COMARE

Committee on Medical Aspects of Radiation in the Environment (COMARE)

SIXTH REPORT

A reconsideration of the possible health implications of the radioactive particles found in the general environment around the Dounreay Nuclear Establishment in the light of the work undertaken since 1995 to locate their source.

Chairman: Professor B A Bridges

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FOREWORD

i. The Committee on Medical Aspects of Radiation in the Environment (COMARE) was established in November 1985 in response to the final recommendation of the report of the Independent Advisory Group chaired by Sir Douglas Black (Black, 1984). Our terms of reference are to "assess and advise Government on the health effects of natural and man-made radiation in the environment and to assess the adequacy of the available data and the need for further research".

ii. The Black Advisory Group had been commissioned by the Minister of Health in 1983 to investigate reports of a high incidence of leukaemia occurring in young people living in the village of Seascale, 3 km from the Sellafield nuclear site, and the suggestion that there might be an association between the leukaemia incidence and the radioactive discharges from Sellafield. The Advisory Group confirmed that there was a higher incidence of leukaemia in young people resident in the area but also concluded that the estimated radiation dose from the Sellafield discharges and other sources, received by the local population, could not account for the observed leukaemia incidence on the basis of knowledge available at that time. The uncertainties in the available data led the Advisory Group to make recommendations for further research and investigation.

iii. Our First Report (COMARE, 1986) examined the implications of some further information concerning discharges of uranium oxide particles from Sellafield in the 1950s, which had not been available to the Black Advisory Group. The Committee concluded that this additional information did not change the essential conclusions of the Black report.

iv. Our Second Report investigated the incidence of leukaemia in young people living near to the Dounreay Nuclear Establishment in Caithness, Scotland (COMARE, 1988). We found evidence of an increased incidence of leukaemia in young people in the area and although the conventional dose and risk estimates suggested that radioactive discharges could not be responsible, we noted that the raised incidence of leukaemia at both Sellafield and Dounreay tended to support the hypothesis that some feature of these two plants led to an increased risk of leukaemia in young people living in the surrounding area. The report also considered other possible explanations and recommended further investigations.

v. Our Third Report considered suggestions of an increased incidence of childhood cancer near the Atomic Weapons Research Establishment at Aldermaston and the Royal Ordnance Factory at Burghfield (COMARE, 1989). We found a small but statistically significant increase in registration rates of childhood leukaemia and other childhood cancers in children in the vicinity of the two sites. However, we judged that the doses from the radioactive discharges were far too low to account for the observed increase in the incidence of childhood cancer. We considered a number of possible explanations for the findings including other mechanisms by which radiation could be involved, but there was insufficient evidence to point to any one explanation, although the possibility remained that a combination of factors might be involved. Further investigations were recommended. Our Third Report concluded by saying that the distribution of cases of childhood leukaemia or other childhood cancers around nuclear installations could not be seen in proper context in the absence of comparable information about the pattern throughout the UK. We recommended, therefore, that further work be carried out to determine the national geographical pattern of distribution of childhood cancer and that this work should be given high priority.

vi. Our Fourth Report (COMARE, 1996) was the result of the Committee's review of the dosimetric, epidemiological and other scientific data relating to the Sellafield Site and the village of Seascale, together with other relevant advances in scientific knowledge, that had become available since the publication of the report of the Black Advisory Group in 1984. In the report we concluded that there was good evidence for a continuing, significantly elevated level of all malignancies in young people (0–24) in Seascale throughout the period considered by the Black report (1963–83) and our subsequent analysis (1984–92), covering a total period of three decades. We considered the current estimate of the radiation doses to the Seascale population, from both routine and accidental discharges from Sellafield, to be too small to account for the observed excess of cases of leukaemia and non-Hodgkin's lymphoma (NHL) on the basis of current knowledge. We considered a number of other hypotheses involving radiation exposure and also those involving exposures to chemicals and infectious agents, either singly or in combination. We concluded that no single factor could account for the excess of leukaemia and NHL but that a mechanism involving infection may be a significant factor affecting the risk of leukaemia and NHL in young people in Seascale. We made five recommendations for further research, all of which were accepted by Government.

vii. Our Fifth Report (COMARE, 1998) examined whether there is or has been any unusual incidence of cancer in the vicinity of the former Greenham Common Airbase and whether there is or has been any association with local levels of radioactivity in the area. With regard to childhood cancers we have examined the local incidence of these diseases in the context of the geographical distribution of these malignancies nationwide. We have found nothing to suggest that a nuclear weapon was involved in the accident or subsequent fire that took place on 28 February 1958. In overall terms, the environmental monitoring data indicated that the levels of man-made and natural radionuclides in this area are low when compared with many other areas of the UK. We also concluded that the environmental monitoring undertaken in the past and currently is consistent with Aldermaston discharges. The finding of an excess of leukaemia in children aged 0–4 years in the West Berkshire area in the current study confirms the excess observed in the studies described in our Third Report. We also noted the excess of leukaemia in young people aged 0–24 years in ward 2 in Newbury, but there was no significant increase of cancer in this age group in the other wards in and around Newbury. We have concluded that the levels of radiation in the local area are so low that they could not be responsible for the local incidence of childhood leukaemia. We have pointed out other factors which might explain the noted excess of childhood leukaemia, particularly those which may be associated with the social class structure of the local area. We hope to examine this further when the results of the geographical studies recommended in our Third Report are complete.

viii. Part of the reason for undertaking the work in our Fifth Report was to examine the possibility that the environmental monitoring data in previously classified reports might have had some effect on the conclusions of our Third Report. These data were not made available to us at the time. In the event, these have not altered the overall conclusions of our Third Report. Nevertheless, we have expressed our concern that the failure of organisations to make available information about relevant activities constrains our ability to comply with our remit. As a result of this particular incident mechanisms have been developed whereby, should issues arise in the future where a high security classification is deemed still to be appropriate, classified information may be made available to appropriate committee members.

ix. In this our Sixth Report we summarise the work undertaken since 1995, and up until October 1998, to locate the source of the radioactive particles found in the general environment around the Dounreay Nuclear Establishment and reconsider the possible health implications of encountering these particles. We have also considered whether ingestion of these particles could be associated with the previously reported excess of leukaemia and NHL in young people living in Thurso.

x. In the preparation of this report the Committee requested data and information from a number of organisations and researchers. Many individuals have given time to present data to us and we wish to take this opportunity to thank all of them for their co-operation.

xi. The views expressed in this report are those of the Committee and not necessarily those of the Secretariat, the Assessors, or those providing evidence. A list of Members, the Secretariat and Assessors is provided in Appendix B. Technical detail is unavoidable in a report such as this and a glossary of terms is provided in Appendix A. However, a complete picture of the scientific background to this report can only be gained by reference to the scientific material consulted, which is listed at the end of the report in the references.

CHAPTER 1

INTRODUCTION

1.1 In 1986 a report (Heasman et al, 1986) published in *The Lancet* stated that there was a marked excess of childhood leukaemia in the vicinity of the Dounreay Nuclear Establishment (the site location is shown in Figure 1.1). The Secretary of State for Scotland asked the Committee on Medical Aspects of Radiation in the Environment (COMARE) to consider and advise on this and related issues. COMARE published its advice in its Second Report in 1988 and made recommendations regarding a case control study already being undertaken in the Dounreay area (Urquhart et al, 1991). Following publication of this case control study COMARE noted the findings of an apparent association between the use of the beaches in the proximity of Dounreay by children and the development of leukaemia and non-Hodgkin's lymphoma (NHL) but advised that this finding should be interpreted with extreme caution. COMARE undertook to update its advice as soon as further relevant research data became available.

1.2 COMARE's request to Her Majesty's Industrial Pollution Inspectorate (HMIPI) produced a document summarising the Dounreay foreshore monitoring since 1983. This described the finding of a number of radioactive metallic particles on the Dounreay foreshore (to which the public has no easy access) between 1984 and 1990 and a single particle on the public beach at Sandside Bay in 1984. In 1988 the UKAEA informed COMARE that it considered that the contamination was a result of a spillage in 1965. COMARE raised queries about specific aspects of beach monitoring data and the nature of the radioactive content and location of these particles.

1.3 COMARE decided that a small working group should address these issues. The working group considered information provided by HMIPI and the Government Division of the UKAEA and at the invitation of the UKAEA visited the Dounreay site and beaches in May 1994. During this visit the working group was informed of other possible sources of particulate contamination on the Dounreay foreshore. These sources included the Intermediate Level Waste Disposal Shaft which had been authorised for solid radioactive waste disposal from 1958 onwards. These issues fell within the remit and expertise of the Radioactive Waste Management Advisory Committee (RWMAC) and COMARE requested its assistance in establishing the source of radioactive contamination.

1.4 COMARE was concerned that the authority of its Second Report may have been diminished by the lack of timely information concerning the source and activity of the particles. This concern was made clear to both the UKAEA and HMIPI. COMARE has received assurances from the UKAEA that there is no other outstanding relevant information and that any information which may arise in the future will be disclosed.

1.5 In May 1995, COMARE and the RWMAC published reports in a document entitled "Potential Health Effects and Possible Sources of Radioactive Particles Found in the Vicinity of Dounreay Nuclear Establishment" (COMARE/RWMAC, 1995). The following is a summary of the conclusions of that document:

i. the RWMAC recommends that the UKAEA should introduce into its advisory structure a greater level of appropriate independent scientific expertise together with regular reviews of progress;

ii. COMARE and the RWMAC agree that the Intermediate Level Waste Disposal Shaft is an unacceptable model for disposal of radioactive waste and recommend that the UKAEA should take steps to propose a solution and a timetable for the treatment of waste;

iii. COMARE believes that the possible health effects from radioactive contamination in the environment around the Dounreay site depend upon the likelihood of encountering one of the radioactive particles and on the particle activity. The chance of a member of the public encountering a metallic particle is considered to be extremely small and COMARE is of the opinion, based on the evidence currently available, that whilst the most active particles could cause acute effects, the metallic particles are most unlikely to explain the observed excess of childhood leukaemia in the Dounreay area.

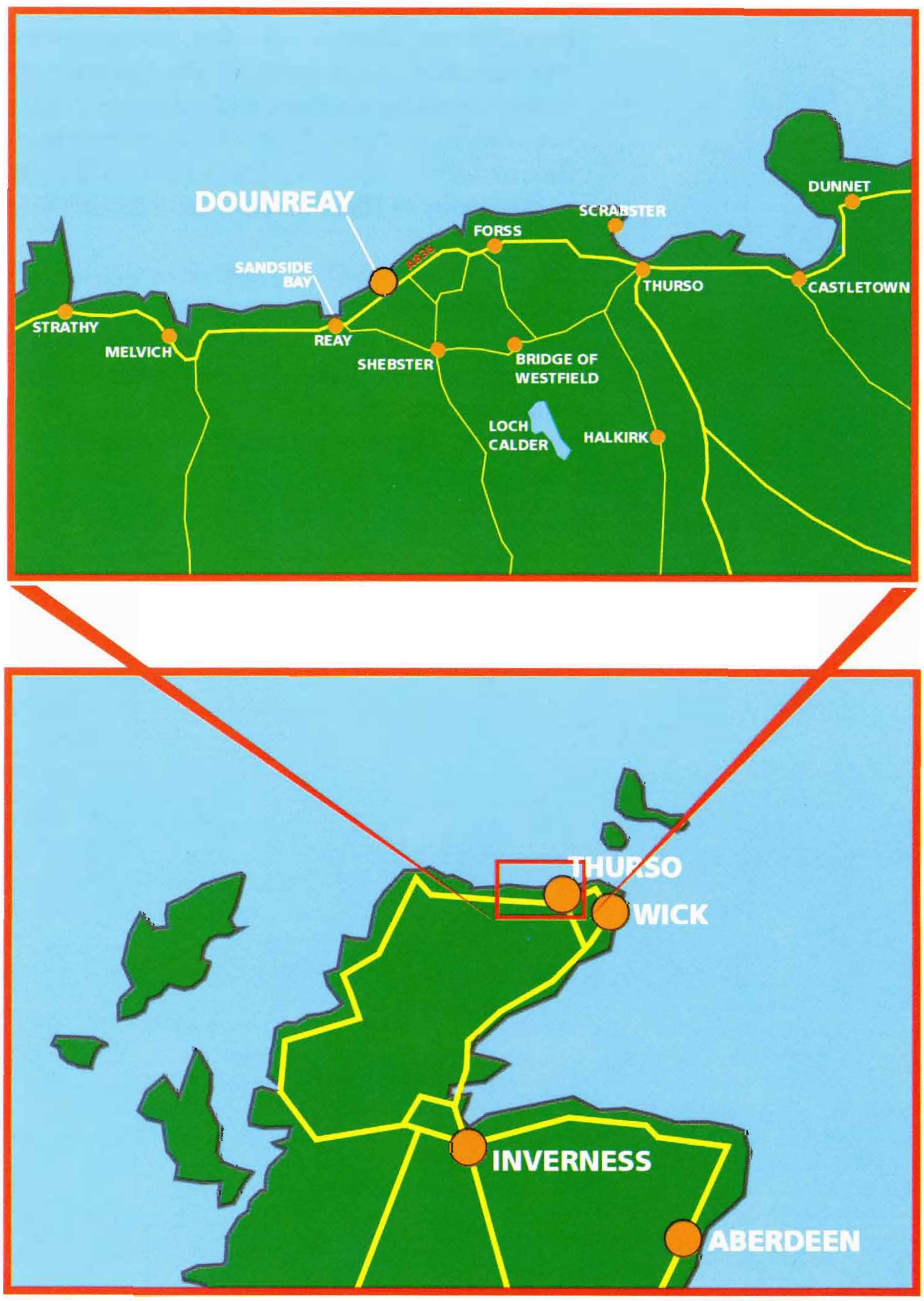

Figure 1.1 Location of Dounreay

1.6 Following publication of the 1995 report, both COMARE and the RWMAC have been kept informed of an ongoing UKAEA programme of work to identify the possible source, or sources, of the particles. The expanded body of knowledge about the particles achieved through these investigations means that it is now an appropriate time to update the findings set out in the 1995 report. This COMARE report will consider the implications of the work undertaken by the UKAEA, assess the current situation, including the two more recent finds of radioactive particles at Sandside Bay in 1997, and will also attempt to reassess the potential health effects of the uncontrolled release of particles to the general environment. A separate report by the RWMAC (RWMAC, 1999) provides a detailed assessment of the UKAEA's work to locate the source, or sources, of the particles and recommends the course of possible future investigations. In short, the RWMAC commends the comprehensive nature and professionalism of the UKAEA's investigations, but notes that while the work has succeeded in narrowing the range of possibilities, no definitive source of the particles has yet been established.

1.7 Since publication of the COMARE/RWMAC report in 1995 there have been important changes in the way nuclear sites and their discharges are authorised and regulated. As a result of the Environment Act of 1995, the issuing of authorisations for the accumulation and disposal of radioactive waste in Scotland became (from April 1996) the responsibility of the newly created Scottish Environment Protection Agency (SEPA). Previously these actions had been the responsibility of HMIPI, part of the Scottish Office.

1.8 We asked SEPA to provide us with a summary of the various authorisations relating to the operations on the Dounreay site, listing the dates and the appropriate authorising body. This information is contained in Table 1.1. This information is important because it could be considered that the body which authorised disposal to the Intermediate Level Waste Disposal Shaft shares the responsibility for the decision to dispose to an inappropriate facility.

Table 1.1 Summary of Dounreay authorisations since beginning of operation to present

Authorisation type	Date signed (date commenced)	Current or date revoked	Organisation responsible for issuing authorisation	Legislation issued under
*Solid (including sludge)	25 July 1958 (1 Sept 1958)	Only valid for a year (issued annually until 1963)	Secretary of State (SoS) for Scotland	Atomic Energy Authority Act 1954
	25 Nov 1963 (1 Dec 1963)	Revoked 7 Feb 1972	SoS for Scotland	Radioactive Substances Act 1960
	3 Feb 1972 (7 Feb 1972)	Current	SoS for Scotland	Radioactive Substances Act 1960
Liquid	11 Jan 1957 (15 Jan 1957)	Only valid for a year (issued annually until 1963)	SoS for Scotland	Atomic Energy Authority Act 1954
	Oct 1963	Revoked June 1967	SoS for Scotland	Radioactive Substances Act 1960
	6 June 1967 (7 June 1967)	Revoked 25 March 1993	SoS for Scotland	Radioactive Substances Act 1960
	2 May 1989 (1 June 1989)	Current	HMIPI – authorised on behalf of SoS for Scotland	Radioactive Substances Act 1960
Gaseous	11 Jan 1957 (15 Jan 1957)	Only valid for a year (issued annually until 1963)	SoS for Scotland	Atomic Energy Authority Act 1954
	25 Nov 1963 (1 Dec 1963)	Revoked 25 March 1993	SoS for Scotland	Radioactive Substances Act 1960
	2 May 1989 (1 June 1989)	Current	HMIPI – authorised on behalf of SoS for Scotland	Radioactive Substances Act 1960
†Transfer of waste	14 May 1964 (14 May 1964)	Revoked 31 March 1971	SoS for Scotland	Radioactive Substances Act 1960
	31 March 197 (1 April 1971)	Current	SoS for Scotland	Radioactive Substances Act 1960

* Solid authorisation covers both the Low Activity Waste Disposal Pits and the Deep Storage Shaft.
† Authorisation covers disposal of radioactive waste "of any description" to any premises occupied by the UKAEA or any premises situated on a licensed site occupied by British Nuclear Fuels Limited.

CHAPTER 2

RADIOACTIVE PARTICLE FINDS AND THE WORK UNDERTAKEN TO FIND THEIR SOURCE

Introduction

2.1 Over the period of time since the publication of the COMARE/RWMAC report in May 1995, a considerable programme of work has been undertaken by the UKAEA in an attempt to find the source of the radioactive metallic particles found at Dounreay and Sandside Bay. The following is a summary description of the work undertaken so far, based largely on information provided by the UKAEA. It is included here to aid the reader to put the health risks discussed later in their proper context. A plan of the Dounreay site is given in Figure 2.1. For detailed information on the UKAEA investigation programme, the reader is referred to the RWMAC report (RWMAC, 1999).

Background

2.2 Metallic swarf was produced at Dounreay during the 1960s by the underwater milling of irradiated fuel elements from Material Test Reactors (MTR) to remove their aluminium casing. The resulting particles, some of which incorporate pieces of irradiated fuel, were disposed of to the Intermediate Level Waste Shaft up until 1973. The shaft, which is 65.4 m deep (approximately 215 feet) and 4.6 m in diameter (approximately 15 feet), had been formed during the construction of the undersea tunnel that carries the main discharge pipelines for low level radioactive liquid effluent. After construction was completed the shaft was isolated from the tunnel by a substantial concrete plug. When waste disposals were made to the shaft, some particles escaped either during transport across the site in flasks or when the flasks were emptied into the disposal shaft. Some particles may also have moved into the low active drainage system when the pond used for milling was cleaned out. In 1977 a chemical explosion occurred in the air space above the waste in the shaft. Given that this explosion was of sufficient force to blow the steel and concrete lid of the shaft – weighing some 40 tonnes – several metres, it must be possible that some of the contents of the shaft might have been dispersed at this time. Clearly, these occurrences show a lack of control of nuclear waste which should not have happened and which should have been rectified following the first occurrence.

2.3 Since 1984, metallic particles have been found through regular surveys of the foreshore at Dounreay at an average rate of about 12 in a year. These particles are composed of aluminium with small, though radiologically significant, quantities of products of fission, irradiation and unburnt fuel, including caesium-137, strontium-90, americium-241 and plutonium-239. They are discovered largely by detectors sensitive to the gamma radiation from caesium-137 although the total activity is dominated by strontium-90 which is a beta emitter. The particles are of similar size (0.4 to 3 mm diameter) to the sand grains found on the foreshore and of similar density (3.1 ± 0.7 g cm^{-3}) to that sand. Activities vary primarily with particle size and the total activity is broadly three times that of the caesium-137 detected, about 5×10^{10} Bq g^{-1}, and thus generally ranging from 10^4 to 10^8 Bq per particle. Depending upon the activity, particles can be detected at up to 50 or 60 cm depth in relatively dry sand.

2.4 The regular beach and foreshore surveys looking for these particles began after a particle was found at the west end of the Dounreay beach on 4 November

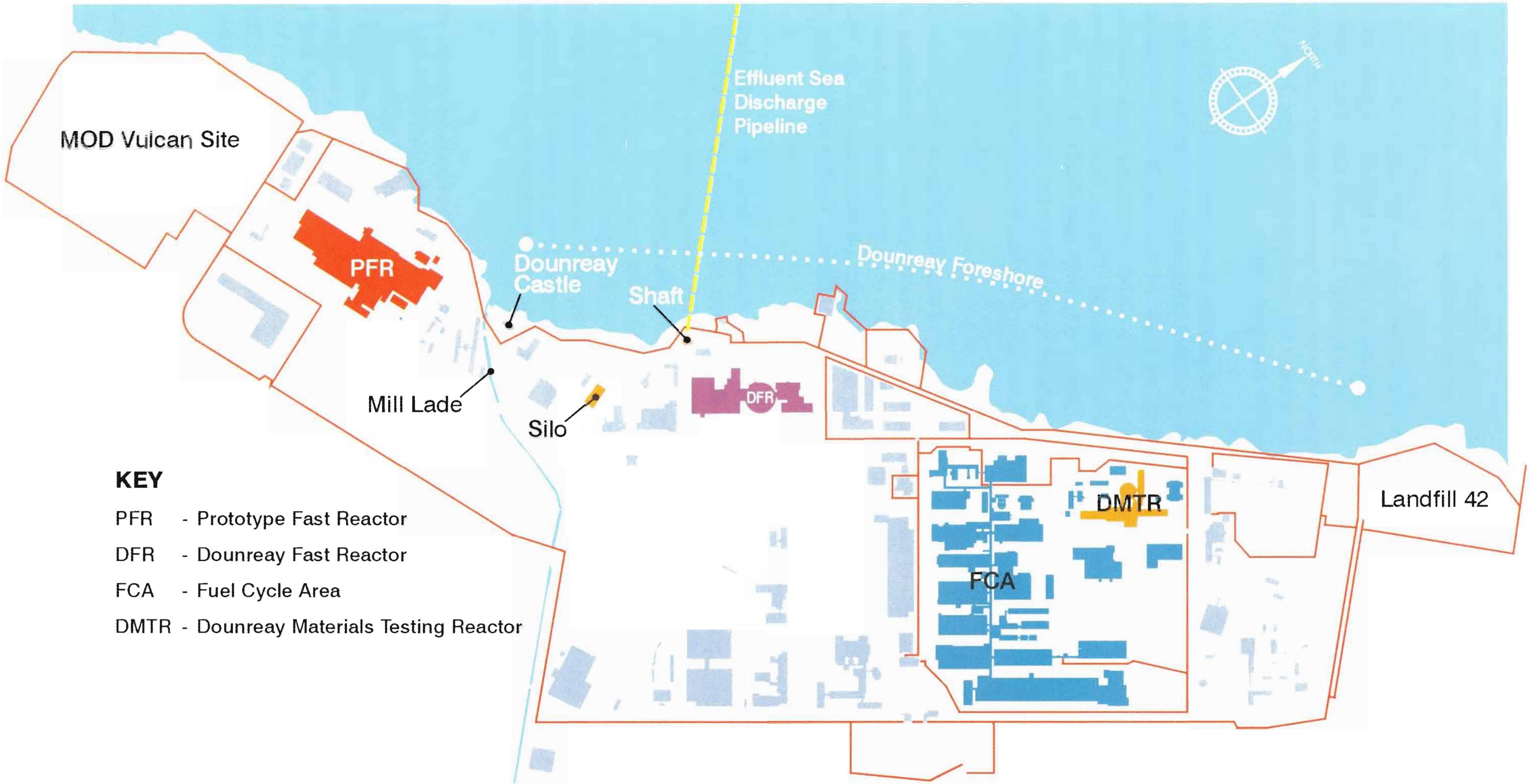

Figure 2.1 Plan of Dounreay site

1983. Prior to this, one particle had been found on the foreshore in 1979 and two more in 1982. These were subsequently identified as being of MTR type. At the start of routine monitoring in January 1984 ten particles were found. This appears to have cleared the accumulated particles from at least the surface layers of the beach since only 16 further particles were found that year. Since then the yearly total (January–December) has been between 4 and 17 with an average, 1985–1996 inclusive, of 12 (strictly 11.92 y^{-1}, a total of 143 particles). In addition, three particles whose activity is towards the lower end of the range of activities found for particles recovered from the Dounreay foreshore, have been found on Sandside Beach at Reay, some 3 km south-west of the site. These were found in 1984 (one particle) and 1997 (two particles).

2.5 At times other types of particles have been found, but these are too few in number to provide much additional information. In 1984 radioactive black waxy particles were identified by beach survey. Changes to site procedures ensured no further releases of waxy particles. Other significant finds have included steel particles with activity due to cobalt-60. Four of these have been found on the Dounreay foreshore (in 1984, 1985, 1986 and 1993). A few finds containing niobium have also been made, although only on the Dounreay site and not on the foreshore. These are thought to come from fuel used in the original Dounreay Fast Reactor (DFR).

2.6 Since the successful survey of seabed features in 1996 and the development in 1997 of a suitable detector for use under water, the first monitoring survey found some 35 metallic particles on the seabed in an incomplete survey of several scattered areas of the seabed just off from the site. Of these particles, six were DFR fuel fragments and 31 were derived from MTR fuel. Further particles have been found in subsequent surveys.

2.7 Prior to the discovery of metallic particles on the beach, finds of contaminated material on the licensed site were removed without ascertaining whether the activity was concentrated in a single particle. To date 79 radioactive hot spots have been positively identified as particles on site. These "site particles" are generally less active than those found on the beach and appear to be less smooth in surface character. Even though a few of these particles have been found on the cliff top, the small number suggests that the adjacent land site is an improbable source for the finds on the foreshore. Starting in 1996, a systematic database listing all particles found and their characteristics was established and is maintained as an ongoing record.

Nature and origin of the metallic particles

2.8 Although the routes and/or stores (caches) of particles remain undiscovered, there is no mystery about their origin. Between the mid-1960s and 1973, MTR fuel elements destined for reprocessing were milled underwater in the Fuel Cycle Area (FCA) at Dounreay. Fuel elements were generally of box section and it was helpful to the reprocessing if the pure aluminium casing around the fuel was first removed. Thus the spacers and outer edges of the fuel plates were removed by milling, originally in the D1204 pond and then in the Dounreay MTR (DMTR) pond, although some fuel milling was carried out at the D1204 pond from about 1963 to 1969. Fuel plates were also milled in the DMTR pond from about 1963 to 1969.

2.9 The swarf had to be collected from the pond, transferred into a flask (commonly called a swarf coffin from its shape), and disposed of by the authorised route to the shaft (D1225). At least 188 disposals of swarf were made between July 1959 and September 1966 and a further 65 disposals from the DMTR between January 1964 and March 1968. From the inventory of shaft disposals the maximum weight of swarf that could have been produced from the 8605 elements is about

6000 kg of which between 0.1% and 1.0% (mainly estimated by reviewing contamination levels in pond water) is thought to be active. Most of the swarf in the shaft probably lies at depths between 30 and 60 m from the surface.

2.10 It is worth noting in passing that although the ratio of non-active aluminium particles to those with activity must be very high, to date no way of effectively separating them from sand has been found. It is also worth recording that in addition to the chemical analysis of the metallic particles, dating (by noting the ratio of caesium-134 to caesium-137) has shown that the particles were irradiated in about 1965 ± 3 years. Dating by this method has now become very difficult because of the natural decay of caesium-134. However, as a check that the same particle source was still involved, a particle found in March 1993 was dated by prolonged counting. The date of irradiation was calculated as being 27 years previous to the date found, confirming the age of irradiation.

Postulated pathways and stores that might be involved in off-site dispersion of active metallic particles

2.11 We have been told that there were occasions in the 1960s when swarf was unintentionally released from the milling pond into the low active drainage system, and other incidents in the same period that could have resulted in particles entering the non-active drains. However, the bulk of the swarf was taken as intended for the shaft, although when disposal occurred on windy days or other problems were encountered some particles may have escaped onto and beyond the site.

2.12 In the early days of investigation of the metallic particles found on the foreshore, the hypothesis favoured was that they had been discharged from the site via the drainage system as a result of a spillage of radioactive liquid known to have occurred in 1965. This spillage occurred when a temporary hose was ruptured and swarf was hosed into the non-active drainage system. The estimated size (activity) of that spillage was far too low to account for the activity accruing as beach finds. Also, it was difficult to explain the limited finds prior to 1984 and the continued and very steady annual level of finds for so many years after this spillage.

Drainage system

2.13 More recent investigations have yielded other incidents when active swarf could have entered the drainage system, but all these events require temporary storage, possibly within the drainage system, to yield the steady pattern of finds that has now persisted for over 14 years. Careful search of the non-active drainage system, as far as the foreshore, has not yielded a single particle. There have been a number of incidents, but it is most likely that they would have resulted in fairly rapid transport to the foreshore, or to the sea via the old diffuser, at the time of the incident. Those particles transported to the foreshore would have been rapidly lost to the sea unless some mechanisms operate which would retain them in the sediments.

2.14 A systematic approach to searching potential dispersal routes was initiated. Particles have been found on site, and it was postulated that there might still be stores on roofs, in gutters, in the surface soil, in drains, or in dumped spoil from excavations on site. Some of the latter has now being eroded by the sea, as it was disposed of to coastal landfills. In all 21 paths were postulated, 18 of these forming possible site/foreshore links. In general, whenever finds of activity have been made on site, the contamination, including any particles, has been cleaned up and disposed of. Since swarf is no longer being transported across the site, and has not been transported for over 20 years, the general surface of the site is unlikely to be a continuing source. However, stores in gutters, on roofs, or in drainage sumps (gulleys) were a possibility. A systematic search of a representative number of gutters and gulleys has essentially eliminated these as a particle source. A careful check was also made on roof chippings removed during routine maintenance, with again negative results. Considerable effort was made to survey all the known drains, and with the exception of short lengths with difficult access this has now been done. Although some contamination has been found, particles have not been identified in the drains. There could still be undiscovered lengths of abandoned drain, and much work has been done checking records of the system and its modification over time, but the UKAEA says that it is now virtually certain that the drainage system is not supplying particles to the beach, even if it did so in the 1960s and 1970s from time to time.

Cliff face

2.15 Past disposal practice had almost certainly allowed the dispersal of some swarf and there was also the possibility that the shaft explosion had scattered particles to the surrounding land. Thus the cliffs adjacent to the shaft, as an eroding store, remained an attractive hypothesis as a possible site of a cache of particles. The soil around the shaft has been examined with particular care and in the past a few particles have been found. In 1996, one cubic metre of soil was removed from near to the shaft, but no particles were found in it. More importantly, the eroding cliff faces were carefully surveyed in 1996 and again in 1997 and no particles were found. Calculations show that if the cliffs were the dominant source, appreciably more than a dozen particles should have been revealed by these surveys, even in the unlikely event that every eroded particle were to remain in the beach or on the rocky foreshore until detected by the regular fortnightly surveys. As no MTR particles were found by the two surveys and only four particles found during safety surveys undertaken at the time of the construction of a bund wall, this effectively rules out the cliffs as the source. The bund wall was built to intercept contaminated water draining from the area around the shaft.

2.16 With the exception of the shaft itself, these investigations together make a very strong case for excluding the site and its drainage or erosional links with the sea as potential sources or caches for the particles found on the foreshore.

Dounreay beach

2.17 For 13 years, most of the off-site particles were found on the sand and pebble beach on the west foreshore at Dounreay or on the rocky east foreshore, separated from the western beach by the deep-water of the cooling water intake for the DFR. Although the beach was not thought to be more than a metre deep, the volume was nevertheless large enough to conceal a large number of particles which might be brought to the surface, thus contributing to the annual supply recovered by beach monitoring.

2.18 After establishing a suitable technique the whole beach was carefully excavated in August 1996. This investigation took 11 days and covered all the beach except for a triangular area of radioactive contamination (detectable quantities of fission products and plutonium) just north of Dounreay Castle which was systematically removed a year later on the insistence of SEPA. The August 1996 excavations found four active particles and it is noteworthy that a further three particles were found between September and December 1996 after the decontaminated sand had been replaced. It is also noteworthy that, despite the additional effort in August, the 1996 total was 16, only 4 more than the long-term average. This investigation not only established that there is no hidden cache of particles within Dounreay beach, but also that a steady recruitment of particles to the beach has continued despite the cleaning of the beach in August 1996.

2.19 Very little is known about the exchange of sand between the beach and the shallow water just below Low Water Mark. Properly structured surveys started in 1998 and in time these will quantify changes in beach volume. The beach level measured at four points in the spring and summer of 1987 showed changes of up to 60 cm in 14 days, demonstrating the mobility of the beach and the way in which buried particles can be brought to the surface.

Particles offshore of the Dounreay foreshore

2.20 Given the gradual elimination of landward sources and routes, the possibility that there was a cache of particles, released to the offshore zone in some past event, and steadily feeding back to the beach and rocky foreshore, became a more attractive hypothesis. One additional potential source involved in this route is the flushing out of the old diffuser at the end of the effluent discharge system, in 1983. This well-documented event has proved a durable hypothesis but has yet to be proved or disproved.

2.21 In 1997, an offshore monitoring device was developed and by using divers in up to 20 m of water an estimated 21,000 m^2 of seafloor off Dounreay was monitored in two periods, late August and early September 1997. Thirty-four particles were found, mostly on or near the surface (within the top 100 mm). Estimates have been made of the number of cubic metres of offshore sand likely to contain a particle which suggest 0.05 to 0.1 particles per m^3 in the area surveyed. This would mean that there could be thousands of active particles in the whole offshore area. Subsequent surveying over a wider area and into deeper water in 1998 produced a further 89 particles and supported the view that the dominant direction of dispersal is to the north-east. Three particles were recovered from the underwater area of the entrance to Sandside Bay, to the west of the site.

2.22 It is, therefore, possible for occasional particles from this offshore population to move onto beaches by way of coastal processes, most probably the disturbance of sand by large waves. This would result in turbulent suspension of particles along with the similarly sized sand grains. Shoreward movement is only likely to occur frequently when the water depth is less than 5 m or so, but occasional shoreward movement is possible from greater depths, although whether this would supply the estimated 120 to 240 m^3 of sand for the 12 particles found on the beach each year may be doubtful. Volumes of that order would readily come from shallower water, in which case it is the shallow-water sand ($\leq$5 m) which would need to contain the postulated reservoir of particles. Shallow-water sands are much more frequently disturbed by wave action than those in deeper water. It is, therefore, hard to imagine an adequate volume of sand, including radioactive particles, remaining in this region for more than a year or two. However, there is some evidence from the offshore studies of a greater stability in some sediments.

Particles at Sandside Bay

2.23 When only one particle had been found at Sandside Bay in 1984 it was impossible to do more than guess at how it might have got there. One particle might be accounted for by an exotic pathway and thus be a unique event. The discovery of two further particles 13 years later suggests that natural coastal processes are involved. All three particles found on Sandside beach have been small and of lower activity than most of those found on the Dounreay foreshore, but this too is most probably due to natural coastal processes for the sand at Sandside is much finer than that in the Dounreay beach. If fine sand moves to and accumulates preferentially at Sandside Bay, then it would be expected that smaller particles of similar dimensions to that sand would move with it.

The shaft as a potential source of particles

2.24 Virtually all of the swarf from the reprocessing of MTR fuel at Dounreay was produced during the 1960s. Up until 1973, it was sent for disposal to the shaft and must be dispersed throughout the waste, apart from the layers added between 1973 and 1977. After the explosion in 1977 all disposals to the shaft were stopped. Thus the shaft is a potential source of metallic particles. In its Eighteenth Annual Report (July 1998) the RWMAC notes that the UKAEA acknowledges that the shaft has the potential to leak particles of this type of irradiated material to the offshore, and if ongoing work proves that the shaft is the source of the particles the UKAEA will consider bringing forward that part of the shaft remediation needed to provide its hydrogeological isolation.

2.25 In order to try and contain contamination in the shaft, the shaft water level is pumped to several metres below normal ground-water level so that ground-water moves towards the cone of depression created by the pump. By this means potentially contaminated water within the shaft is discharged by the pump through the low level effluent system (no filtration system was installed in this pumping process until 1980, but we are informed that no particle has been intercepted by the filtration process since its installation). This does, of course, mean that the particles could have been carried out before filtering began, particularly when relatively large volumes of uncontained particulates were deposited and settled down through the head waters. If pumps had been operating during this time it is likely that particles could have been carried into the low active drainage system. Thus ground-water does not move from the upper levels of the shaft towards the coast. There are inevitably many uncertainties about this situation. The main reason for this is that the Devonian sandstones of Caithness are much broken by bedding planes, joints, faults and other discontinuities. Hence almost all the ground-water moves through these fissures and not through the rock itself. Thus movement is more rapid than in rocks where such fissures are absent. More importantly, models of ground-water behaviour such as Darcy's Law, so powerful in modelling permeable rocks, contain inappropriate assumptions and simplifications for the Caithness sandstones. Furthermore, water movement through such rocks at a local scale does not meet the prerequisites of such common models as Darcy's Law (see the glossary).

2.26 An early geological inquiry (Dawson, 1967, also cited by Davidson, 1995, and Mowat, 1995) by implication criticised the shaft as "it is unlined, too near the coast and the disturbed nature of the bedrock on the new Fast Reactor site makes this area unsuitable for waste disposal". There is also the evidence that the tunnel seaward from the shaft built to contain the main effluent pipes was delayed by seawater ingress for a month or more and was eventually allowed to flood, even though the original design called for it to be dry. Hartley et al (1996) concluded that the probable fracture widths were not large enough to allow the escape of particles from the shaft and subsequent, more sophisticated computer modelling called Fracman supported that conclusion. If there existed other attractive potential sources for the beach particles, these conclusions might be taken at face value, but increasingly the elimination of other sources throws attention back on the shaft and possibly the old diffusion chamber located some 25 m below the seabed and about 600 m offshore.

2.27 No conclusion can be reached, but the following two essential points should be understood.

i. Modelling, especially if it uses probabilistic models, cannot provide a certain negative answer, it can at best indicate a route as highly unlikely.

ii. In 1996 it was established using pump rate data and modelling that the permeability of the waste within the shaft has probably declined greatly over the years (it had visibly settled by about 3 m between 1977 and 1992) and the volume of water pumped from the shaft annually has declined to a quarter of its 1960 value (Hartley et al, 1996). It appears that the pumping at the top of the shaft no longer draws water up through the waste and there is likely to be a head difference of 5–6 m across the plug at the base of the shaft.

2.28 It seems likely that water flows from the lower part of the shaft towards the sea despite the continued pumping at the top which now closely matches the estimated inflow above the top of the waste. This does not prove that particles of

1 mm diameter can be carried from the shaft, but since very little water emerges from the cliffs or to the foreshore (or beach) above low tide, it is worth searching for freshwater springs seaward of Low Water Mark, and this is currently being done. A line of reduced salinity, thought to indicate up-welling freshwater was discovered in April 1998 about 300 m offshore, as well as a few scattered freshwater springs on the seabed nearer the shoreline.

2.29 There is also the question of the integrity of the concrete plug which was cast to separate the base of the shaft from the effluent tunnel, itself full of freshwater. Visual inspection by Remote Operated Vehicle (ROV) has shown the plug to be in good condition and has failed to find any evidence of radioactivity. However, if particles as well as water could flow around this plug, they would pass into the flooded effluent tunnel. Whether particles could proceed along the tunnel and then up and out through the diffusers (a long and low energy route) seems rather unlikely, but not impossible.

Some unconsidered source

2.30 Whilst the current programme continues, the hope persists that a source or sources of the particles will be discovered. But the possibility remains that all current ideas will, like all past hypotheses which have been thoroughly investigated, prove negative. There is a need, therefore, to remain alert and imaginative to some hitherto unconsidered source. The persistent and constant supply becomes ever more obvious as each year's finds are added to the inventory and imposes a considerable constraint on ideas of a long-lasting cache. The proportion of finds on the rocky foreshore east of the DFR outfall compared to those found on the west beach has persisted at about 1 : 2 every year except 1992 when all particles came from the west beach. Over the long term there are more winter than summer finds but the mechanism for this is unclear. It has previously been explained by winter storms disturbing the beach to a greater depth than normal but it is already known that the beach does not hold a cache of particles. It could be that winter storms remix offshore sediments containing particles making them more available for transport to the shoreline. However, the particle finds are also consistent with a continued leakage from the diffuser or the shaft. Of considerable significance is the fact, that despite wider searches, foreshore particles stop abruptly south-westward at the Mill Lade and to the north-east before Landfill 42 is reached. Perhaps this fact alone, if supported by more extensive monitoring offshore, may suggest that unusually the sediments near Dounreay are fairly stable with a fairly low loss. The pronounced lack of a longshore dispersion implies a very local source (or sources).

2.31 The average size of the beach particles is larger than the average size of those found on the site. Beach particles are well rounded, hardly surprising given the marine environment, although many recovered from the seabed still exhibit a more rugged structure. Increasing attention is being given to the chemistry of their surface coating, which for most beach grains is iron-rich and contains other elements not normally associated with MTR fuel. There seems general agreement that this indicates prolonged residence in a stable environment. Further detailed analysis may be able to distinguish what that environment may have been.

Future investigations

2.32 The signs of freshwater discharge already discovered by conductivity meter offshore will be followed up by further hydrogeological investigations of the shaft. A wider survey of sand offshore will allow a better estimate of the number of particles present and, more importantly, the extent to which they have been dispersed along the coast. Completion of the ongoing current flow and wave height investigations will assist the development of sea models and assist decision making for further action. The UKAEA is also intending to investigate the contents of the old diffuser chamber which is located some 25 m below the seabed.

CHAPTER 3

POSSIBLE HEALTH EFFECTS OF THE PARTICLES

3.1 Because of the level of radioactivity contained in the particles found on the foreshore and at Sandside Bay, COMARE agreed that the possible health effects that were most likely to arise from exposure to a particle would be acute radiation effects arising from surface exposures (for example, from direct exposure of the skin or gut, if ingested, of an intact particle.) However, following ingestion, some of the radionuclides in the particles will be soluble in the gastric acid of the stomach. These radionuclides (principally strontium-90 and caesium-137) would then be absorbed into the body and redistributed in particular tissues. Because most of the activity present in a particle is due to the presence of strontium-90, a bone seeking isotope, there would be a subsequent exposure of the bone marrow to the radioactivity contained in a particle. This would give rise to an increased risk of the development of leukaemia or possibly non-Hodgkin's lymphoma. The chances that members of the public could sustain either of these very different types of radiation damage is essentially dependent upon the likelihood of an individual coming into contact with particles of the activities measured so far [10^4–10^8 becquerels (Bq) of caesium-137 gamma activity approximately]*.

3.2 The possible relationship between exposure to such particles and the known level of childhood leukaemia in Thurso will, therefore, be dependent upon the number of children who might come into contact with such particles.

NRPB dose estimates and health effects

3.3 The National Radiological Protection Board (NRPB) has estimated the radiation dose that a member of the public might receive in the unlikely event that such a particle were encountered. The NRPB considered the health consequences of an individual swallowing a particle and also the effect of prolonged contact on the skin or gut. The activity in the first particle found at Sandside Bay was at the lower end of the observed range (10^5 Bq). If such a particle was swallowed and the radioactivity absorbed, the estimated dose to the whole body would be of the same order as that received every year by the average person in the UK from all sources of radiation, that is 2.6 millisieverts (mSv). Much higher localised doses could result if such a particle were in prolonged contact with the skin or a specific point in the gut when all the radioactivity would remain in one small area rather than being absorbed and dissipated throughout the body. Contact times of about an hour to 1 cm of skin could result in a dose equivalent of about 1000 mSv (1 sievert, Sv), sufficient to give rise to acute effects such as inflammation or ulceration. Such effects would occur following shorter contact times for more active particles. There is also a risk of late health effects such as leukaemia where the probability of occurrence depends upon the activity ingested. In the case of the first particle found at Sandside Bay, the increased risk would be extremely small.

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* Activities given are the levels of caesium-137 contained in the particles, not the total activity, of which about 50% is contributed by strontium-90. This is the current activity. Particles released in the 1960s would also have contained short-lived radionuclides which have now decayed away. It is not possible to say accurately what dose would have been received from a particle of 10^6 Bq caesium-137 activity in the early 1960s but it would have been higher than that received from a particle of 10^6 Bq caesium-137 activity in the late 1990s.

3.4 However, only a few particles have been found with activities lower than 10^5 Bq, with some having activities as high as 10^8 Bq. The majority of the particles found on the Dounreay foreshore have activities in the range 10^6 to 10^7 Bq. Any resultant doses from the ingestion of particles with these levels of activity would give an equivalent bone marrow dose of tens of millisieverts, sufficient to cause a significant increase in the risk of leukaemogenesis. In the unlikely event that a particle similar to the most active found so far was swallowed, the dose equivalent to the intestine could be tens of sieverts, a dose likely to cause severe acute effects. The dose to the red bone marrow would be in the region of hundreds of millisieverts, sufficient to increase substantially the probability of leukaemogenesis over a number of years.

Leukaemia risk to children resulting from ingestion of radioactive particles

3.5 Although very few radioactive particles have been found on the publicly accessible Sandside beach, it is necessary to consider whether larger numbers of particles (as might hypothetically have occurred in the past) could have given rise to a substantial risk of leukaemia to children visiting the beach. The question that COMARE needed to address was essentially whether it was possible that particles could have been present, and ingested in sufficiently large numbers, that they could have given rise to the known level of childhood leukaemia in the area around Dounreay.

3.6 We have approached this question by mathematical modelling and have attempted to calculate the number of cases of leukaemia which would have resulted from the ingestion of large numbers of particles, having the level of radioactivity observed in those particles found on the Dounreay foreshore, by a population of young children. Although it is unlikely that a particle encountered by a child would be ingested, this event would pose the greatest risk of leukaemia.

3.7 In constructing the model, it was assumed that the statistical distribution of activities of ingested particles was the same as that reported for the Dounreay foreshore (ie that the foreshore and beach particles derive from the same stock). Radioactive particles found on the Dounreay foreshore have a wide range of activities expressed as 10^4 to 10^8 Bq caesium-137 gamma activity, with a median value of about 10^6 Bq. The particles also contain considerable activity due to strontium-90. In the computer simulation study, the particle activity was assumed to be distributed log-normally with a mean of 10^6 Bq per particle. This corresponds approximately to the observed range of particle activities, and is roughly the correct shape, although it is not an exact fit to the observed data. The total activity can then be computed from the level of caesium-137 activity using 'Fispin code'.

3.8 The bone marrow dose to a 1 year old child due to ingestion of a particle of this composition is about 2×10^{-6} mSv per Bq of caesium-137. Using models described by Simmonds et al (1995), the NRPB has estimated the risk of leukaemia and non-Hodgkin's lymphoma from exposure of the bone marrow of a 1 year old to be about 1.7×10^{-2} Sv^{-1}, up to the 25th birthday. We have used these data to compute the number of "ingestion events" which, on average, would result in five or six radiation-induced leukaemias or non-Hodgkin's lymphomas. This figure equates to the number of cases observed in the vicinity of Dounreay in the period 1979–1984.

3.9 Table 3.1 shows the computer model prediction of the numbers of leukaemia cases resulting from radioactive particle ingestion, with the radioactivity per particle conforming to the activity found for Dounreay foreshore particles. The model used a Monte Carlo approach to estimate the likely number of leukaemia cases corresponding to a given level of particle ingestion; the estimated number varies from one simulation to another. The data shown were generated by ten simulations for each level of ingestion.

Table 3.1 Computer simulation of the number of leukaemia cases which might arise from differing numbers of ingestion event. Results of ten simulations for each specified number of ingestions

Ingestions	Leukaemias									
5.000	1	1	1	0	0	0	3	2	1	0
10.000	3	4	2	0	2	0	1	4	1	5
15.000	2	1	2	8	2	1	2	2	4	1
20.000	3	7	4	6	2	6	1	4	5	2
25.000	6	2	5	11	4	3	11	4	9	6
30.000	7	9	6	5	4	8	3	4	5	5
35.000	6	4	3	8	5	6	7	7	5	8
40.000	6	10	4	13	4	4	9	10	9	10
45.000	7	8	10	7	11	12	8	11	13	12
50.000	8	12	13	12	8	12	8	9	7	6

These data are shown graphically in Figure 3.1.

Technical Note to Table 3.1

The computer study was carried out as follows. For each choice of number of ingested particles a sample of doses was obtained by Monte Carlo simulation from the theoretical distribution and the corresponding risks calculated using the NRPB risk coefficient. Each computed risk value was translated into a simulated leukaemia event, defined here to be the occurrence of leukaemia before the 25th birthday (designated 1), or non-event (designated 0), by means of a binomial distribution. The number of leukaemia events is then computed. This procedure was repeated ten times for each of the ingestion event groups in the range 5.000 to 50.000 to provide the table above. The simulated data were fitted by a least-squares procedure to a straight line relationship between "ingested" particle number and number of leukaemias resulting in the fitted relationship:

Leukaemia events = 1.982×10^{-4} × Ingested particle number, ($p < 0.0001$), the slope having a standard error of 7.20×10^{-6}.

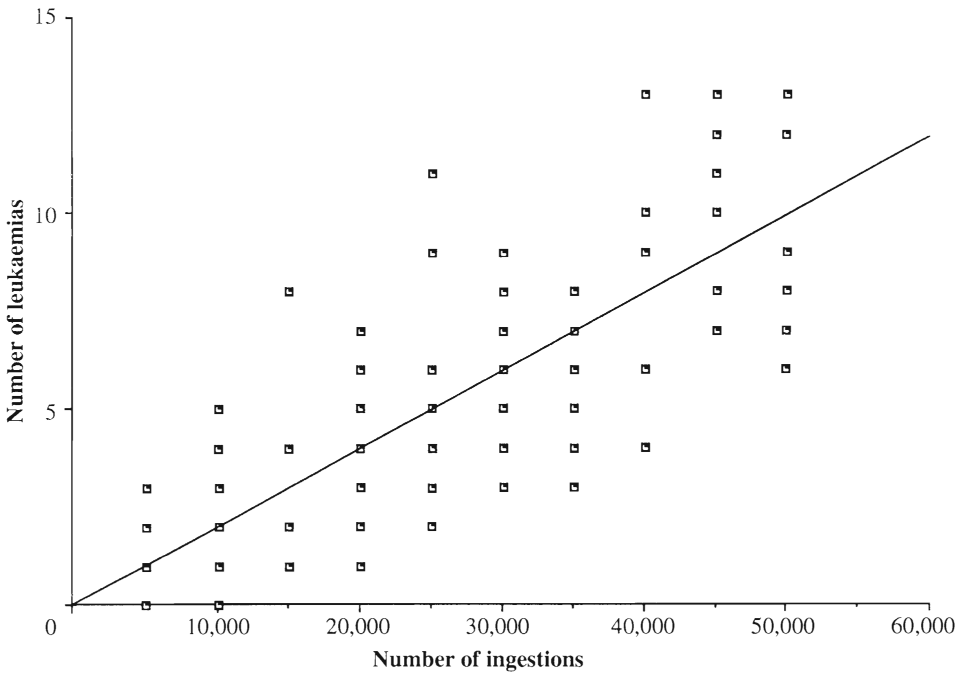

Figure 3.1

3.10 The computer simulations suggest that about 25,000 particle ingestions would be required to produce about five radiation-induced cases of leukaemia. Given that the particles so far found at Sandside Bay have a lower activity than the mean for the Dounreay foreshore particles used for the simulation, this estimate of the number of ingestions may also prove to be a conservative assumption. Moreover, for such a large number of ingestions to have occurred, a huge number of particles (millions) would have to have been present and readily accessible on local beaches. Although the calculations are to some extent dependent upon the detailed assumptions made, it seems clear that an implausibly large number of particles would need to be ingested causing exposures in an implausibly large number of children to produce the excess of leukaemia seen in Thurso. Radioactive beach particles cannot, therefore, realistically account for the increased incidence of leukaemia.

Whole body monitoring

3.11 In 1996 a study was published in which the measurement of radioactivity in people living near the Dounreay Nuclear Establishment was undertaken (Watson and Sumner, 1996). This study was instigated as a result of Recommendation 7 of our Second (Dounreay) Report in which, recognising the uncertainties involved in dose and risk calculations, we recommended that where possible whole body monitoring and measurement of radioactivity in placentae should be undertaken near major nuclear installations and in control areas as a check on dose estimation procedures. The study detailed results of measurements of radioactive contamination in 66 subjects associated with the Dounreay area and 42 control subjects. The methods included measurement of plutonium-239 in urine, americium-241 in the skull and whole body monitoring gamma counting. On subsets of the study group an investigation of the levels of strontium-90 in urine were carried out to investigate the possibility that local people might have ingested one of the "hot particles" known to have been found on the Dounreay foreshore. Chromosome abnormality analysis was carried out on the lymphocytes of eight subjects (four leukaemic patients and four controls).

3.12 The radiation measurements showed that only very low levels of the various radionuclides were present in any of the subjects in the study and the chromosome abnormality analysis showed no differences between the leukaemia and control groups. The authors concluded that no significant inter-group differences for measurements of contamination were demonstrated for groups of leukaemia cases, siblings, parents and matched controls. The authors also concluded that the findings suggested that it was unlikely that the observed increased incidence in leukaemia was due to the single factor of personal radioactive contamination from the Dounreay site.

Discussion

3.13 As the radioactive particles do not appear to be able to explain the excess number of cases of leukaemia and NHL in young people living around the Dounreay site, we have considered other possible hypotheses. We have previously concluded that the authorised discharges from Dounreay are too small to account for the excess. Monitoring of the environment including house dust is generally compatible with the authorised discharges and has not suggested that there has been some other unauthorised release of activity that would count for the excess.

3.14 The whole body monitoring study of affected individuals (Watson and Sumner, 1996), which addressed Recommendation 7 of our Second Report, also showed that the measured levels of activity in the Dounreay area were very small and could not account for the observed number of cases.

3.15 In our Second Report we discussed other possible factors such as occupational exposure to radiation, exposure to chemicals and social factors but concluded that none of these could account for the excess cases. However, there is now a further plausible hypothesis that was not considered at the time of our Second Report. We discussed in our Fourth Report on Sellafield the role of infectious agents in the aetiology of childhood leukaemia and the effect of population mixing, particularly influx into remote rural areas. Whilst accepting that population mixing was likely to be a contributory factor around Sellafield we were not persuaded, on the basis of the available evidence, that it could account entirely for the magnitude and duration of the excess of childhood cancer in the village of Seascale.

3.16 In studies by Kinlen and his colleagues (Kinlen et al, 1995) at other sites of population mixing the magnitude of the excess number of cases found was around two-fold on average. The size of the excess number of cases near Dounreay and the fact that they have occurred in a distinct timespan are consistent with the predictions of the population mixing hypothesis. Currently, to our knowledge, no biological agent or agents have been demonstrated to occur in the populations in which the population mixing effect has been observed. Hence, no specific agent suspected of being that by which this effect may be promulgated has been identified. However, we note that, in the absence of any reasonable alternative, this may be the currently most plausible hypothesis to explain the level of leukaemia in young people in the Dounreay area.

CHAPTER 4

DISCUSSION AND CONCLUSIONS

Acute effects of ingesting hot particles

4.1 As we noted in Chapter 3 of this report, if individuals were to ingest particles with activities at the top of the range of those particles already found on the Dounreay foreshore (ie 10^8 Bq), fatalities would be observed. However, particles with lower activities, such as 10^6 to 10^7 Bq, may cause severe gut upsets which might not be attributed to ingested radioactivity. We have concluded that the particles, if encountered, present a hazard to health, and that the hottest particles could induce serious acute radiation effects. Whilst the probability of encountering a particle is small, it is not negligible.

Leukaemia risk to children resulting from ingestion of radioactive particles

4.2 Leukaemia is a group of malignant diseases of the blood-forming tissues characterised by abnormal white blood cells which divide in a manner outside the control of the body. Most leukaemias start in the red bone marrow but some start in the lymphatic system. In all instances the bone marrow ends up being the main site of the disease. The principal groups are the chronic leukaemias which are very rare in people under the age of 25 years and the acute leukaemias. Acute lymphoblastic leukaemia (ALL) currently accounts for 75–80% of all cases of childhood leukaemia in the UK. Both ALL and non-Hodgkin's lymphoma (NHL, which is closely related to ALL) derive from lymphoid cells. Acute myeloblastic leukaemia (AML, also known as acute non-lymphoblastic leukaemia, ANLL) derives from myeloid bone marrow cells. The current scientific consensus is that the risk of developing acute leukaemia increases with exposure to ionising radiation. This topic is dealt with in more depth in our Fourth Report (COMARE, 1996).

4.3 Very few radioactive particles have been found on the publicly accessible Sandside beach. However, we have had to consider whether contact with such particles could have given rise to a substantial risk of leukaemia to children visiting the beach. The question that COMARE needed to address was essentially whether it was possible that particles were present, and ingested in sufficiently large numbers, such that they could have given rise to the known level of childhood leukaemia in the area around Dounreay.

4.4 We have approached this question by mathematical modelling and have attempted to calculate the number of cases of leukaemia which would have resulted from the ingestion of large numbers of particles with the appropriate level of radioactivity, by a population of young children. The computer simulations suggest that about 25,000 particle ingestions would be required to produce about five radiation-induced cases of leukaemia. It seems clear that an implausibly large numbers of particles would need to be in the coastal environment to produce the excess of leukaemia seen in Thurso. Radioactive beach particles do not, therefore, provide a realistic mechanism for the increased incidence of leukaemia in young people.

Criticism of UKAEA past practices

4.5 COMARE considers that severe criticism of UKAEA past practices relating to radioactive waste management is warranted. However, there is some doubt as to whether the UKAEA was entirely to blame for practices which would be considered unacceptable today. The Scottish Office has been responsible for authorising discharges and disposals of radioactive waste from or at the Dounreay site. A summary of the past and current authorisations has been produced for COMARE by SEPA and is included in Table 1.1. We consider that the resources applied by the Scottish Office to overseeing the regulation of waste disposal at this important site have in the past been inadequate for their purpose. The current arrangements and funding of SEPA will, it is hoped, address these shortcomings.

4.6 COMARE's Second Report had noted the UKAEA's failure to investigate abnormal monitoring results. The strontium-90 gradient with distance from the site was one such example. The UKAEA had attributed this to variation in farming practice with little attempt at scientific investigation, illustrating how results conflicting with predictions were often not properly investigated. We wish to stress that every effort needs to be made to ensure that such scientific and investigative complacency is combatted. The particles found on the Dounreay foreshore and at Sandside Bay do not appear to be responsible for the number of cases of leukaemia and NHL in young people resident in Thurso. However, the UKAEA has dispersed and may be continuing to disperse, albeit in part inadvertently, an unknown and unauthorised range of radioactive materials into the coastal environment and therefore cannot escape criticism.

4.7 COMARE pointed out in its comments on the proposed new Dounreay authorisation that the appropriate inspectorate should ensure that current facilities are adequate to be operated at modern standards of safety, before a new authorisation is given. COMARE notes that this point was further emphasised in the Nuclear Installations Inspectorate (NII) audit of health and safety at Dounreay published in September 1998 (HSE, 1998).

4.8 Whilst the audit team has identified a number of shortcomings, which it believes are deep rooted and stem from the historical background to the site, the team has also shown that much has already been done to improve safety at Dounreay. The HSE also believes, that subject to the recommendations in the audit report (HSE, 1998) concerning organisation, management and training, the current staff at Dounreay have the appropriate knowledge, skills and commitment to operate the Dounreay facility to modern standards of safety.

RWMAC recommendation to find a solution to problems presented by the Intermediate Level Waste Shaft

4.9 The Intermediate Level Waste Shaft would be of concern to COMARE even if it were not suspected as a source of particles. A geological enquiry carried out at Dounreay in 1967 concluded that an unlined shaft in the geological substratum there was not suitable for the disposal of radioactive waste. Moreover, the probability of coastal erosion was singled out for particular comment. It is of concern that ten years later materials were still being disposed of to the existing unlined shaft. In 1995 the RWMAC stated that the shaft was not an acceptable model for the disposal of radioactive waste and that the UKAEA should propose a solution and timescale for the treatment of waste in accord with modern standards. COMARE endorsed this recommendation and is now pleased to note that possible actions have been put forward for the shaft remediation and that these have been accepted, in principle, by Government.

4.10 It is disappointing that all of the work carried out so far has not yet discovered, definitively, sources of the particles or allowed much verification of conceptual offshore pathways, although it has eliminated many postulated sources. Such negative evidence narrows the range of sources and pathways still to be checked, but does not allow many positive statements to be made about the likely source or sources of the particles found on the beaches at Dounreay and Sandside Bay. For all these reasons, progress in the understanding of the origins of the particles is yet to be completed. However, the work required is being designed, authorised and completed at good speed and, we are assured, will continue until all the problems are solved.

CHAPTER 5

RECOMMENDATIONS FOR FURTHER WORK

5.1 In the light of the comments made in paragraph 4.10 COMARE can do no more than repeat its recommendation from its 1995 report that appropriate action is continued until the source and nature of all the particles are finally discovered and their continued release dealt with satisfactorily. This may require further offshore monitoring as well as those studies being conducted on site. The only current method by which it is possible to ensure that the general public does not come into contact with these particles, is to have a level of environmental monitoring such that any particles are discovered and removed before the public can be exposed.

Beach monitoring

5.2 SEPA's view is that the monitoring on Sandside Beach has not been in the past, nor is it currently, sufficiently comprehensive. At best the areas surveyed on each visit amounted to no more than the cumulative coverage of the whole beach once or twice in a year and the effectiveness rested strongly on the unproven assumption that particles were most likely to be found near the high tide line. SEPA has asked the UKAEA to produce a beach monitoring strategy and to make improvements in its monitoring regime. In response, the UKAEA has trialed the use of *Groundhog* which collects data rapidly and uses satellite navigation devices to determine the area monitored. However, this is essentially only a single detector moved around by a single person. COMARE's view is that a motorised device employing several monitors, similar to that used to monitor the roads on site, could be developed for use on the local beaches. Such a device would allow large areas to be monitored quickly and in a variety of weather conditions.

5.3 COMARE *recommends* that, at least until the source and routes by which the particles enter the local environment are discovered, beaches in the area should be monitored regularly and comprehensively. The UKAEA should seek ways to improve the monitoring programme by:

i. developing a beach monitoring strategy document;

ii. continuing to monitor beaches after storms;

iii. developing new monitoring technology;

iv. extending more frequent monitoring to the whole of Scrabster and Thurso beaches.

5.4 In practical terms, COMARE would like to see all local beaches monitored on a regular basis and Sandside Bay monitored on a weekly basis, with each visit covering the whole area of potential occupancy rather than just the high tide line. This level of monitoring should be continued at least until the particle sources and the routes by which they reach the shore and beaches are determined and understood. COMARE would also wish to see the monitoring strategy document as soon as it is available so that it can add further comments, if it believes they are necessary, at that time.

5.5 Furthermore, COMARE *recommends* that the appropriate authorities should prudently consider the adequacy of beach monitoring near other nuclear sites in Britain, as the Dounreay experience has demonstrated how small an area might be covered by current monitoring practices and activities.

REFERENCES

Black D (1984). Investigation of the possible increased incidence of cancer in West Cumbria. Report of the Independent Advisory Group. HMSO, London.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (1986). First Report. The implications of the new data on the releases from Sellafield in the 1950s for the conclusions of the report on the investigation of the possible increased incidence of cancer in West Cumbria. HMSO, London.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (1988). Second Report. Investigation of the possible increased incidence of leukaemia in young people near the Dounreay Nuclear Establishment, Caithness, Scotland. HMSO, London.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (1989). Third Report. Report on the incidence of childhood cancer in the West Berkshire and North Hampshire area, in which are situated the Atomic Weapons Research Establishment, Aldermaston and the Royal Ordnance Factory, Burghfield. HMSO, London.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (1996). Fourth Report. The incidence of cancer and leukaemia in young people in the vicinity of the Sellafield site, West Cumbria: further studies and an update of the situation since the publication of the report of the Black Advisory Group in 1984. HMSO, London.

Committee on Medical Aspects of Radiation in the Environment (COMARE) (1998). Fifth Report. The incidence of cancer and leukaemia in the area around the former Greenham Common Airbase. An investigation of a possible association with measured environmental radiation levels. NRPB, Chilton.

Committee on Medical Aspects of Radiation in the Environment (COMARE) and the Radioactive Waste Management Advisory Committee (RWMAC) (1995). Potential health effects and possible sources of radioactive particles found in the vicinity of the Dounreay Nuclear Establishment. HMSO, London.

Davidson L (1995). Coastal erosion: summary of previous findings. AEAT, Dounreay, ES/PTD/TN(95)P24.

Dawson J (1967). The disposal of high-active solid radioactive waste at Dounreay Experimental Reactor Establishment, Caithness, Scotland. IGS, Geochemical Division Report No. 275.

Hartley A C, Baker A C and Jefferies N L (1996). An evaluation of the effectiveness of the ground water containment scheme in the Dounreay Intermediate Level Waste Shaft. AEAT, Dounreay, AEAT-0351 (draft).

Health and Safety Executive (HSE) (1998). Safety audit of Dounreay 1998. HSE, London.

Heasman M A, Kemp I W, Urquhart J D and Black R (1986). Childhood leukaemia in Northern Scotland. *The Lancet,* **I**, 266.

Kinlen L, Dickson M and Stiller C A (1995). Childhood leukaemia and non-Hodgkin's lymphoma near large rural construction sites, with a comparison with Sellafield nuclear site. *British Medical Journal,* **310,** 763–768.

Mowat A (1995). Coastal erosion (WP03) – a review of previous studies. AEAT, Dounreay, ES/PTD/TN(95)P22.

Simmonds J R, Robinson C A, Phipps A, Muirhead C R and Fry F A (1995). Risks of leukaemia and other cancers in Seascale from all sources of ionising radiation exposure. NRPB, Chilton, NRPB-R276.

Radioactive Waste Management Advisory Committee (RWMAC) (1998). Eighteenth Annual Report. Department of the Environment, Transport and the Regions, London.

Radioactive Waste Management Advisory Committee (RWMAC) (1999). Radioactive particles at Dounreay: a review. Department of the Environment, Transport and the Regions, London.

Urquhart J D, Black R J, Muirhead M J, Sharp L, Maxwell M, Eden O B and Jones D A (1991). Case-control study of leukaemia and non-Hodgkin's lymphoma in children in Caithness near the Dounreay nuclear installation. *British Medical Journal*, **302**, 687–692.

Watson W S and Sumner D J (1996). The measurement of radioactivity in people living near the Dounreay Nuclear Establishment, Caithness, Scotland. *International Journal of Radiation Biology,* **70**, 117–130.

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In particular, we wish to thank Dr Tom Wheldon for his leadership of the Dounreay Working Group during his time as its Chairman and the hard work he put into the investigation which led to the publication of this report. Our particular thanks are also due to Tom for carrying out the simulation described in Chapter Three of the number of leukaemia cases which might arise from the ingestion of radioactive particles. This work was completed after Tom had left COMARE and when he was fighting a most serious illness. We wish to express our sincere best wishes for his full recovery.

THE APPENDICES

APPENDIX A

GLOSSARY

Notes

The descriptions below are intended to help the reader understand the text; they are not necessarily definitive scientific terms, for which the reader is advised to consult specialist sources. This glossary does not form part of the report.

Underlined words are defined separately.

ABSORBED DOSE (Radiation)
The quantity of energy imparted by ionising radiation to a unit mass of matter such as tissue. Absorbed dose has the units J kg^{-1} and the special name gray (Gy).

AETIOLOGY
The study of causes of disease.

ALPHA PARTICLES
The nucleus of a helium atom which is positively charged and consists of two protons and two neutrons. An alpha particle is ejected in the process of alpha decay.

AMERICIUM-241 (^{241}Am)
A radionuclide with a half-life of 460 years, which decays with the emission of alpha particles and gamma rays. It is formed as a daughter product of the decay of plutonium-241.

BEDDING PLANES
The arrangement of sedimentary rocks in layers.

BEQUEREL (Bq)
The international (SI) unit for the number of nuclear disintegrations occurring per unit time, in a quantity of radioactive material. 1 Bq = 1 radioactive disintegration per second. Replaced the Curie (Ci) – 1 Bq = 2.7×10^{-11} Ci. Because this is an extremely small unit, levels of activity expressed in Bq are often prefixed with mega (10^6 Bq – Mbq), or giga (10^9 Bq – GBq), particularly in the context of discharges of activity into the environment. Conversely, under normal circumstances activity concentrations in environmental materials are generally low and so prefixes such as milli (10^{-3} Bq – mBq) and micro (10^{-6} Bq – µBq) may be employed.

BETA EMITTER
A radionuclide which decays through the emission of beta particles.

BETA PARTICLE
An electron emitted by a radioactive nucleus in beta decay.

CAESIUM-134 (^{134}Cs)
A radionuclide which has a half-life of 2.2 years and which decays with the emission of beta particles and gamma rays.

CAESIUM-137 (^{137}Cs)
A radionuclide which has a half-life of about 30 years and which decays with the emission of beta particles and gamma rays.

CANCER REGISTRATION
The registration of new cases of cancer occurring in the population of Scotland is the responsibility of the Information and Statistics Division of the Common Services Agency for the National Health Service in Scotland. Data are collected from medical notes by specially trained Cancer Registration Officers based at the major hospitals treating cancer patients. These data are collated at the Scottish Cancer Registry, and used on a confidential basis for epidemiological research and the management of cancer services provided by the NHS in Scotland.

CASE CONTROL STUDY
A study in which the characteristics of people with a disease are compared with those of people without the disease.

CHROMOSOME ABNORMALITY ANALYSIS
An analytical technique carried out to see whether damage has occurred on the chromosomes. This is done by staining the chromosomes when they become visible during cell division and looking to see whether the shape is normal.

COBALT-60 (^{60}Co)
A radionuclide which has a half-life of 5.29 years and which decays with the emission of beta particles and gamma rays. It is produced in nuclear reactors and used as a source of gamma rays (as for radiotherapy).

CONDUCTIVITY METER
An instrument for measuring electrical resistance.

DARCIAN
See Darcy's Law.

DARCY'S LAW
An equation derived by experiments of the flow of fluids through porous media such as sandstone. It applies at scales at which the various irregularities of flow can be averaged over a large number of voids and is based on the assumption that the velocity of flow is directly proportional to the hydraulic gradient. Thus it may be applied to local situations (eg flow to a well) only where the flow is granular and the rock is reasonably homogeneous. Where flow is mainly through fissures much larger areas must be covered for the relationship to be applicable. In such cases the approach is often described as an equivalent continuum concept.

DAUGHTER PRODUCT see DECAY PRODUCT

DECAY
The process of spontaneous transformation of a radionuclide. The decrease in the activity of a radioactive substance.

DECAY PRODUCT
A nuclide or radionuclide produced by decay. A decay product may be formed directly from a radionuclide or as a result of a series of successive decays through several radionuclides.

DEVONIAN
Fourth period of the Paleozoic era.

DISCHARGES see RADIOACTIVE DISCHARGES

EFFECTIVE DOSE
The effective dose is the sum of the weighted equivalent doses in all the tissues and organs of the body. It takes account of the relative biological effectiveness (RBE) of different types of radiation and variation in the susceptibility of organs and tissues to radiation damage. Unit sievert (Sv).

ELECTRON
An elementary particle that has a negative charge and orbits the nucleus.

EPIDEMIOLOGY
The study of the distribution and determinants of health-related states or events in specified populations and the application of this study to the control of health problems. In the past 50 years or so, the definition of epidemiology has broadened from concern about communicable disease epidemics to include all phenomena related to health in populations.

EQUIVALENT DOSE
The quantity obtained by multiplying the absorbed dose by a factor to allow for the different effectiveness of the various ionising radiations in causing harm to tissue. Unit sievert (Sv). Usually the factor for gamma rays, X rays and beta particles is 1 but for alpha particles is 20.

FAULTS
A break in the earth's crust caused by tectonic forces which have moved the rock on one side with respect to the other. Faults vary in length from a few centimetres to many kilometres and vary widely in the movement or displacement along the fault.

FIRST-ORDER APPROXIMATION
An approximation using the largest term of an equation.

FISPIN CODE
A computer code for nuclide inventory calculations. It calculates the production and removal of three groups of nuclides: the fission product group, the actinide group, and the structural material group.

FISSION
The spontaneous or induced disintegration of a heavy atomic nucleus into two or more lighter fragments (nuclei). The energy released in the process is referred to as nuclear energy.

FREE RADICAL
A grouping of atoms that normally exists in combination with other atoms, but can sometimes exist independently. Generally very reactive in a chemical sense.

GAMMA RAYS
High energy photons, without mass or charge, emitted from the nucleus of a radionuclide following radioactive decay, as an electromagnetic wave. They are very penetrating but have a low linear energy transfer (LET).

GRAY (Gy)
The international (SI) unit of absorbed dose. 1 Gy is equivalent to 1 joule of energy absorbed per kilogramme of matter, such as body tissue.

HALF-LIFE ($t_{1/2}$)
The time taken for the activity of a radionuclide to lose half its value by decay. During each subsequent half-life its activity is halved again so its activity decays exponentially.

HELIUM (He)
A gaseous element found in the atmospheres of the sun and earth and in some rare minerals. A noble (or rare) gas.

HYDROGEOLOGY
The part of geology concerned with the functions of water in modifying the earth, especially by erosion and deposition; geology of ground-water, with particular emphasis on chemistry and movement of water.

HYPOTHESIS
A suggested explanation for a group of facts or phenomena.

INCIDENCE
The number of instances of illness commencing or of persons falling ill during a given period in a specified population. The term incidence is sometimes used to denote "incidence rate".

ION
Electrically charged atom or grouping of atoms.

IONISATION
The process by which a neutral atom or molecular acquires or loses an electron. The production of ions.

IONISING RADIATION
Radiation which is sufficiently energetic to remove electrons from atoms in its path. In human or animal exposures, ionising radiation can result in the formation of highly reactive particles in the body (known as free radicals) which can cause damage to individual components of living cells and tissues. The term includes radiation at least as energetic as X rays; gamma rays and charged particles such as alpha and beta particles are also forms of ionising radiation.

ISOTOPE
Nuclides containing the same number of protons (ie same atomic number) but different number of neutrons.

JOINT
A plane of fracture, or divisional plane, of a rock transverse to the stratification.

LEUKAEMIA
A group of malignant diseases of the blood-forming tissues characterised by abnormal white blood cells which divide in a manner outside the control of the body. Most leukaemias start in the red bone marrow but some start in the lymphatic system. In all instances the bone marrow ends up being the main site of the disease. The principal groups are the chronic leukaemias (very rare in the 0–24 years age group) and the acute leukaemias, of which acute lymphoblastic leukaemia (ALL, also known as acute lymphatic leukaemia) currently accounts for 75–80% of all cases of childhood leukaemia in the UK. Both ALL and non-Hodgkin's lymphoma (NHL, which is closely related to ALL) derive from lymphoid cells. Acute myeloblastic leukaemia (AML, also known as acute myeloid or acute non-lymphoblastic leukaemia, ANLL) derives from myeloid bone marrow cells.

LEUKAEMOGENESIS
The beginning of the development of leukaemia.

LINEAR ENERGY TRANSFER (LET)
A measure of the density of ionisation along the track of an ionising particle in biological tissue or other medium. Particles or rays of radiation are generally described as having a high or low LET, ie their tracks leave high or low density deposits of energy in the tissue they pass through. High LET radiation is more damaging to body tissue than low LET radiation.

LYMPHOCYTE
A type of white blood cell that is part of the body's immune system.

MALIGNANCY
Cancerous growth, a mass of cells showing uncontrolled growth, a tendency to invade and damage surrounding tissues and an ability to seed daughter growths to sites remote from the primary growth.

METALLIC SWARF
Material removed by a cutting or grinding tool.

MONTE CARLO
Random sampling techniques and often the use of computer simulation to obtain approximate solutions to mathematical or physical problems, especially in terms of a range of values each of which has a calculated probability of being the solution.

NEUTRON
The uncharged particle in an atomic nucleus; its mass is similar to the mass of a hydrogen atom.

NHL see NON-HODGKIN'S LYMPHOMA

NIOBIUM (Nb)
A light grey metallic element used in alloys. The stable isotope is ^{93}Nb and the main radioactive isotope is ^{95}Nb, which decays with the emission of beta particles and gamma rays and has a half-life of 35 days.

NON-HODGKIN'S LYMPHOMA (NHL)
A heterogeneous but histologically recognisable group of cancers whose primary cell of origin is in lymphoid tissue and which tends to form solid tumours. A leukaemic form of the disease is seen in some cases. It is closely related to acute lymphoblastic leukaemia (ALL), both being part of a spectrum of disease, rather than truly separate entities, in most cases.

NUCLEAR REACTOR
A structure in which neutron-induced nuclear fission can be sustained and controlled in a self-supporting chain reaction. In power reactors, the heat produced by fission is absorbed by coolant, producing steam which in turn powers a turbine for generating electricity. Some reactors can be put to other uses, eg materials testing, plutonium production. In a thermal reactor the fission is brought about by slow or thermal neutrons which are produced by slowing fast neutrons by the use of a moderator such as carbon or water. In a fast reactor most of the fission is produced by fast neutrons and therefore requires no moderator. Most thermal reactors use uranium as fuel, in which the uranium-235 content has been artificially raised (this fuel is known as enriched uranium). Fast reactors use a mixture of plutonium and uranium dioxide.

NUCLEAR REPROCESSING
The processing of spent fuel from a nuclear reactor, to remove fission products and to recover fissile and fertile material for further use. Chemical solvents play a major role in this process.

NUCLEAR SITE OR ESTABLISHMENT
A facility which includes a nuclear reactor and/or capability for handling radionuclides associated with the nuclear fuel cycle.

PARTICULATE
Of or relating to minute discrete particles.

PROTON
The positively charged particle in an atomic nucleus; its mass is similar to the mass of a hydrogen atom.

PLUTONIUM (Pu)
An element which exists in several different isotopic forms. The five main isotopes are:

^{238}Pu: alpha emitter, half-life c.86 years
^{239}Pu: alpha emitter, half-life c.24,000 years
^{240}Pu: alpha emitter, half-life c.6,600 years
^{241}Pu: beta emitter, half-life c.13 years which decays to americium-241, which is an alpha emitter with a half-life of c.460 years
^{242}Pu: alpha emitter, half-life c.379,000 years

RADIOACTIVE PARTICLES
An isotope of an element that has an unstable nucleus. It tries to stabilise itself by giving off ionising radiation.

RADIOACTIVE DISCHARGES
Some establishments produce radioactive waste as byproducts and this is disposed of, usually to the environment, as radioactive discharge.

RADIOACTIVE CONTAMINATION
When radioactive substances have mixed with a non-radioactive substance, or where radioactive materials have spread to areas so that people may be harmed or equipment made unsafe.

RADIOACTIVITY
The property of radionuclides of spontaneously emitting ionising radiation. Measured in becquerels (Bq).

RADIONUCLIDE
A type of atomic nucleus which is unstable and which may undergo spontaneous decay to another atom by emission of ionising radiation (usually alpha, beta or gamma radiation).

RED BONE MARROW
The cellular material found in bones in the axial skeleton (ie bones excluding the arms and legs) and is the organ responsible for producing cells in the blood. (In infants, because the demand for blood is so great, all bones are used for blood production.) On average, red bone marrow produces 5 million cells every second, or 400 billion every 24 hours.

REGISTRATION see CANCER REGISTRATION

RELATIVE BIOLOGICAL EFFECTIVENESS (RBE)
The relative biological effectiveness of one radiation compared with another is the inverse ratio of the absorbed doses producing the same degree of a defined biological effect.

REPROCESSING see NUCLEAR REPROCESSING

RISK
The probability that an event will occur, eg that an individual will become ill or die within a stated period of time or age group.

SIEVERT (Sv)
The international (SI) unit of effective dose, obtained by weighting the equivalent dose in each tissue in the body with the tissue weighting factors recommended by the International Commission on Radiological Protection, and summing over all tissues. Because the sievert is a large unit, effective dose is commonly expressed in millisieverts (mSv), ie one-thousandth of one sievert, and microsieverts (μSv), ie one-thousandth of one millisievert. The average annual radiation dose to the UK population is 2.6 mSv.

STOCHASTIC
Something that is random.

STRONTIUM-90 (^{90}Sr)
A radionuclide with a half-life of 28 years, which decays with the emission of beta particles only. It is present in fallout from nuclear explosions and is hazardous because it can be assimilated in biological processes and deposited in the bones of human beings and animals.

TUMOUR
Mass of tissue formed by a new growth of cells, normally independent of the surrounding structures. Can be either benign or malignant.

URANIUM (U)
A hard grey metal which exists in seven isotopic forms (uranium-233 to uranium-239) of which the two most important are uranium-235 (the only naturally-occurring readily fissile isotope) and uranium-238. Both isotopes decay through a series of daughter products which emit alpha, beta and gamma radiation. Principal source of fuel for nuclear reactors.

APPENDIX B

COMMITTEE ON MEDICAL ASPECTS OF RADIATION IN THE ENVIRONMENT

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THE COMARE DOUNREAY WORKING GROUP

Chairman Dr T E Wheldon (COMARE) until March 1998

Professor Neva Haites (COMARE) since April 1998

Members Professor K Boddy (COMARE)

Professor K M Clayton (COMARE)

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Department of Health

Department of Health and Social Services (Northern Ireland)

Department of Trade and Industry

Health and Safety Executive

Scottish Environment Protection Agency

Environment Agency

Information and Statistics Division, Common Services Agency, NHS in Scotland

Medical Research Council

Ministry of Agriculture, Fisheries and Food

Ministry of Defence

National Radiological Protection Board

Office of National Statistics

Scottish Office

Welsh Office

APPENDIX C

DECLARATION OF MEMBERS' INTERESTS CODE OF PRACTICE

Introduction

1 This code of practice guides members of COMARE as to the circumstances in which they should declare an interest in the course of the Committee's work.

2 To avoid any public concern that commercial interests of members might affect their advice to Government, Ministers have decided that information on significant and relevant interests of members of its advisory committees should be on the public record. The advice of the Committee frequently relates to matters which are connected with the nuclear industry generally and, less frequently, to commercial interests involving radioactivity and it is therefore desirable that members should comply with the code of practice which is set out below.

Scope and definitions

3 This code applies to members of COMARE and sub-groups or working groups of COMARE which may be formed.

4 For the purposes of this code of practice, the "radiation industry" means:

(a) companies, partnerships or individuals who are involved with the manufacture, sale or supply of products processes or services which are the subject of the Committee's business. This will include nuclear power generation, the nuclear fuel reprocessing industry and associated isotope producing industries, both military and civil;

(b) trade associations representing companies involved with such products;

(c) companies, partnerships or individuals who are directly concerned with research or development in related areas;

(d) interest groups or environmental organisations with a known interest in radiation matters.

It is recognised that an interest in a particular company or group may, because of the course of the Committee's work, become relevant when the member had no prior expectation this would be the case. In such cases, the member should declare that interest to the Chairman of the meeting and thereafter to the Secretariat.

5 In this code, "the Department" means the Department of Health, and "the Secretariat" means the secretariat of COMARE.

Different types of interest – definitions

6 The following is intended as a guide to the kinds of interests which should be declared. Where a member is uncertain as to whether an interest should be declared he or she should seek guidance from the Secretariat or, where it may concern a particular subject which is to be considered at a meeting, from the

Chairman at that meeting. Neither members nor the Department are under an obligation to search out links between one company and another, for example where a company with which a member is connected has a relevant interest of which the member is not aware and could not reasonably be expected to be aware.

If members have interests not specified in these notes but which they believe could be regarded as influencing their advice they should declare them to the Secretariat in writing and to the Chairman at the time the issue arises at a meeting.

Personal interests

6.1 A personal interest involves payment to the member personally. The main examples are:

(a) Consultancies or employment: any consultancy, directorship, position in or work for the radiation industries which attracts regular or occasional payments in cash or kind.

(b) Fee-paid work: any work commissioned by those industries for which the member is paid in cash or kind.

(c) Shareholdings: any shareholding in or other beneficial interest in shares of those industries. This does not include shareholdings through unit trusts or similar arrangements where the member has no influence on financial management.

Non-personal interests

6.2 A non-personal interest involves payment which benefits a department for which a member is responsible, but is not received by the member personally. The main examples are:

(a) Fellowships: the holding of a fellowship endowed by the radiation industry.

(b) Support by industry: any payment, other support or sponsorship by the radiation industry which does not convey any pecuniary or material benefit to a member personally but which does benefit their position or department, eg

(i) a grant from a company for the running of a unit or department for which a member is responsible;

(ii) a grant or fellowship or other payment to sponsor a post or a member of staff in the unit for which a member is responsible. This does not include financial assistance for students, but does include work carried out by postgraduate students and non-scientific staff, including administrative and general support staff;

(iii) the commissioning of research or work by, or advice from, staff who work in a unit for which the member is responsible.

(c) Support by charities and charitable consortia: any payment, other support or sponsorship from these sources towards which the radiation industry has made a **specific and readily identifiable** contribution. This does not include unqualified support from the radiation industry towards the generality of the charitable resource.

Trusteeships: where a member is trustee of a fund with investments in the radiation industry, the member may wish to consult the Secretariat about the form of declaration which would be appropriate.

Members are under no obligation to seek out knowledge of work done for or on behalf of the radiation industry within departments for which they are responsible if they would not reasonably expect to be informed.

Declaration of interests

Declaration of interests to the Department

7 Members should inform the Department in writing when they are appointed of their current personal and non-personal interests and annually in response to a Secretariat request. Only the name of the company (or other body) and the nature of the interest is required; the amount of any salary, fees, shareholding, grant, etc, need not be disclosed to the Department. An interest is current if the member has a continuing financial involvement with the industry, eg if he or she holds shares in a radiation company, has a consultancy contract, or if the member or the department for which he or she is responsible is in the process of carrying out work for the radiation industry. Members are asked to inform the Department at the time of any change in their personal interests, and will be invited to complete a form of declaration once a year. It would be sufficient if changes in non-personal interests are reported at the next annual declaration following the change. (Non-personal interests involving less than £1000 from a particular company in the previous year need not be declared to the Department.)

Declaration of interests at meetings and participation by members

8 Members are required to declare relevant interests at Committee meetings and to state whether they are personal or non-personal interests. The declaration should include an indication of the nature of the interest.

(a) If a member has a current (personal or non-personal) interest in the business under discussion, he or she will not automatically be debarred from contributing to the discussion subject to the Chairman's discretion. The Chairman will consider the nature of the business under discussion and of the interest declared (including whether it is personal or non-personal) in deciding whether it would be appropriate for the relevant member to participate in the item.

(b) If a member has an interest which is not current in the business under discussion, this need not be declared unless not to do so might be seen as concealing a relevant interest. The intention should always be that the Chairman and other members of the Committee are fully aware of relevant circumstances.

9 A member who is in any doubt as to whether he or she has an interest which should be declared, or whether to take part in the proceedings, should ask the Chairman for guidance. The Chairman has the power to determine whether or not a member with an interest shall take part in the proceedings.

10 If a member is aware that a matter under consideration is or may become a competitor of a product process or service in which the member has a current personal interest, he or she should declare the interest in the company marketing the rival product. The member should seek the Chairman's guidance on whether to take part in the proceedings.

11 If the Chairman should declare a current interest of any kind, he or she should stand down from the chair for that item and the meeting should be conducted by the Deputy Chairman or other nominee if he or she is not there.

12 Some members of the Committee may, at the time of adoption of this note, or (in the case of new members) of their joining the Committee, be bound by the terms of a contract which requires them to keep the fact of the contractual arrangement confidential. As a transitional measure, any member so affected should seek to agree an entry for the public record (see paragraph 14) with the other party. If such agreement does not prove possible, the members shall seek a waiver permitting them to disclose their interest, in confidence, to the Chairman and the Secretariat. The Secretariat will maintain a confidential register of such disclosures which will not form part of the public record.

13 On adoption of this note members shall not enter into new contractual obligations which would inhibit their ability to declare a relevant interest.

Record of interests

14 A record will be kept in the Department of the names of members who have declared interests to the Department on appointment, as the interest first arises or through an annual declaration, and the nature of the interest.

15 Information from the record will be made available by the Secretariat to bona-fide enquirers and published by any other means as and where the Department deems appropriate.

Members' declarations of interests – 1998

Member	Company	Personal interest	Company	Non-personal interest
Prof B Bridges		None		None
Prof K Boddy		None		None
Prof R Cartwright		None		None
Prof K Cheng		None		None
Prof K Clayton		EPSC*		None
Prof S Cox		None	BNFL	MSc students and short course attendees
Prof S Darby		None		None
Dr G Draper		None		None
Prof O Eden		None		None
Prof N Haites		None		None
Prof J Little		None		None
Prof T McMillan		None	Westlakes Research Inst	PhD students and consumables
Dr M Spittle		None		None
Prof A M R Taylor		None		None
Prof J Thacker		None		None
Prof R Waters		None		None
Prof M Whitehouse		None		None
Prof E Wright		None		None

* Professor Clayton has declared his membership of Dounreay's Environmental Projects Steering Committee (EPSC) even though this does not impair his independence. Indeed, COMARE suggested his membership, so that his expertise was available to help expedite the investigations undertaken by the UKAEA to find the source of the Dounreay particles.

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