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RADIATION PROTECTION ISSUES ASSOCIATED WITH THE PROCESSING OF MINERAL SANDS IN THE UK

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INTRODUCTION

A number of Companies within the UK use materials containing naturally occurring radioactive materials (NORM). This paper describes the experience of one particular company engaged in the large-scale processing of certain mineral sands. Attention is focussed on two particular issues: the control of occupational exposure, and the disposal of waste materials containing enhanced concentrations of NORM.

DESCRIPTION OF PROCESS AND MATERIALS

The raw material is imported in either drums or bulk bags and stored in large quantities until required for production. Batches of this material are mixed with various additives and are then fused at high temperatures in an electric arc furnace. During this process, fine dust and furnace fume are released and are collected by an extraction system. The dust typically contains the same radionuclides found in the raw materials, albeit at slightly higher activity concentrations. The fume contains volatile radionuclides that condense and attach to dust particles in the extraction system. This process leads to a substantial increase in the activity concentration of radionuclides such as polonium-210 and lead-210. The extraction system transports the dust and fume (via a filter house) to a collection point where it is collected in drums. The combined dust and condensed fume at this point is referred to as furnace dust collector fines or "furnace DCF". The furnace produces a solid 1 tonne ingot of fused material that is progressively crushed and milled until the required product size is achieved. The products are bagged and stored in bulk awaiting onward distribution. The NORM activity concentrations in the raw material, furnace DCF and a typical product are shown in Table 1.

APPLICATION OF UK LEGISLATION

UK legislation distinguishes between ownership/use of radioactive materials and working with such materials. The ownership/use of radioactive materials is regulated by the Radioactive Substances Act 1993[(1)] (RSA93) which is enforced by the Environment Agency. The Act imposes controls on the use of radioactive materials, and on the accumulation and disposal of radioactive wastes, through a system of registration and authorisation. The RSA93 definition of "radioactive material" excludes radioactivity of natural origin provided that specified elemental activity concentrations are not exceeded. These values are quite restrictive and different concentration levels are specified for different elements (actinium, polonium, uranium, etc), and for different forms (solid, liquid and gas/vapour).

***Table 1:* Activity concentrations of NORM radionuclides in process materials**

Radionuclide	Typical activity concentration ($Bq\ g^{-1}$)[1]		
	Raw material	Furnace DCF	Products
Thorium-232	0.3	1.8	0.3
Radium-228	2.0	11	2.0
Thorium-228	0.4	3.6	0.5
Uranium-238	9.5	16	8.0
Thorium-230	1.3	2.5	1.0
Radium-226	10	30	10
Lead-210	10	200	10
Polonium-210	3.7	600	3.0

[1]Based on analyses undertaken 1990 to 1996. A replacement raw material has since been introduced and activity concentrations from 1997 are lower than the tabulated values.

A number of Orders have been made that provide exemption from registration and authorisation under RSA93. For materials such as mineral sands the most commonly applied is the Phosphatic Substances, Rare Earths, etc. Exemption Order[2]. This provides exemption for solid materials (and liquids containing suspended solids) containing up to 37 Bq g^{-1} of certain naturally occurring elements. All of the raw materials and products handled by the company are exempt from the requirements of RSA93 by virtue of this Order. These materials may, therefore, be used and disposed of in the UK without requiring prior registration or authorisation from the Environment Agency. This does not apply to the furnace DCF (due to the much higher activity concentrations of lead-210 and polonium-210) and authorisation is required to accumulate and dispose of this material.

Liquid and air discharges are not covered by the Exemption Order and these have to be directly compared with the definition of "radioactive material" in the Act. To be regarded as non-radioactive, air discharged from the main stack must contain less than 0.2 mBq g^{-1} of polonium-210, and improvements in stack filtration and monitoring were required to achieve this. Cooling water from the furnace bays has also been sampled to ensure that the polonium-210 content is below the value of 25 mBq g^{-1} defined in the Act.

Work with radioactive materials is regulated by the Health and Safety Executive as part of its wide ranging remit to protect the health and safety of employees and other persons. The Ionising Radiations Regulations 1985[3] (IRR85) define a radioactive material as "any substance which contains one or more radionuclides whose activity cannot be disregarded for the purposes of radiation protection". Dusty processes involving NORM containing thorium-232 or uranium-238 (plus daughter products) at activity concentrations above 0.3 Bq g^{-1} or 1.0 Bq g^{-1}, respectively, would normally be regarded as work with ionising radiation. For bulk storage, the equivalent figures are 5 Bq g^{-1} (thorium-232) or 9 Bq g^{-1} (uranium-238).

All the materials listed in Table 1 may be regarded as radioactive under IRR85 when used in dusty operations or kept in bulk storage. Indeed, the Company have decided that IRR85 will be applied to all areas where these materials are kept or handled. A key principle in IRR85 is optimisation; all exposures shall be kept as low as reasonably practicable (ALARP). The employer is expected to assess the risks from NORM, and then introduce appropriate measures to restrict radiation exposures. Such measures (in order of priority) include the application of engineering controls, systems of work and the provision and use of personal protective equipment.

The likely exposure of employees is also used as the basis for designating work areas as either controlled or supervised. Controlled areas, for example, require demarcation, warning signs, and restrictions on access. In addition, IRR85 specify a number of other management responsibilities including radiation monitoring (individuals and areas), accounting for radioactive materials, information and training, supervision of the work and written local rules.

THE CONTROL OF OCCUPATIONAL EXPOSURE (IRR85)

The radiological problems associated with this process were formally recognised by the Company in 1991 and immediate steps were taken to evaluate the radiation exposure of employees. Inhalation was found to be the dominant exposure pathway. Doses from this pathway were estimated from the results of the personal air sampling programme (respirable dust) already undertaken in the works. The highest doses were received by persons working in the product milling and bagging areas. Estimated annual committed effective dose equivalents for these workers are shown in Figure 1. In 1990 and 1991, average doses exceeded 10 mSv y^{-1}. In comparison, the mean dose received by all classified radiation workers in the UK[4] in 1991 was 1 mSv.

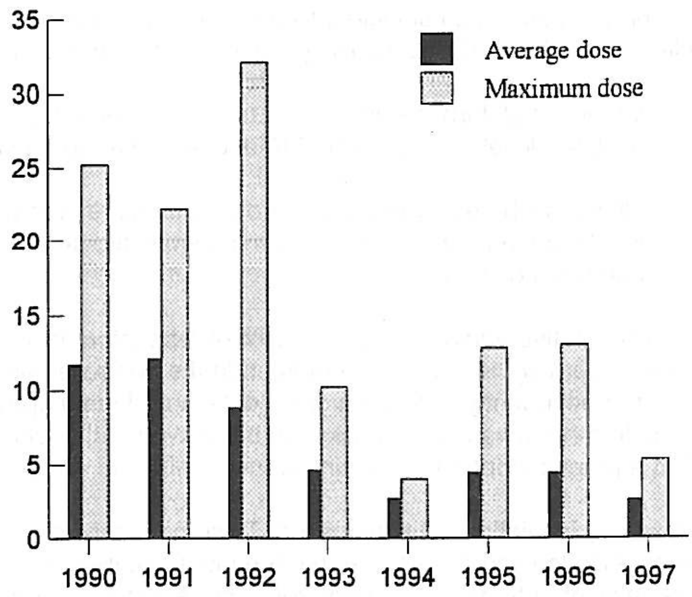

Figure 1: Estimated annual exposures from inhalation to finishing plant workers

Under IRR85, controlled areas need to be designated where an 8 hour air sample indicates that doses might exceed three-tenths of a dose limit (i.e. in this case 15 mSv committed effective dose equivalent). The maximum doses shown in Figure 1 have been calculated from the highest air sampling results obtained. Results for the period 1990 to 1992 indicate that the designation of controlled areas was required. This would have entailed controlling access to large parts of the works and demarcating all such areas with radiation warning signs. Instead, it was decided to implement a combination of dose reduction measures, as follows:

a) engineering controls:
   - some batch transfer operations (usually done by hoppers) were replaced with enclosed systems such as screw feeds;
   - separate pieces of plant were combined or replaced with a single new plant;
   - the dust extraction system was upgraded and extended;
   - the bag filling operation was redesigned to reduce dust generation; and
   - the furnace DCF drum collection point was enclosed to prevent dust dispersion.

b) Working procedures:
   - employees were provided with written local rules that stressed the importance of dust control;
   - routine dose rate and contamination surveys were introduced; and
   - training sessions were provided for employees.

c) Protective clothing:
   - dust masks were made compulsory for work in furnace DCF areas;
   - dust masks were required to be worn for cleaning and maintenance procedures;
   - the optional use of dust masks was stressed for all work.

Most of the above measures were introduced between 1992 and 1994 and Figure 1 shows a substantial drop in estimated doses over this period. It is difficult to determine which protection measures have been the most effective, but it considered likely that the engineering controls have contributed most to dose reduction. Since 1994, minor improvements to the plant have continued to be made, but further reductions in inhalation doses have not resulted.

The dose reductions achieved have been sufficient to prevent large parts of the works being designated as controlled areas. Instead, the following system of designation has been adopted:

Controlled areas -	interior of all furnace dust extraction units where DCF is present (due to elevated levels of polonium-210 and lead-210 contamination).
Supervised areas -	all areas where raw materials and products are processed (due to dust inhalation) and areas where such materials are stored (due to external gamma radiation).

The wearing of personal protective equipment, in the form of respiratory protection (disposable) dust masks and protective clothing, is rigorously enforced in the controlled areas. This, in conjunction with the limited occupancy of these areas, has ensured that exposures from furnace DCF have been minimal. In other areas, dust masks are being worn voluntarily for certain tasks, but are not regarded as a practical option for routine work.

Since 1994, worker doses by inhalation have increased. To some extent, this is due to increased production, although there is also some evidence that the plant installed between 1992 and 1994 has become less efficient in terms of dust control. Another factor is undoubtedly working procedures. Despite the provision of local rules and training, it has proved difficult to maintain the right level of safety awareness amongst employees. Consequently, poor working practices (for example, not cleaning up spills, using hand brushes instead of vacuum equipment, and leaving inspection hatches open) still occur.

Figure 1 shows that doses reduced in 1997, roughly back to the 1994 levels. This reduction, however, is due to the introduction of a new raw material that has a lower NORM content.

DISPOSAL OF FURNACE DCF (RSA93)

For many years, furnace DCF had been disposed of to a local landfill site as controlled (non-radioactive) industrial waste. In 1991, an analysis of the material indicated polonium-210 activity concentrations of 600 Bq g^{-1}, and disposal was immediately suspended. As an interim measure, arrangements were made to store the material pending a decision by the regulatory bodies on how the waste should be handled in future. A survey was made of the existing landfill site and this indicated that there was no measurable environmental impact arising from previous disposal practices. On this basis, applications to resume disposals were made in 1992.

To accept the furnace DCF, the landfill site now needed a license to dispose of the radioactive material. To facilitate this, the local waste regulators recommended a different landfill site already designated as suitable for hazardous waste. An environmental assessment of this site confirmed that it would be suitable for the disposal of furnace DCF. Despite this, the disposal site operators eventually decided not to accept the waste, apparently due to local political problems. The same problems were encountered at other disposal sites, none of which were ultimately willing to accept the waste.

By 1995, over 100 tonnes of waste had been accumulated, with no viable means of disposal identified. Concerns were also beginning to arise about the condition of the stored waste; drums were beginning to rust, and bags were splitting. As a last resort, the Company began to consider blending the furnace DCF with an inert non-radioactive material to reduce the activity concentration. The waste could then be considered exempt from the requirements of RSA93, thus permitting disposal as non-radioactive waste to landfill. This disposal route is not, however, favoured by either the Company or the regulatory bodies and has not yet been pursued. Instead, the Company have continued to look for a site that would be willing to accept the Furnace DCF.

To date, over 200 tonnes of DCF waste have been accumulated. A satisfactory disposal route has still not been secured, although there are signs that an agreement with a landfill site might eventually be secured. In the meantime, the Company intend to blend some of the oldest accumulated waste with damp sand (in a purpose built plant) to avert any problems with long term storage. The blended material will be exempt from RSA93 and will be disposed of as standard industrial waste.

SUMMARY AND CONCLUSIONS

1. For the practice described in this report, the radiation doses to workers handling NORM were found to be high compared to other types of occupational exposure.

2. The need to reduce doses was driven by both the optimisation principle and the desire to avoid designating controlled areas. Substantial dose reductions were achieved; mostly through engineering controls, but also through working procedures and the use of respiratory protection. Recently, the main dose reductions have arisen through the use of a raw material with a lower radioactive content.

3. The high temperature treatment of NORM has resulted in enhanced levels of polonium-210 and lead-210 in furnace dust collector fines (DCF). Occupational hazards from DCF have been readily controlled through containment and the strict use of respiratory protection. The disposal of this material, however, has been a significant problem and, as yet, no suitable disposal route has been identified.

REFERENCES

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

2. The Radioactive Substances (Phosphatic Substances, Rare Earths, etc) Exemption Order 1962 (London, HMSO)

3. The Ionising Radiations Regulations 1985 (London, HMSO)

4. Central Index of Dose Information, Summary of Statistics for 1991, HSE (1993)