for an exempt consignment (Bq)[A]	1×10^5	1×10^5

[A] Value in regulations multiplied by 10 because material contains natural radiation and is not used for its radioactive properties.

A2.11

5.3.3 Phosphorus

Phosphorus is currently imported into the UK in two forms:
(a) as crude green phosphoric acid which is produced from phosphate rock mined and processed in Morocco. The crude green phosphoric acid is used to make pure phosphoric acid and phosphate based fertilisers. The radioactive content of the crude green phosphoric acid (see Table 5) is carefully regulated at the request of the UK buyer[13] and its transport will be unaffected by the new IAEA Transport Regulations (ST-1) 1996.

(b) as phosphate rock. The radioactive content of phosphate rock is dependent on its origin and can be very variable. The majority of phosphate rock imported into the UK comes from Morocco and its radioactive content, where known, is listed in Table 5.3.3. Since the radioactive content of the phosphate rock is due to natural radionuclides none of the specific activities of the radioactive isotopes present in Moroccan phosphate rock, or any other form of phosphate rock[14,15], exceed the activity concentrations for exempt materials and therefore the rock does not fall within the scope of the new IAEA Transport Regulations (ST-1) 1996.

Table 5. Specific activity of isotopes in phosphoric acid and phosphate rock.[13,14]

Isotopes Present	Radioactive content of green (crude) phosphoric acid from Morocco imported into the UK (Bq/g)	Radioactive content of Moroccan phosphate rock (Bq/g)	Activity concentration for exempt material (Bq/g)[A]	Activity limit for an exempt consignment (Bq)[A]
Bi-214	<0.002	<1.474	NL	NL
K-40	NA	0.01-0.2	1000	1×10^7
Pb-210	<0.043	<1.474	100	1×10^5
Pb-214	<0.002	<1.474	NL	NL
Po-210	<0.011	<1.474	100	1×10^5
Pa-231	0.109 ± 0.009	1.474	10	1×10^4
Ra-223	<0.003	NA	100	1×10^6
Ra-226	NA	1.474-1.7	100	1×10^5
Th-227	<0.002	NA	100	1×10^5

Th-232	NA	0.02-0.03	100	1 x 10^5
U-235	0.089 ± 0.002	NA	100	1 x 10^5
U-238	1.758 ± 0.087	1.474-1.7	100	1 x 10^5

A Value in IAEA Transport Regulations (ST-1)19961 multiplied by 10 because material contains natural radiation and is not used for its radioactive properties.
NA not available; NL Isotope not listed IAEA Transport Regulations (ST-1)1996

5.3.4 Potash

In excess of one million tonnes of potash (95% potassium chloride) is mined in the UK each year[16], mainly for use in the fertiliser industry. The remaining potash requirements of the UK are imported. The potash is used to make fertilisers and as rock salt for spreading on the roads to prevent ice formation. The concentration in potash of several radioactive isotopes is shown in Table 6. In all cases the activities fall well below the activity concentrations for an exempt material. Therefore the movement of potash will be exempt from the new IAEA Transport Regulations (ST-1) 1996.

Table 6. Activity content of potash mined in the UK[16,17]

Material	Concentration (Bq/g)			
	Ac-228	Bi-212	Bi-214	K-40
Standard potash	<0.03	<0.2	<0.01	15.8
Road salt	<0.01	<0.06	<0.008	NA
Activity concentration for exempt material (Bq/g)[A]	100	100	NL	1000
Activity limit for an exempt consignment (Bq)[A]	1 x 10^7	1 x 10^6	NL	1 x 10^7

[A] Value in IAEA Transport Regulations (ST-1)1996 multiplied by 10 because material contains natural radiation and is not used for its radioactive properties.

NA not available

NL not listed in IAEA Transport Regulations (ST-1)1996

5.3.5 Other ores and minerals and materials produced from them

The radioactive content of a number of ores and some of the products refined from them are listed in Table 7. The majority of these items are exempt from the IAEA Transport Regulations (ST-1) 1996 because the activity concentrations for the isotopes quoted all fall below the activity concentration for an exempt material for natural radiation. These values were obtained from some samples imported into the UK.

There may, however, be potential problems with some of the materials because in some parts of the world some ores deposits have a high thorium content. The items of concern are rare earth and zirconia ores because of their Th-228 content, glazes and refractories because of their Th-230 content and special alloys because of their content of both Th-228 and Th-230.These materials all may contain sufficient of the highlighted isotopes to exceed the activity concentration of that isotope for an exempt material for natural radiation. Therefore they could be classified as radioactive materials if they are transported in sufficient quantities to also exceed the activity limit for an exempt consignment. These quantities are listed in the third column of Table 8 and are less than 10 kg in the case of Th-228 and Th-230. Since most of these materials (with the exception perhaps of glazes) are transported in metric tonne quantities they may be radioactive substances under the IAEA Transport Regulations, 1996.

Table 7. Typical activity concentrations for ores and products generated from ores from some samples measured in the UK[18,19,20]

Material	Specific Activity (Bq/g)						
	Po-210	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-238
Zircon	NA	NA	NA	NA	NA	0.7	3
Refractories[A] , Company 1	20	10	2	2	10	1	10
Refractories[A] , Company 2	10	10	5	2	10	1	10
Casting[A]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Zirconia	20	20	0.4	9	1	1	5
Glazes[B]	20	20	9	5	20	0.4	1
Rare Earth	0	0	10	10	0	10	0
Glass	1	1	3	5	1	3	1
Special Alloys	6	6	7	7	6	7	6
Tin Smelting: Ores	0.3	0.3	1	1	0.3	1	0.3
Ilmenite	0.5	0.5	1	1	0.5	1	0.5
Rutile	0.5	0.5	0.2	0.2	0.2	0.2	0.2
Bastnasite	NA	NA	NA	NA	NA	6.0-8.0	NA

Lanthanum ore	NA	NA	NA	NA	NA	3.0-4.0	NA
Activity concentration for exempt material (Bq/g)[C]	100	100	100	10	10	100	100
Activity limit for an exempt consignment (Bq)[C]	1×10^5	1×10^5	1×10^6	1×10^5	1×10^5	1×10^5	1×10^5

[A] Made from Zircon ore (silicate)

[B] Made from Zirconia (oxide)

[C] Value in IAEA Transport Regulations (ST-1)1996 multiplied by 10 because material contains natural radiation and is not used for its radioactive properties.

NA not available

Table 8. Data showing materials that will be classified as radioactive if they exceed the activity limit for an exempt consignment for thorium-228 and/or thorium-230.

Material	Isotope of concern	Mass of material exceeding the specified isotope activity limit for an exempt consignment (kg)	Mass of material normally transported (kg)	Comments
Refractories	Th-230	10	5-5000	
Zirconia	Th-228	11	2 x 10^4 (lorry); 3 x 10^6 (ship)	
Glazes	Th-230	5	NA	
Rare Earth	Th-228	10	NA	moved in metric tonne (10^3 kg) quantities
Special alloys	Th-228/Th-230	7.1/8.3	NA	

NA not available

5.4 Fertilisers

There are several types of fertilisers the main ones being:-

- phosphate based fertilisers
- potash (potassium chloride) based fertilisers
- nitrogen based fertilisers
- complex fertilisers containing combinations of some or all of the first 3 in various proportions

Nitrogen fertilisers may be considered non-radioactive. The other 3 types, however, all contain detectable levels of natural radioactive isotopes. The specific activity of these isotopes is dependent on the exact phosphate and/or potassium content of the fertiliser. Although it was not possible to obtain specific data on the radioactive content of fertilisers used in the UK, the British Fertiliser Manufacturers Association provided information on the radioactive content of various types of fertiliser imported into Eire in 1992 and the activity content of these fertilisers should be similar to the content of UK fertilisers. Table 9 shows the activity content for phosphate and potash based fertilisers. Since none of the concentrations of any of the isotopes quoted in any of the fertilisers exceed the relevant activity concentrations for exempt materials, fertilisers do not fall within the scope of the new IAEA Transport Regulations, 1996, and therefore their transport will be unaffected by these regulations.

Table 9 Natural radionuclide concentrations in fertilisers imported into Eire in 1992[17]

Fertiliser	Sampled from	Natural radionuclide concentrations in fertilisers (Bq/g)			
		K-40	Ra-226	U-235	U-238
Di-ammonium phosphate	Company 1	0.074	0.028	0.1	1.698
Di-ammonium phosphate	Company 2	0.053	0.075	0.107	1.768
Di-ammonium phosphate	Company 3	0.095	0.069	0.097	1.551
Di-ammonium phosphate	Company 4	0.107	0.032	0.082	1.339
Mono-ammonium phosphate	Company 2	0.022	0.053	0.118	2.002
Triple Superphosphate	Company 1	0.061	0.517	ND	1.894
Triple Superphosphate	Company 2	ND	0.56	0.128	1.497
Triple Superphosphate	Company 3	0.066	0.571	0.092	1.162
Potash	Company 1	14.82	ND	ND	ND
Potash	Company 2	15.9	ND	ND	ND
Potash	Company 3	15.91	ND	ND	ND
Potash	Company 4	15.78	ND	ND	ND

Activity concentration for an exempt material (Bq/g)[A]	1000	100	100	100
Activity limit for an exempt consignment (Bq)[A]	1×10^7	1×10^5	1×10^5	1×10^5

ND - not measured

[A]Value in IAEA Transport Regulations (ST-1) 1996 multiplied by 10 because material contains natural radiation and is not used for its radioactive properties.

In complex fertilisers quantities of nitrogenous products, phosphate, and potash are blended. The compound blend is described by its percentage elemental composition of nitrogen (N), phosphorus (P), and potassium (K) in that order. Four typical blends on the Irish market have the composition given in Table 10.

Table 10. Elemental composition of different blends of fertiliser on sale in Ireland.

Element present	Percentage of element in each blend			
	Blend 1	Blend 2	Blend 3	Blend 4
N	18	10	0	0
P	6	10	10	7
K	12	20	20	30

Generally the phosphate and potash in commercial compound fertilisers varies between 0 and approximately 50% of the total quantities in the blends. Therefore natural radionuclide concentrations vary in compound fertilisers between 0-50% of that shown in the Table 9. Examples of the percentage content of both simple and compound fertilisers imported into Ireland are shown in Table 11. Since simple fertilisers contain higher percentages of processed phosphate and potash ores than complex fertilisers and simple fertilisers will be exempt under the new IAEA Transport Regulations (ST-1) 1996, then complex fertilisers will also be exempt from the regulations.

Table 11. Simple and Compound Fertilisers imported into Ireland in 1992[17]

Material	Percentage of element present	
	P	K
Di-ammonium phosphate (some Mono-ammonium phosphate)	20	0
Triple Superphosphate	20	0
Potash 2 (KCl)	0	50
NPK (Compound)	2.5-10	5-20
PK (Compound)	5-10	15-30

5.5 Thoriated Welding Rods and Gas Mantles

5.5.1 Thoriated welding rods

Thoriated welding rods contain a set percentage of natural thorium oxide. The most common type in the UK contains 2% thorium oxide, but 1% rods are also sold and 4% rods were sold in the past. It appears that 1% rods are gradually becoming obsolete and the sale of 4% rods is now very rare, however, 4% rods are still made in Germany[21]. Thoriated welding rods are manufactured in and imported ready made into the UK. The rods are produced in various diameters (with different weights associated with each diameter) depending on their application.

Information from one of the companies which imports rods is given in Table 12. The company imports rods of various diameters between 0.8 and 6.4 millimetres [mm] (Table 12 only gives a few examples). The 2% rod is the most popular. The company imports a total of 1,000-20,000 rods per month. The smaller diameters predominate and the company never buys more than 4-6 of the 6.4 mm diameter rods at a time. Apart from the large diameter rods which are sold singly, the rods are normally sold to customers packaged in lots of 10. The minimum order would normally be 10 boxes whilst the average would be 300-600 boxes[22].

Table 12. Information on thoriated welding rods imported into the UK[22]

Rod Diameter (mm)	Weight of a single rod (g)	Packaging of rods
0.8	1.4	Plastic boxes of 10 wrapped in corrugated cardboard
2.4	12.8	10 wrapped in corrugated cardboard
6.4	100.0	Individually wrapped in corrugated cardboard

The rods manufactured in the UK are made from sintered ingots containing 2% natural thorium oxide which are imported by ship and transferred to the manufacturer by road. Each ingot weighs 2.5 kg. It has been estimated by a major manufacturer that the total import of ingots for all users is about 200-300 kg per month (whilst about 400-600 kg of ready made thorium welding rods are imported into the UK per month). The ingots are packaged in wooden boxes and each box probably holds 24 ingots. Once the ingots arrive at the manufacturers, they are worked, cut and ground to produce a variety of products. The main product is lamp metal which probably accounts for two thirds of the imported thorium ingots. Five lamp metal ingots are produced from one sintered thorium ingot. Most of the lamp metal is utilised in the UK but some is exported to Europe. The remaining one third of the sintered thorium ingots are used to produce welding electrodes, eg 200 x 12g welding electrodes can be generated from one thorium ingot[21].

Transport of welding rods has always been a problem because every 1% of natural thorium in the rods is equivalent to an activity concentration 70 Bq/g. Thus a 1% rod was not considered radioactive under the transport regulations but any rod with an activity greater than 1% was radioactive. These materials have therefore been transported as Excepted material and will continue to be so under ST-1. Working practices operated by companies supplying welding rods are unlikely to be affected by the new IAEA Transport Regulations, 1996.

5.5.2 Gas mantles

Several UK companies which sell gas mantles have been contacted and none now sell thoriated gas mantles. The technical support officers in both of the main caravanning clubs and two of the caravan manufacturers have all indicated that thoriated gas mantles are no longer used in caravans and were phased out in about 1979-1980. All of the companies contacted have indicated that non-radioactive gas mantles are now widely sold. It is therefore unlikely that thoriated gas mantles are available on the UK market. Gas mantles are, however, now made abroad in Malta, the USA and India and since India still makes thoriated gas mantles[23] it is possible that they are still being imported into the UK. It can be derived from the data in Table 13 that if the Indian gas mantles were imported into the UK in larger numbers than groups of four then they would fall within the scope of the IAEA Transport Regulations, 1996.

Table 13. Average natural thorium content of gas mantles produced in India[23]

Average mass of natural thorium in Indian gas mantles(mg thorium/g mantle)	125 ± 28
Specific activity of natural thorium in Indian gas mantles (Bq/g).(Average mantle mass is 3 grams)(assuming that in natural thoriumTh-232 and Th-228 are in equilibrium, the mass of natural thorium is effective 100 % Th-232; and that the specific activity of Th-232 is 4071 Bq/g)	1018 ± 228
Activity concentration of Th(nat) for exempt material (Bq/g)[A]	10
Activity limit of Th(nat)for an exempt consignment (Bq)[A]	1×10^4

[A] Value in IAEA Transport Regulations (ST-1) 1996 multiplied by 10 because material contains natural radiation and is not used for its radioactive properties.

5.6 Lighting Products

Discussions with the UK Lighting Federation and members of individual companies have indicated that:-

(a) these companies are satisfied that they do not have any transport problems in respect to radioactive materials in their products

(b) all the companies involved in the production of lighting products have at least a Europe wide base and therefore the information from Germany which has been collected by GRS for this study would also apply to the UK[24]

5.7 Smoke Detectors

Radioactive smoke detectors are currently transported from the manufacturer in Excepted packages under the transport regulations. They normally contain a single isotope of either Am-241, Pu-238 or Ra-226. Three suppliers were approached in the UK. All three supplied detectors containing Am-241 only. The detectors supplied contained sources with one of three distinct activities 18.5, 33.3 or 40.7 kBq Am-241. The two most commonly supplied were probably 18.5 and 33.3 kBq sources. Each detector probably weighs about 100g[25].

Detectors were both manufactured in the UK and purchased and imported from abroad. The number of detectors moved at one time depended on the company approached. One company imported detectors by ship in lots of 20,000-40,000 in a single 20 or 40 foot long container[25]. The container was then moved by road to their warehouse for breaking down the lots into units of 6, 10 or 12 detectors. The detectors were then sold on to wholesalers in lots of 10 units up to a maximum of 5,000 units. Another company imported units of 100-4,000 by air which were then transported to their warehouse for breaking down into smaller lots for resale. In each case the detectors were imported in Excepted packages[25] within containers.

The wholesaler who supplied the information[26] orders one pallet containing 1080 detectors at a time. This was delivered by road from their supplier to their main distribution warehouse where the detectors were stored. The pallet was unloaded by their stores staff , which took about 5 minutes. A new pallet was only ordered when most of the previous stock have been used up. The detectors were redistributed in small quantities (no more than 5 at a time) to their local offices by road as required. An engineer then collected them from the local store and took them to customers for fitting when required. The detectors were stored on a shelf in the engineers van during transit. It would be rare for more than one or two to be transported at a time[26].

The 1996 edition of the IAEA Transport Regulations[1] excludes radioactive material in consumer products which have regulatory approval, following their sale to the end user and this applies to smoke detectors, so when they are transported to the consumer they will be unaffected by the regulations. Since the larger batches of smoke detectors which are imported and passed to wholesalers are actually transported in Excepted packages the 1996 regulations should also have no effect on this traffic.

5.8 Other Consumer Products

5.8.1 Thoriated Lens coatings

One of the main lens manufacturers in Germany no longer use radioactive materials at all in the manufacture of products for the photographic industry. It is probable that this practice has now ceased because other non-radioactive coatings cause fewer problems for the companies involved[27].

5.8.2 Luminised Watches, Diving Regulators, Compasses etc

It appears that these items are not now manufactured in the UK. Several of the importers of these materials were contacted but they were uncertain whether the items contained radioactivity[28].One of the manufacturers was contacted to try to clarify the situation and kindly provided information[29] on their total sales in the UK for 1996, shown in Table 14. Unfortunately it is impossible to extrapolate from this information to the total UK sales for this type of item. Since the manufacturer contacted tended to supply the items in small numbers it is probable that any other companies trading in these items also supply them in small numbers. The transport of these items is therefore unlikely to be affected by the new IAEA Transport Regulations, 1996. Even if larger numbers of the items were despatched together the regulations would only affect their shipment if the lots exceeded 165 items (taking the worst case into account).

Table 14. Total sales of field compasses, clinometers etc containing tritium made in the UK by one manufacturer in 1996[29]. (Total UK sales are likely to be several thousand units)

Instrument	No. of Units sold in 1996	Tritium activity contentper unit (MBq)
Handbearing Compasses (KB)	47	2.96
Clinometers (PM)	51	2.96
Twin (combination of handbearing compass and clinometer)	1	5.92
Field compasses	8	5.18
Activity concentration of Tritium for exempt material (Bq/g)[A]		1×10^6
Activity limit of Tritium for an exempt consignment (Bq)[A]		1×10^9

[A] Value in IAEA Transport Regulations, 1996.

5.9 Radioactive anti-static devices

Only one company in Europe makes anti-static devices containing radioactive materials and they are based in the UK[30]. The company produces anti-static guns, discs, half rings (full rings can be made by bolting 2 half rings together), bars and air ionisers. The isotope used in all cases is Polonium-210. All the products are important because, unlike non-radioactive products, they do not require electricity and therefore they can be operated safely in areas containing solvents. A list of products on the market is given in Tables 15-18. The items are normally supplied singly (although up to 10 items may be despatched in exceptional circumstances) and are transported by an independent carrier in individual Type A packages. All the items currently come within the transport regulations and in this respect the transport of these materials will be unaffected by the new regulations; see Table 19.

Table 15. Air Ionisers containing Po-210

Dimensions	Activity (MBq)	Weight (g)
10.5 x 5.1 cm diameter	370	316 (including air hose adaptor)
4.3 x 5.1 cm diameter	370	130

Table 16. Anti-static Gun containing Po-210

Equipment	Dimensions	Activity (MBq)	Weight (g)
Gun	19.7 x 2.54 cm (dia.)	370	418
Gun refill	6.6 x 2.54 cm (dia.)	370	130

Table 17. Static control discs and rings containing Po-210

Device	Activity (MBq)	Internal diameter (cm)	External diameter (cm)	Weight (g)
Disc source for precision balances	62.9	-	3.2	NA
Half ring 1	518	10	14	NA
Half ring 2	740	15	19	NA

Note: Two half rings can be bolted together to make a whole ring.

NA. Not available

Table 18. Active and combination static control bars containing Po-210 (activity content of bar depends on length of bar)

Bar Length (cm)	Activity (MBq)
6	148
11	296
16	444
21	592
30	888
40	1184
50	1480
75	2220
100	2960
125	3700
150	4440
175	5180
200	5920
225	6660

Table 19. A_1 and A_2 values for Po-210 given by IAEA[1]

	A_1(TBq)	A_2(TBq)
Maximum allowed activity[A]	4×10^{1}	2×10^{-2}

[A] Value in IAEA Transport Regulations (ST-1) 1996

5.10 Oil and Gas pipeline scale

Scale builds up inside pipes, pumps and other equipment during the recovery of gas and oil. The nature of the scale produced during the recovery of oil and gas (and hence the natural radioactive isotopes present in the scale) differ[31].

The scale found in oil exploration equipment is due to the deposition of insoluble compounds and forms a layer which may eventually block the pipe. The main component of the scale is non-radioactive calcium sulphate, whilst the main radioactive component is radium in the form of radium sulphate. Normally the oil scale contains no isotopes in the decay chain above radium because they are either fixed in the rock from which the oil is extracted (some uranium species), or remain in solution and the scale contains no lead-210 or polonium-210 because regular pipe replacement means they do not have time to grow in. Piping is replaced at least every 10 years and usually much more often.

The scale found in gas exploration equipment forms a thin layer. The scale contains only lead-210 and polonium-210. In some cases the polonium-210 content is higher than lead-210 content suggesting a different mechanism for scale deposition compared to that found in oil exploration.

The majority of the scale is removed from equipment and disposed of at the site of operations. Some items, however, cannot be descaled easily and about 200 metric tonnes of radioactive scale per year is removed from oil and gas pipework, pumps etc onshore by specialist companies in the UK[32]. The scale in the UK comes mainly from offshore oil exploration, although there is a small amount from onshore oil exploration. The radioactive content of the two forms of scale is given in Table 20. The values are estimates made by personnel who are regularly involved in descaling equipment for the oil and gas exploration industry[31].

Table 20. Activity of radioactive isotopes present in oil and gas scale[31]

Scale Type	Oil		Gas	
Isotope	Ra-226	Ra-228	Pb-210	Po-210
Average activity (Bq/g)	15-25	10-20	NA	NA
Activity range (Bq/g)	0.37-2000	0.1-2000	1-2000	1-600
Comments	Upper values unusual, most samples would not exceed 50 Bq/g			
Activity concentration for exempt material (Bq/g)[A]	100	100	100	100
Activity limit for an exempt consignment (Bq)[A]	1×10^5	1×10^6	1×10^5	1×10^5

NA - not available

[A]Value in IAEA Transport Regulations (ST-1) multiplied by 10 to account for the material containing natural radiation.

Two types of material covered in oil scale (no information is available on gas scale) are transported from offshore sites to the descaling companies:-

(a) lengths of pipe (called tubulars) of various diameters, varying in length between 25 and 45 feet, and;
(b) non-tubular components, eg pumps valves, flexible hoses etc

Prior to shipping the material from the off-shore site each individual item of plant, equipment or bundle of tubulars is marked with a ti-wrap bearing a unique identification number which cross references to a site record that includes the sample identity and an estimate of both the specific activity of the scale (estimated using monitoring equipment) and the mass of scale attached to the item. The external surface of each item is decontaminated and the item is packaged to prevent the escape of internal contamination, eg large openings in individual items are capped or sealed with flange plates, the ends of tubulars are closed with solid end caps and small items or items where the external surfaces can not be completely decontaminated are bagged or wrapped in sheeting (probably polythene). In some cases small tubulars or small items are bundled together in single packages (referred to as “overpacks”). Items which are suitable for containerisation are individually labelled and securely stowed within a cargo carrying unit (CCU).

Individual packages, overpacks and CCU's are then shipped as Excepted packages with no external marking or label if they fulfil the following criteria[33]:-

(i) the package, overpack or CCU contains less then 20 MBq (eg 100 kg at 200 Bq/g) of radium-226 equivalent activity
(ii) maximum surface dose rate is less than 5 μSv/h
(iii) non-fixed surface contamination on external surfaces of packages and external and internal surfaces of overpacks and CCU's is less than 0.4 Bq/cm^2
(iv) no leakage of radioactive substance can occur
(v) individual packages are internally marked "Radioactive" in a manner which is visible on opening the package
(vi) a correctly completed Shippers Declaration for Dangerous Goods (an uncompleted example is shown in Table 21) for each package, overpack or CCU is attached to the supply vessels manifest together with a list showing the date of removal of each item, its origin (eg well number, production train location or valve tag number) and its identification number.

Table 21. Example of an uncompleted Shipper's Declaration of Radioactive Material as used in the oil industry[33]

Shipper's Declaration of Radioactive Material

Description of Material

Proper shipping name:	I) UN 2910 RADIOACTIVE MATERIAL, EXCEPTED PACKAGE LIMITED QUANTITY OF MATERIAL ii) UN 2913 RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO)	]delete as]appropriate]]]]
United Nations Class:	Number 7	
Radionuclides:	Ra-226, Th-nat, SCO-I	
Physical/Chemical Form:	Solid sulphate incrustation	
Maximum activity:	MegaBecquerels (MBq)	
Package type:	Industrial (IP-1) I) Package ii) Overpack ii) Freight container	]delete as]appropriate]
Category	I) I - WHITE ii) II - YELLOW iii) III - YELLOW	]delete as]appropriate]
Transport Index		
Package identification number		

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name and are classified, packaged, marked and labelled, and are in all respects in proper condition for transport by seagoing vessel/passenger aircraft/cargo aircraft/road transport according to the applicable international and national governmental regulations.

Consignor:- Consignee:-
Signed..Date...
Authority...

If they do not fulfil the above criteria then individual packages, overpacks and CCU's are shipped as radioactive packages with the appropriate Radioactive Category I, Category II or Category III labels depending on the dose rates at the surface and at 1 metre from the package. The labels would be marked as shown in Table 22. Non-fixed surface contamination on the external surfaces of the packages, overpacks or CCU's would not exceed 4 Bq/cm^2. As for Excepted packages a correctly completed Shipper's Declaration (see Table 21) would accompany the item.

Table 22. Markings on radioactive labels placed on individual packages containing items contaminated with scale[33]

Contents:	"Ra-226, Th-nat, SCO-I"	
Activity:	"kBq" (found by multiplying the estimated weight of scale (kg) by the specific activity (Bq/g)	
Transport Index (TI):	Determined as follows:- (a) For packages: maximum dose rate (μSv/h) at 1 metre divided by 10 (b) For non-rigid overpacks: sum TI's of all packages contained (c) For rigid overpacks: maximum dose rate (μSv/h) at 1 metre divided by 10 or sum TI's of all packages contained. (d) For CCU's: sum TI's of all packages and overpacks contained or measure the maximum dose equivalent rate and multiply it by a factor obtained using the information given below:-	
	Largest cross-sectional area of CCU being measured	Multiplication factor
	size of CCU < 1 m^3	1
	1 m^3 < size of CCU < 5 m^3	2
	5 m^3 < size of CCU < 20 m^3	3

	20 m^3 < size of CCU	10

Depending on the package the labels would be affixed as follows:-
(i) rigid package or overpack: two labels on opposite sides
(ii) non-rigid or irregular shaped package or overpack: two labels on opposite sides
(iii) CCU: two labels on opposite sides and two labels at opposite ends of each tubular bundle or one label on individual small diameter pipes. (The labels on the piping would probably be pieces of tape from a roll showing a small radioactive icon with the word “Radioactive”).

The packages would be segregated for the journey by ship to port as follows:-
On an “exclusive use” vessel where all the loading and unloading was carried out in accordance with the directions of the consignor or consignee the total sum of transport indices in a CCU or on board the vessel itself would be unlimited.

Where a vessel was not under “exclusive use” the limit on the total sum of transport indices would be 50 in a package, overpack or CCU, or 200 per vessel or CCU where each group of packages, overpacks or small freight container each had a total TI which did not exceed 50 and where each group was handled and stowed so that the groups were separated by at least 6 metres.

The equipment contaminated with scale is transported from the rigs by ship to either Aberdeen, Montrose, Peterhead or Great Yarmouth where it is loaded onto lorries for immediate shipment to the descaling companies which are all based in Scotland. The journey time for a lorry is about 1 hour (except from Great Yarmouth). On reaching its destination, small components are off-loaded from the lorry by fork lift truck, whilst pipework and larger components are unloaded by crane. The personnel who unload the materials from the lorry wear protective equipment and operate strict working practices to prevent skin contact, ingestion and inhalation of the scale. The components are stacked for storage prior to descaling. The personnel stand on racks to do the stacking. The dose rate on these racks is normally undetectable; on the occasions when it is detectable it rarely exceeds 7.5 μSv/h. Some loose scale is produced but process equipment minimises handling of loose scale.

Some of the worst cases of scale treated by one of the companies involved in this kind of work are given in examples (a) and (b) below[31].

(a) 45 foot lengths of pipe of various diameters:

Table 23. Mass of scale per pipe

Pipe diameter (inches)	Scale mass per pipe (kg)
3	114.1
4.5	179.76
5.5	223.55
7	289.21

(b) Non-tubular components, eg pumps, valves and flexible hoses:

Scale weight per component vary from as little as 0.5 kg (eg in small valves and pumps) to as high as 5,000 kg, eg in flexible hoses

5.10.1 Summary of pipeline scale transport

Since material contaminated with scale is currently transported either in Excepted packages or as LSA Category I, II or III radioactive material its transport would be unaffected by the IAEA Transport Regulations (ST-1) 1996.

5.11 Radioactivity in Hospitals, Universities and Research Establishments.

Hospitals despatch two categories of radioactive materials off site:-
(a) pre-prepared radioactive injection kits. [section 5.11.1]
(b) combustible radioactive waste. [section 5.11.2]

5.11.1 Pre-prepared radioactive injection kits

Most hospitals in the UK have their own radiopharmacies and prepare their own radiopharmaceuticals on site for carrying out nuclear medicine investigations on patients. Some hospitals, however, do not have radiopharmacies on site and their radiopharmaceuticals are therefore prepared by a radiopharmacy at a nearby hospital and transported to them by road.

There are about 160 hospitals with radiopharmacies in the UK of which approximately 40 prepare and supply other hospitals in their immediate area with radiopharmaceuticals for injection into patients[34] (other hospitals may do so under exceptional circumstances but this would be a rare occurrence). The radiopharmaceuticals are normally prepared as single or multiple patient doses in a glass vial sealed with a rubber closure (usually in liquid form). One or more vials are then packed into Type A containers carrying Category I or Category II labels (or occasionally into Excepted packages) and transported to the other hospital(s) by road by hospital van or car. The packages are made up carefully, taking the radioactive transport regulations into account. The majority of the movements concern Tc-99m treatments but a variety of other radionuclides are also transported. The area served by this process is very localised and the journey time is usually from a minimum of approximately 10 minutes up to a maximum of about 2 hours with most times being below 1 hour. The driver, who has received appropriate training, is normally a member of the hospital staff. Doses in the cab of the vehicle are usually <0.1 mSv/h and are often undetectable. The dose received by the driver in a year normally falls below the detectable level of the dose detection badges used; the maximum dose that has been quoted during this study is <0.5mSv/year. In almost all cases the receiving hospital disposes of any waste and unused activity so no radioactive material is returned to the radiopharmacy producing the injection solutions.

It should be noted here that the information given above is only a broad outline of these procedures. A much more in depth, detailed study would be required to give a completely accurate picture of the movement of radiopharmaceuticals between hospitals. Some examples of the packages transported by this process are given in Table 24. It should be noted that these data only reflect the movements at one particular hospital.

Table 24. Examples of radioactive materials despatched by one large radiopharmacy to other hospitals[35]

Isotope Transported	Activity of Isotope in glass vial	Type of package used to	Number of glass vials in	Number of movements

	(MBq)	transport material	a package	
Cr-51	5	Excepted	1	15/month
I-131	400	Type A	1	2/week
Tc-99m	<800	Excepted	1-2	40/week
Tc-99m	>800	Type A	1-8	20/week
Tl-201	100	Excepted	1	5/week

5.11.2 Hospital combustible radioactive waste.

The radioactive waste produced by hospitals normally falls into one of two categories; aqueous waste, which is disposed of to the ordinary trade drains, and solid waste, which is incinerated or in a few cases buried. A few hospitals also produce small amounts of organic scintillant waste which is incinerated and radioactive gas which is vented to the atmosphere. A few hospitals operate their own incinerators but the majority dispose of their combustible waste via waste disposal companies which take both radioactive and non-radioactive clinical waste and transport it off site by road to specific, designated incinerators.
The type of packages used to contain the solid waste for incineration vary for different hospitals and are probably dependent on the requirements of the company which removes the waste. Some packages are very large, such as 820 litre wheeled bins, or $2m^3$ packages which are equivalent to small skips. These large containers hold smaller packages of material wrapped in polythene bags (eg gloves, paper etc) or contained in “safesharp” boxes (eg needles, syringes, glass etc). Normally they are transported in batches of 1-3 by lorry to the site of incineration. Each hospital probably transports between 12-14 consignments by road per year[34].

Smaller packages are used by some hospitals, for example one hospital uses 60 litre bins and another uses 15 x 15 x 15 cm packages or larger 32 x 24 x 20 cm (21 litre) packages and either despatches more packages per consignment, eg 5-10, and/or despatches more consignments per year (one hospital quoted 80-90 consignments per year). They are transported by lorry or van.

The waste is always transported in Excepted packages and conforms to the required dose rates for these packages. A consignment probably contains between 2-6 MBq (usually nearer the 2 MBq level) of mixed isotopes normally including some or all of the following C-14, Co-57, Co-58, Cr-51, I-125, I-131, Tl-201 plus a few others occasionally. (The consignments almost never contain Tc-99m because of its short half-life.)

The packages are normally loaded by the vehicle driver which usually takes around 5 minutes. Journey times for the waste normally vary between about 20 minutes to 1 hour but for isolated hospitals and those in outlying regions of the country the journey may take much longer; one hospital quoted 4 hours. The dose rates received by the driver are either undetectable or negligible (probably not exceeding 0.2 mSv/h).
Most of the waste is incinerated but some very low level waste from a few hospitals is buried at normal domestic waste tips.

The information given here is only a broad outline of these movements. A much more in depth, detailed study would be required to give a completely accurate picture of the movement of radioactive waste from hospitals to the site of disposal.

5.11.3 Universities and Research Laboratories.

Universities and some other experimental research units, eg NRPB, produce small amounts of radioactive waste[36,37]. Where possible they make maximum use of storage for decay and aqueous disposal to trade drains and very low level disposal to trade rubbish to reduce the levels of waste. They do, however, produce small amounts of low level solid waste and organic scintillant waste which is disposed of by incineration via a contractor. The material is transported in Excepted packages and each institution ensures that the dose rates from the packages fall within the required limits. Each institution probably makes 1-2 disposals each year. Transport times for these consignments vary from institution to institution but are probably in the range of 1-4 hours. The dose rates to which the collection drivers are exposed are probably negligible.

It is possible that these institutions generate a small number of Type A packages on rare occasions but these would be correctly handled and transported within the regulations because the staff handling them should be familiar with the requirements of the regulations. It is unlikely that these institutions would be adversely affected by the new transport regulations.

5.11.4 Summary of hospitals, universities and research laboratories

The new transport regulations are unlikely to affect either the transport of radiopharmaceuticals for patient or radioactive waste by hospitals or the transport of radioactive waste by research institutions because their staff are trained in respect to the regulations and packages are unlikely to be affected.

5.12 Radioactive wastes from decommissioning

The radioactive content of waste produced from the decommissioning of power stations[38] and other sites[39] is either non-active (below 400 Bq/kg) in which case it is disposed of as normal trade waste or is definitely radioactive waste and falls squarely within all of the regulations concerning radioactive materials.

Intermediate level radioactive waste from the decommissioning process is stored on the site where it is produced in special stores for it to decay. Low level waste is transported to the Drigg repository site, operated by British Nuclear Fuels Limited, in sealed full height or half height ISO (**I**nternational **S**tandards **O**rganisation) containers for long term storage by lorry. The material is transported as Low Specific Activity material Type II (LSA II). At present, it is never transported as either category of Surface Contaminated Object (SCO) material. All movements are carefully arranged to adhere to the transport regulations for radioactive materials and therefore when the new IAEA Transport Regulations (ST-1) 1996 are applied to the UK they are unlikely to seriously affect the movements of this material.

5.13 Summary of the impact of radionuclide-specific exemption values

The majority of materials transported in the UK will be unaffected by the new IAEA Transport Regulations (ST-1) 1996 because the materials transported were either not radioactive under the old regulations and are still not radioactive under the current ones or they were radioactive and remain so under the new regulations. In the latter case where minor amendments to the regulations have been made these will probably be adapted to by the companies involved easily because their staff have a good knowledge of the regulations and are well trained.

A few materials may be affected by the changes in the regulations, especially those materials containing large quantities of thorium, eg rare earth and zirconia ores, glazes, refractories, special alloys and welding rods, and certain other items such as smoke detectors. Some of these items, however, carry exemption in the UK at present, mainly related to the keeping and use of materials, so they may not necessarily be affected by the changes in regulations. These exemptions are, however, subject to review.

5.14 References

1. Safety Standards Series No. ST-1. Regulations for the Safe Transport of Radioactive Material. 1996 Edition. International Atomic Energy Agency, Vienna.

2. Safety Standards Series No. 6. Regulations for the Safe Transport of Radioactive Material. 1985 Edition (Amended 1990). International Atomic Energy Agency, Vienna.

3. The Radioactive Substances Act, 1993. London, HMSO (1993).

4. The Radioactive Substances (Substances of Low Activity) Exemption Order (1986, No 1002, amended 1992, No 647).

5. The Health and Safety at Work etc. Act, 1974. London, HMSO (1974).

6. The Ionising Radiations Regulations 1985. London, HMSO, SI(1985) 1333.

7. E.J. Bradley. Natural radionuclides in environmental media. Department of the Environment (UK) Report: DoE/HMIP/RR/93/063.

8. Personal communication from UK electricity generating companies.

9. H.L.Beck. Radiation exposures due to fossil fuel combustion. Radiation, Physics and Chemistry 34 No2 (1989) 285-293.

10. S.L. Wan and A.D. Wrixon. Radiation doses from coal-fired plants in Oxfordshire and Berkshire. NRPB Report No. R203, 1988.

11. Personal communication from a UK supplier of china clay.

12. K.D.Cliff, J.C.H.Miles and K.Brown. The incidence and origin of radon and its decay products in buildings. NRPB Report No. R159, 1984.

13. Personal communication from a UK importer of crude phosphoric acid.

14. Commission of the European Communities, Nuclear Science and Technology: Study of the radionuclides contained in wastes produced by the phosphate industry and their impact on the environment. Report EUR 13262 EN, by L.H. Baetsle, under contract ETCC-0006, 1991. [ISBN 92-826-0525-6. Catalogue Number: CD-NA-13262-EN-C.

15. A.K.Sam and E.Holm. The Natural radioactivity in phosphate deposits from Sudan. The Science of the Total Environment 162 (1995) 173-178.

16. Personal communication from a UK company which mines and supplies potash.

17. Dr J. O'Grady. Radioactivity and Fertilisers. Technology Ireland, October 1992, 41-45.

18. Personal communication from UK companies which import various ores.

19. J.Hipkin and R.A.Paynter. Radiation exposures to the work force from naturally occurring radioactivity in industrial processes. Radiation Protection Dosimetry V36 No2/4 pp 97-100 (1991).

20. Personal communication from UK companies which process and utilise various ores.

21. Personal communication from a UK company which manufactures lamp metal and thoriated welding rods.

22. Personal communication from a UK company which imports thoriated welding rods.

23. G. Sadagopan, K.S.V. Nambi, G. Venkataraman, V.K. Shukla and S. Kayasth. Estimation of thorium in gas mantles to ascertain regulatory compliance. Radiation Protection Dosimetry 71 (1) 53-56 1997.

24. Personal communication from the UK Lighting Federation and a UK lighting company.

25. Personal communication from UK companies importing radioactive smoke detectors.

26. Personal communication from a UK wholesaler selling radioactive smoke detectors to the general public and companies.

27. Personal communication from the UK office of a German company manufacturing photographic lenses.

28. Personal communication from UK companies selling tritium luminised compasses etc to the general public in the UK.

29. Personal communication from a Finnish company exporting tritium luminsed compasses etc to the UK.

30. Personal communication from the UK company which makes radioactive antistatic devices.

31. Personal communication from a UK company involved in descaling pipework contaminated with radioactive scale.

32. Estimate made after consultation with the Scottish Environmental Protection Agency and a UK company involved in descaling pipework contaminated with radioactive scale.

33. Information supplied, via NRPB Scottish Centre, from the offices of an oil company operating in Scotland.

34. Personal communication from a number of UK hospitals.

35. Personal communication from a large of UK hospital.

36. Personal communication from the safety/radioactive disposal officers of two UK universities.

37. Personal communication from the safety/radioactive disposal officers for the National Radiological Protection Board.

38. Personal communication from the safety/radioactive disposal officers for the nuclear power

industry.

39. Personal communication from the safety/radioactive disposal officers for other nuclear sites such as those operating experimental reactors.

ANNEX 3

Practical Implications of the Adoption of the Exemption Criteria embodied in the 1996 Transport Regulations to Transport Practices in Germany

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1. INTRODUCTION

The „Regulations for the Safe Transport of Radioactive Materials“ of the International Atomic Energy Agency (IAEA) have always contained some criteria which define the domain of application of the system of regulatory controls and safety requirements embodied in the Transport Regulations and which transport practices are exempted from these controls and requirements. A crucial element in establishing such exemption criteria for transport practices or undertakings involving ionizing radiation or radioactive materials is the extent and nature of risk and detriment of a practice warranting the imposition of a system of regulatory controls, e.g. notification, authorization, supervision etc. and requirements. Transport practices where the associated risks or detriment is so small as to warrant the imposition of a system of regulatory controls and requirements can, however, be reasonably exempted from these controls and requirements.

In this perspective, exemption of a practice such as the movement and handling of radioactive material in the public domain from the safety requirements of the Transport Regulations should be envisaged as the limit of what is to be considered as warranting control and supervision by the competent authority. The exemption criteria, however, should in no way be interpreted to define what is radioactive material and what is not.

The 1986 IAEA Transport Regulations and consequently the national and international transport regulations demand any material having a specific activity per unit mass in excess of 70 Bq/g subject to the requirements of the Regulations. The newly edited 1996-Transport Regulations, however, have adopted a different approach, based on the European Directive /EC 96/, and define materials subject to the regulatory controls of the Regulations as any materials containing radionuclides where both the **activity concentration per unit mass** <u>and</u> the **total activity** exceed the specified levels prescribed by the Regulations. The specified levels, generally known as exemption levels, are radionuclide-specific and are tabulated in the Regulations (§ 401-406). The radionuclide-specific exemption levels tabulated in § 401-406 range over several orders of magnitude from very low specific activity values of about 1 Bq/g (and 0.1 Bq/g for unknown radionuclides and mixtures) to about 10^7 Bq/g.

In addition, the 1996 IAEA Transport Regulations do not apply to:

- radioactive material that is an integral part of the means of transport;
- radioactive material moved within an establishment which is subject to appropriate safety regulations in force in the establishment and where the movement does not involve public roads or railways;
- radioactive material implanted or incorporated into a person or live animal for diagnosis or treatment;
- radioactive material in consumer products which have received regulatory approval, following their sale to the end user;
- natural material and ores containing naturally occurring radionuclides which are not intended to be processed for use of these radionuclides provided the activity concentration of the material does not exceed 10 times the values specified in § 401-406.

The foreseen implementation of the 1996 exemption criteria into national and international legislation raises the question as to the potential radiological and economical implications on transport practices involving primarily small quantities and low-level radioactive material. One of the potential concerns include, for example, that some low-level radioactive materials and consumer products which are currently exempted may come under the scope of the 1996 Regulations. This is of particular relevance to transport operations of radioactive materials where the specific activity exemption levels have been drastically reduced compared to the 1985 Regulations by up to about two orders of magnitude below the current exemption level of 70 Bq/g.

This paper summarizes the results of work undertaken by GRS with the objective to evaluate the potential implications on transport practices on a national basis resulting from the anticipated implementation of the exemption criteria embodied in the 1996 IAEA Transport Regulations into national and European legislation. In addition, the structure and implementation of the regulatory framework controlling exemption of radioactive material shipments from the system of regulatory controls and requirements on a national basis in Germany has been examined and is described below. To the extent possible and where relevant, a preliminary assessment of the potential radiological and economical consequences will be made for radioactive materials from being subject to the requirements of the 1996 Transport Regulations.

2. SCOPE OF WORK

Attempts have been made within the EU-funded research project described herein to identify and characterize transport practices and radioactive materials which are currently exempted from the controls and safety requirements of the Regulations, but may potentially fall in the domain of application of the newly edited 1996 Transport Regulations. The work focuses necessarily an radioactive substances and consumer products containing natural or deliberately incorporated radionuclides in the specific activity concentration range around or below the current exemption level of 70 Bq/g. This material category is believed to be prone to be potentially affected by falling in the scope of the newly edited 1996 Regulations, while it was exempted under 1985 Regulations and its previous versions. A table listing the potentially relevant „candidate radionuclides“ in the context of this paper is included in Appendix II.

The use and management of low-level substances and consumer products where radionuclides have been incorporated by purpose or as natural radioactivity has been established for many years. One of the earliest known applications involved the use of uranium compounds in the production of coloured glasses and glassware. Over the last decades the number and variety of consumer products and materials containing radioactive substances increased substantially.

In this paper emphasis has been placed on the following manufactured (consumer) products and materials containing low-level natural or artificial radionuclides:

- building materials
- mining (e.g. ores) and agricultural products
- fertilizer
- thorium products including thoriated welding rods and
- lighting products, e.g. electric lights and fluorescent lamp starter.

It is recognized that a variety of other radioactive materials and radionuclides exist which are prone to fall into the realm of the newly edited 1996 Regulations, but have not been analyzed in detail due to time constraints. These materials include, for example, food, smoke and aerosol detectors, process waste, oil and pipeline scale, radioactive waste, contaminated/irradiated materials from decommissioning of nuclear fuel cycle facilities and other consumer products.

3. ASSESSMENT APPROACH

The approach taken throughout this study is to review the currently available information for radioactive materials and consumer products which are currently exempted from the regulations but may potentially subject to the requirements of the newly edited 1996 Transport Regulations.
The primary resources explored to characterize low-level radioactive materials and consumer products with relevance to the study include the general literature, e.g. /BMU 96, EC 95, NCRP 87, BEC 91/. In addition, information has been acquired from various industrial establishments in Germany with the objective to identify and to collect information relevant for judging the implications for radioactive material transport. The specific information collected comprise particularly data on characteristics of materials and consumer products containing deliberately added or natural radioactive substances in quantities relevant to the study and the volume of materials being manufactured, processed or shipped annually.
Important in exercising judgment is also the structure and implementation of the nationally relevant regulatory framework controlling exemption of radioactive material shipments in Germany. Although Germany has implemented and fully enforces the safety principles embodied in the Regulations there are a number of specific exemptions in effect nationally of practices and materials from the requirements of the Regulations beyond the general exemption provisions specified by the Regulations. A full description of the relevant regulatory framework in effect on a national basis is given in Appendix I. However, currently there is a lack of information whether or not these national exemption orders will remain in effect subsequent to implementation of the

newly edited 1996 Transport Regulations into national and European legislation. For the purposes of this study the assumption has been made that the general exemption provisions embodied in the 1996 Transport Regulations will be the only basis for exemption of transport practices and materials from the controls and requirements of the Regulations.

4. MATERIALS CONSIDERED IN THE STUDY

4.1 Building and Road Construction Materials and Mining, Agricultural and Industrial Products containing naturally occurring Radioactivity

Natural radioactivity is an ubiquitous constituent of the earth's crust and any material derived from it. The major radionuclides of importance are the isotopes of uranium (U), thorium (Th) and their associated decay products and potassium (K). The level of concentration of these radionuclides varies considerably with the type of material and the geographical regime.

The principal information to describe and to compare the activity concentration of naturally occurring radionuclides in typical building, road construction, raw and aggregate materials has been adopted from a recent summary report / BEC 91, BMU 96/ and has been compiled in Table 1. The concentration values given represent - unless otherwise indicated - reported upper ranges of activity concentrations of potassium 40 (K 40), radium 226 (Ra 226), thorium 232 (Th 232) and natural uranium U(nat) in various raw, processed and aggregate materials. The reported upper range activity concentrations must be compared with the 1996 IAEA exemption levels.

Data relevant to describe the extent of commercial use of these materials, e. g. the annual production volume, were not readily available to the study.

Resume: The data in Table 1 indicate that the upper natural activity concentration levels of materials widely in use for building and road construction, as fertilizer and for other industrial applications are generally well below the exemption levels of the 1996 Transport Regulations for the radionuclides typically present in materials derived from the earth's crust.

The production and shipment of some specific mineral concentrations such as mircolith, tantalite and monazite concentrate (which contain several rare earth elements, e. g. Ce. La, Nd, Pr, Sm, etc.), however, may constitute one of the few raw and processed materials containing naturally occurring radionuclides in such quantities that they - similar to the current situation - may come under the scope of the 1996 Transport Regulations, unless specific exemption orders are issued for these materials.

4.2 Thoriated Tungsten Welding Electrodes: Radiological Characteristics and Commercial Usage

Some of the electrodes utilized in electric arc welding, e.g. for the so-called WIG-welding method, contain natural thorium incorporated into the solid metallic tungsten material. Such electrodes have the reported advantage of easier starting, greater arc stability and other advantageous features. Such electrodes are widely used in the construction industry, and in the aircraft, petrochemical and food processing equipment industry.

The quantity of tungsten welding electrodes (TWE) distributed in Germany has been estimated of being on the order of about 60 - 120 Mg per year.

The content of natural thorium contained in TWE ranges typically from about 1 - 4 weight percent in the form of thorium dioxide (ThO_2). The thorium dioxide is generally derived from thorium of natural origin by wet-separation methods and contains, thus, primarily the radioisotopes Th 228 and Th 232 in amounts equivalent to the secular equilibrium of the thorium decay chain, i.e. the Th 228-activity equals the Th 232-activity in any given quantity of material.

The half-lives of the two isotopes differ substantially and are for Th228 and Th232 approx. 1.91 yr and 1.41×10^{10} yr, respectively. The corresponding specific activities per unit mass of isotope ($a = A/m = \ln 2\ N_A / (T\ M)$ where T=half-life, $N_A = 6.0225 \times 10^{23}$ mol^{-1} and M=atomic weight) for Th228 and Th232 are 3.039×10^{13} Bq/g and 4.046×10^{3} Bq/g, respectively.

Given the information of activity equality (A(Th228)= A(Th232)) in the thorium decay chain under secular equilibrium conditions yields the isotope mass ratio of the two radionuclides:

$$a_{228} \cdot m_{228} = a_{232} \cdot m_{232}$$

$$\frac{m_{232}}{m_{228}} = \frac{a_{228}}{a_{232}} = \frac{3.039x10^{13}}{4.046x10^{3}} = 7.511x10^{9}$$

In other words: Thorium 228 represents only a minuscule mass fraction of natural thorium incorporated in the solid metallic tungsten welding electrode material.

The specific activity a_{Thnat} per unit mass of natural thorium (Th 228 and Th 232) contained in the solid TWE material can be determined from the following relationship:

$$a_{Thnat} = \frac{A_{Thnat}}{m_{Thnat}} \approx \frac{2 \cdot A_{Th232}}{m_{Th232}} = 2 \cdot a_{Th232} = 2 \cdot 4046\ Bq / g = 8092\ Bq / g$$

The specific activity a_{TWE} per unit mass of TWE material can than be determined from the following considerations:

Suppose that w_i represents the mass fraction of material component i in the TWE material. Then it is:

$$w_{ThO_2} = \frac{m_{ThO_2}}{m_{TWE}} \approx \frac{m_{ThO_2}}{m_W} \approx 1 \ldots 4\ wgt - \%$$

With the following mass-ratio relationship and the atomic weight M for thorium and thorium dioxide of 232 g/mol and 264 g/mol, respectively, we find:

$$w_{Thnat} = \frac{m_{Thnat}}{m_{TWE}} = \frac{m_{Thnat}}{m_{ThO_2}} \cdot \frac{m_{ThO_2}}{m_{TWE}} \approx \frac{232}{264} \cdot \left(1 \ldots 4\ wgt - \%\right)$$

The specific activity a_{TWE} per unit mass of TWE material is then given by:

$$a_{TWE} = \frac{m_{Thnat} \cdot a_{Thnat}}{m_{TWE}} = \frac{232}{264} \cdot \left(0.01 \ldots 0.04\right) \cdot a_{Thnat}$$

The specific activity per unit mass of TWE material has been - based on the previous equation - tabulated as a function of the natural thorium dioxide mass fraction incorporated in the solid TWE material in the following table:

ThO_2 Mass Fraction contained in the Thoriated Tungsten Electrode Material (%)	Specific Activity a_{TWE} per Unit Mass of Thoriated Tungsten Electrode Material (Bq/g Electrode)
1	71
2	142
3	213
4	284

The activity inventory of a single typical thoriated tungsten welding rod with a diameter of 3 mm, a length of 175 mm and an approximate density of 18 g/cm³ is then given by:

$$m_{rod} = (0.3\ cm)^2 \times 3.14 / 4 \times 17.5\ cm \times 18\ g/cm^3 = 22\ g$$

Consequently, the Th228/232-based activity inventory of a single welding rod containing for example 2 % of ThO_2 is approx. 142 Bq/g x 22 g = 3124 Bq.

Resume: From the information presented above it may be concluded, that thoriated tungsten welding electrodes (TWE) up to a content of about 1 percent ThO_2 have a specific activity concentration below the exemption level of 70 Bq/g specified in the 1985 Transport Regulations and, thus, are not subject to the regulatory controls of the current Regulations. TWE containing ThO_2 in excess of 1 percent, however, would clearly fall in the domain of application of the current Regulations.

Implementation of the newly edited 1996 Regulations where the exemption levels for thorium have been reduced drastically to levels as low as 10 Bq/g (enhancement factor of 10 for naturally occurring radionuclides taken into account according to §107) and an activity limit of 10^3 Bq would for any practical level of ThO_2 (1 ... 4 wgt-%) contained in TWE result in that (almost) any quantity of TWE material shipped in the public domain would come under the scope of the 1996 Regulations, unless specific exemption orders are issued for these low-level radioactive material.

4.3 Electric Lights and related Consumer Products: Radiological Characteristics and Commercial Distribution and Use

The information acquired from various sources reveals that natural thorium, i.e. Th 228 and Th 232, and Krypton 85 are the commercially most significant radionuclides for applications in electric light devices and related consumer product, cp. Fig. 1.

Thoriated Luminous Products:

Thoriated electrode systems are in use internationally in various high performance and special application luminous products operated e.g. at airports, car parks, large public buildings, light houses, cinemas etc. and for lithography, endoscopy etc. The thorium as a component part of the electrode system is generally derived from naturally occurring resources and applied in various ways and may take the form of thorium (ThO_2)-coated tungsten, thoriated tungsten (ThO_2), and thorium-mixtures (e.g. ThI_4) depending on the type and application of the light device.

The thorium serves to enhance the reliability of ignition by reducing the electron exit energy and the stability of the electric arc. Another advantage of the application of thorium in light devices is the beneficial effect on the metallurgical properties of the tungsten electrodes. The estimated activity concentration per unit mass of natural thorium containing the radionuclides Th 228 and Th 232 is approximately 8090 Bq/g.

Information acquired from a major German producer indicates that the quantity of natural thorium in such lights is typically in the range of a few hundred Becquerel with a reported average of about 500 Bq/unit and a maximum of about 10000 Bq/unit. The activity concentration per unit mass of electrode has been estimated making the assumption, that the Th(nat) is (more or less homogeneously) distributed throughout the tip of the electrode volume of less than 0.5 cm^3.

For calculational purposes a tip electrode volume of 0.25 cm^3 and a tungsten density of 18 g/cm^3 have been assumed. The corresponding <u>averaged</u> activity concentration per unit mass of the tungsten electrode material is then approximately 110 Bq/g (500 Bq/(0.25cm^3x18g/cm^3). The estimated <u>maximum</u> activity concentration per unit mass of electrode material would be on the order of about 1000 Bq/g (10000 Bq/0.5cm^3x18g/cm^3).

The following table provides an overview of the available information for thoriated luminous products required for judging the relevance for transport operations.

Consumer Product	Th(nat) Activity Inventory (Bq/unit)	Averaged Th(nat) activity concentration per unit mass of electrode (Bq/g)
Metal halide lamps (Halogenmetalldampflampen)	70 - 80 (max. 100)	---
Xenon short arc lamps/ mercury vapor short arc lamps (Xenon-/Quecksilberdampf-kurzbogenlampe)	300 - 700 (max. 10000)	110 (max. 1000)
1996 IAEA Exemption level	1000 Bq per consignment	10 [a)]

a) Value includes a factor of 10 according to IAEA No. ST-1, §107(e)

The production volume of high performance and special application luminous products is, however, by its very nature relatively limited. Specific data on the production volume or the annual use and distribution in Germany are not readily available.
Shipping arrangements of metal halide lamps and electric arc lamps typically include at the most a few tenth of individually cardboard-packaged lamps. Other lamp types such as mercury vapor lamps, however, may be shipped in larger quantities per consignment.

Krypton 85 in Luminous and related Consumer Products:
Krypton 85, a radioactive noble gas, is a widespread constituent contained in the filling gas of various luminous and related consumer products such as metal halide lamps, fluorescent lamp starters (glow switches) etc. to produce ionization within the the filling

gas atmosphere (e.g. Xenon) to conduct an electric current. The volumetric Kr 85 activity concentration within the filling gas atmosphere has been reported to be in the range of about 1 - 20 MBq/l. These range of values correspond to a Kr 85 activity concentration per unit mass of filling gas of about 0.2 - 3.7 MBq/g assuming xenon (Xe) as filling gas (ρ = 5.4 g/l (= $1.01 x 10^5$ Pa/(63.3 J kg^{-1} K^{-1} x 293 K))).

Metal halide lamps (Halogenmetalldampflampen) contain Kr 85 typically in quantities up to about 5000 Bq/unit with an average of approx. 1000 Bq/unit.

Consumer Product	Kr 85 Activity Inventory (Bq/unit)	Reported average Kr 85 activity concentration within the filling gas (Bq/g)
Metal halide lamps (Halogenmetalldampflampen)	1000 (max. 5000)	approx. 10^6
Fluorescent lamp starter	150 - 250 (max. 1000)	approx. 10^6
1996 IAEA Exemption level	10^4 Bq per consignment	10^5

Fluorescent lamp starters contain Krypton 85 to ionize the starter. The starter works basically as a switch which applies the voltage to the fluorescent tube after sufficient preheating to allow the tube to conduct an electric current. Commercially available fluorescent lamp starters contain on average a Kr 85 inventory of about 150 - 250 Bq/unit, Kr 85 inventories in excess of 1000 Bq/unit can, however, practically be excluded. Several millions of these devices are manufactured and distributed annually in Germany.

<u>Resume:</u> The information provided in the previous tables reveals that the radiological properties of a variety of light devices containing radioactive thorium (Th 228/232) or Krypton (Kr 85) approach or exceed both the 1996 IAEA exemption limits of the total activity per consignment and the activity concentration per unit mass of material. Consequently, shipment and delivery of such luminous devices and related consumer products, especially if shipped in larger quantities of a few tenth (cardboard) packaged items, would clearly fall in the regulatory regime of the 1996 Transport Regulations, unless specific exemption orders are issued for these items or regulatory approval has been granted, following their sale to the end user (ST-1, §106(d).

In Germany, luminous devices and related consumer products containing radioactive materials are currently exempted from the safety requirements of the Transport Regulations by virtue of the exemption provisions codified in the Hazardous Cargo Exemption Ordinance (Verordnung über Ausnahmen von den Vorschriften über die Beförderung gefährlicher Güter (Gefahrgut-Ausnahmeverordnung - GGAV).

5. REFERENCES

/BEC 91/ Becker, D. E. und Reichelt, A.:
Anthropogene Stoffe und Produkte mit natürlichen Radionukliden,
Teil I: Überblick über die wichtigsten Expositionspfade
Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen (Hrg.), München, Aug. 1991

/BMU 96/ Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU):
Umweltradioaktivität und Strahlenbelastung, Jahresbericht 1993
BMU (Hrg.), Bonn, Juni 1996

/EC 95/ European Commission:
Study on Consumer Products containing Radioactive Substances in the EU Member States
Radiation Protection 68, Report EUR 15846 EN (1995)

/EC 96/ European Commission:
Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the public against the dangers arising from ionizing radiation Official Journ. of the European Communities. No. L 159 Vol. 39, 29. 6.1996

/NCRP 87/ National Council on Radiation Protection and Measurement (NCRP):
Radiation Exposure of the U.S. Population from Consumer Products and

Miscellaneous Sources

NCRP Report No. 95, Dec. 1987

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