INFORMATION FOR MEMBERS

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Briefing Note

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CHERNOBYL FALL-OUT

7 years later, areas of the UK remain contaminated with radioactive fall-out from Chernobyl, to the extent that the movement and slaughter of almost 500,000 sheep on more than 600 farms are still subject to restrictions.

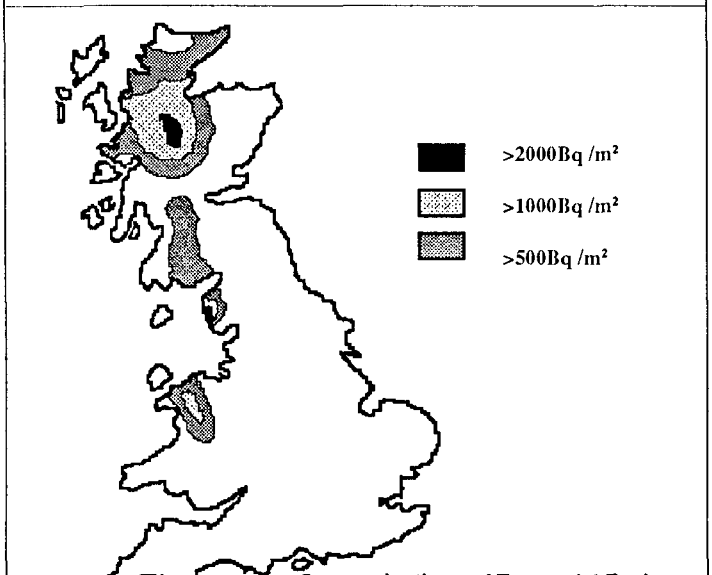
This note examines knowledge of the fate of Chernobyl radioactivity and its implications.

BACKGROUND

On 26 April 1986, an explosion in the Chernobyl nuclear power station blew the top from the reactor core, releasing highly radio-active material. While around 70% of the fall out was deposited in the Northern Ukraine and Byelorussia, the rest was dispersed further by the wind to be washed out by rainfall over parts of Eastern, Central and Northern Europe. The heaviest deposition in the UK was in the upland areas of Wales, Cumbria, Scotland (**Figure 1**) and Ireland.

The radioactivity comprised a complex mixture of radionuclides with different health effects (see **Box 1**). Advice from bodies such as the National Radiological Protection Board (NRPB) identified the main concern as contamination of food, particularly **milk**, which was the subject of monitoring by the Ministry of Agriculture, Fisheries and Food (MAFF). This showed that levels of radioactive iodine and caesium in milk peaked within a few days at less than 20% of the NRPB 'derived emergency reference level (Box 1) and no action was thus deemed necessary to restrict milk from affected areas.

Figure 1 EXTENT OF RADIOACTIVE DEPOSITION IN BRITAIN, 1986.



Source: Institute of Terrestrial Ecology

BOX 1 RADIATION RISKS AND THEIR CONTROL

The plume from Chernobyl included 36 different radioactive substances (**radionuclides**) when it reached the UK, the main components being:-

- **Iodine-131** (I-131; half life 8 days)
- **Caesium-137** (Cs-137; half life 30 years)
- **Caesium-134** (Cs-134; half life 2 years)

Guidance from the National Radiological Protection Board on the potential hazards takes into account a number of risk factors: e.g.-

- **Chemical properties of the element**
  (I-131 accumulates in the thyroid gland,
  Cs is distributed throughout soft body tissues).
- **Type and level of radiation involved**
  Levels of radioactivity are measured in Becquerels (Bq).
- **The amount of radiation (dose) received**
  (measured in Sieverts (Sv) or millisieverts (mSv).
- **The type of tissue involved.**

The Government response was based on NRPB guidance in the form of **emergency reference levels (ERLs)** and **derived ERLs (DERLs)** which provide a basis for deciding when to take certain countermeasures (e.g. evacuation, sheltering, taking iodine tablets, restrictions on contaminated foodstuffs). At the time of the accident, the DERLs for introducing restrictions on the distribution of milk contaminated with I-131 and Cs-137 were set at 2,000 Bq per litre and 3,600 Bq per litre respectively. Since there was no DERL for meat, the Government adopted an action level of 1,000 Bq/kg, based on advice issued by the Group of Experts set up under Article 31 of the Euratom Treaty.

NRPB have estimated that the average total UK dose from Chernobyl fallout was 0.05 mSv, although the dose to people living in areas of high deposition was higher (e.g., the average dose per person in Cumbria was 6 times the UK average). For reference, the average UK annual dose per person from all sources (natural, medical etc.) is~ 2.5 mSv. This translates into a 'background' of around 6,500 fatal cancers per year;- estimates of the number of UK cancers likely to arise from Chernobyl range from 100-400.

However, the MAFF monitoring programme also indicated that high levels of radioactive caesium (which decay at a much slower rate than iodine) were building up in **meat** from sheep in some areas. In June 1986, the Government used its emergency powers under the Food and Environment Protection Act (1985) to restrict the movement and slaughter of lambs exceeding 1,000 Bq/kg (see Box 1) from affected areas of Britain, and later (September 1987) in Northern Ireland when areas exceeding the limit were identified.

The original Emergency Prohibitions placed a complete ban on the movement of well over 4 million sheep. Most restrictions were lifted within a few months, but there remain upland areas where levels of radioactive caesium have not declined as expected. As a result,

Table 1 NUMBERS OF ANIMALS AND HOLDINGS SUBJECT TO RESTRICTIONS

Area	Original Restrictions		1993 Restrictions	
	Holdings	Sheep	Holdings	Sheep
England	1,670	870,000	126	110,500
Wales	5,100	2,100,000	353	248,000
Scotland	2,144	1,360,000	54	106,000
N Ireland	123	35,000	98	17,750
Total	9,037	4,365,000	631	482,250

some 630 holdings with around 480,000 sheep are still covered by restrictions (see **Table 1**). Since late 1986, restricted areas have been covered by a 'mark and release' scheme in order to minimise disruption to normal farming practice[1].

REASONS FOR CONTINUED CONTROLS

Previous knowledge of the behaviour of deposited radionuclides (based on lowland farming systems) suggested that caesium would bind to clays and not be taken up extensively into plants and animals. Thus the prediction was that levels of radioactivity would fall rapidly, with most being immobilised within the soil in a matter of weeks. While this turned out to be correct for lowland areas, high levels of radioactive caesium persisted in plants (and thus animals) in certain upland areas with peaty soils. This prompted MAFF and the Department of the Environment (DoE) to commission research into why caesium behaves differently in these areas. The results of this research (**Box 2**) show that the highly acid, low mineral, low clay and highly organic upland soils fail to immobilise caesium, and it remains available for uptake into plants and animals.

CURRENT ISSUES

Factors Affecting Future Restrictions

Figure 2 shows the fall in radioactivity that has occurred since 1987 in sheep from selected holdings in Cumbria. The rate of decline is too great to be due solely to the decay of caesium isotopes, indicating that some of the caesium is indeed being bound in the soil; however, the decline now appears to be tailing off. Earlier experience with caesium fallout from nuclear weapons testing in the 1950s and '60s suggests that upland soils may take as long as 30 years to immobilise most of the caesium. Holdings with animals failing the current action level of 1,000 Bq/kg may thus be restricted for some time. MAFF are working on computer models to improve understanding of caesium's behaviour.

Caesium levels vary **locally** (even between different parts of the same field) as a result of initial deposition patterns and the different types of vegetation. There may also be **regional** differences; for instance it appears that caesium will persist in vegetation longer in North Wales than in Cumbria. Work is still underway to define the key factors involved (Box 2). Improved drainage can decrease caesium transfer to plants by up to 24%. But the most reliable method remains simply moving sheep to graze on lowland pasture (i.e. with low caesium levels), which can halve radioactive caesium levels in meat within 3-4 weeks. If other husbandry practices prove to be important, further advice on ways of minimising effects could follow.

Treatment possibilities. Various substances have been tested as **soil** treatments. Some bind to caesium (e.g. clays such as bentonite or 'chelating' agents such as Prussian blue); others (e.g. potassium salts) compete with caesium for uptake by plant roots. Trials commis-

BOX 2 CHERNOBYL-RELATED RESEARCH

Since Chernobyl, MAFF have commissioned around 50 research projects in 4 main areas:-

- **Assessing the extent of radioactive deposition.**
- **Understanding the behaviour of fallout in ecosystems.**
- **Developing ways of ameliorating the effects of fallout.**
- **Improved methods for dealing with future accidents.**

Between 1986-1990, support was ~£0.9M pa; in 1991-1992, this halved to ~£0.45M pa. Total spending has thus been ~£5.4M since 1986. The results of this work has helped *inter alia* in understanding the fate of radioactive caesium.

Behaviour of Caesium in Upland Areas

Following deposition, some types of soil can immobilise radioactive caesium. In this event, the effects on agriculture are minor. If however, caesium remains unbound it is readily taken up by plants and thence into animals. Caesium can then become continuously recycled; i.e. excreted by animals, re-incorporated into plants, re-ingested by animals and so on. The following **soil factors** all tend to **increase** caesium uptake into plants (and thus animals).

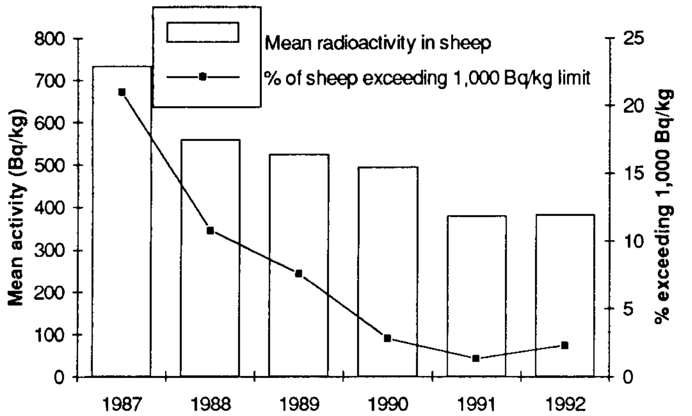
- **Low clay content** - low capacity to bind caesium.
- **High acidity** - caesium is more mobile in acid conditions.
- **Low mineral (especially potassium) content** - minerals such as potassium compete with caesium for plant uptake.
- **High organic content** - this retains 'free' caesium near the surface (where it is taken up by roots).
- **Waterlogging** - increases the 'pool' of mobile caesium.

Rates of caesium uptake also depend upon both **vegetation** and **animal factors** such as;

- **type of plants** - e.g. upland species such as heather are more efficient at accumulating caesium than lowland grasses.
- **fungi** - certain fungi take up caesium from soil and may thus increase caesium uptake into plants via root contact.
- **rate of growth** - high rates of growth (e.g. in spring and summer, or after grazing) increase caesium uptake.
- **individual differences** - sheep exhibit marked differences in grazing behaviour, whether between the site grazed or the type of vegetation preferred.
- **husbandry practices** - removing animals from upland to lowland areas halves their caesium levels within weeks.

1. Marked (i.e. painted) sheep can be moved from the affected area (e.g. for lowland grazing), but not slaughtered until radioactivity levels fall below 1,000 Bq/kg.

Figure 2 RADIOACTIVITY LEVELS IN SHEEP FROM RESTRICTED HOLDINGS IN CUMBERLAND 1987-1992 (Source: MAFF)



N.B. Data are from sheep from selected holdings which may vary from survey to survey within the restricted area.

sioned by MAFF suggest the potential is limited by:-

- Application of the substances concerned to large areas of upland terrain is difficult and costly.
- Treatments could have unwanted side-effects (e.g. potassium is a fertilizer; Prussian blue colours the grass).
- Adding some substances (e.g. bentonite) reduces feed palatability and hence weight gain.

These disadvantages mean that soil treatments are likely to be limited to smaller, more contaminated areas.

An alternative approach is to administer substances to **animals** to limit the uptake of caesium across the gut lining. Of the substances tested, Prussian blue has shown the most promise, either administered as boli (which dissolve slowly in the gut and can reduce caesium levels by up to 60% over a period of 7 weeks) or as blocks which are licked by sheep. In general, the disadvantages for soil treatments do not apply to animal treatments. Field trials are still underway in the affected areas, although MAFF emphasises that much work remains to be done before any method can go into more widespread use.

Action levels. Current restrictions are based on the 1,000 Bq/kg level (caesium-137) suggested by the Article 31 group (see Box 1) and adopted by the Government in 1986. At the time, some experts considered this to be unduly cautious, and proposed a limit of 5,000 Bq/kg. However, since 1986, the NRPB has increased its estimates of radiation risks by a factor of three, and the 1,000 Bq/kg limit is now generally considered to be prudent, as well as being close to the EC limit of 1,250 Bq/kg (total radio-isotopes) introduced in 1987 (which would apply in any future emergency). Hence there is little prospect of the scope of current restrictions being affected by a revision in the action level. Indeed, restricting meat with radioactive caesium levels exceeding 1,000 Bq/kg is generally acknowledged to have been an effective means of reducing the dose to the population, despite the cost to date of around £5.5M in compensation.

Lessons for the future

In 1988, the House of Commons Agriculture Committee examined the Government's response and drew attention to areas where, with the benefit of hindsight, the response could be improved.

Co-ordination. Since Chernobyl, the Government has drawn up a **National Response Plan** for any future release of radioactivity overseas. DoE would co-ordinate all monitoring activities, and act as a central point for collating, assessing and disseminating information to Parliament, Departments, other bodies and the public. The responsibilities of all the other bodies involved have also been clarified; for example the Health Departments are responsible for treatment of those returning from affected areas overseas; DoE, MAFF and the Scottish, Welsh and Northern Ireland Offices for monitoring contamination of food and water; and DTI, Health Departments and MAFF for monitoring import/export of contaminated goods.

Radiation monitoring. The National Response Plan also established a network of ground-based monitors to detect radioactivity arriving in the UK. Phase 1 of **RIMNET** - Radioactive Incident Monitoring Network - is operational and consists of some 46 detectors for gamma radiation read manually every hour at Meteorological Office (MO) sites throughout the UK. Phase 2, expected to be operational by the end of 1993, will replace existing detectors and establish new sites. 92 detectors will then operate continuously, automatically transfer data to the DoE's central database facility (CDF), and trigger alarms if threshold limits are exceeded. The CDF will also be able to accept data from other (DoE approved) monitoring sources such as the nuclear industry, local authorities, hospitals and universities, as well as other data (e.g. of radioactivity levels in vegetation and animal products).

Local authorities bore the brunt of public enquiries during the Chernobyl episode and many set up their own radiation monitoring facilities, co-ordinated through the Local Authorities Radiation & Radioactive Monitoring Advice & Collation Centre). **LARRMACC** has 349 members throughout the UK and operates a quality assurance scheme to ensure that monitoring data are collected, analysed and interpreted to consistent standards. In addition, there is a third source of environmental information via the **Argus** network - this consists of 24 networked UK (plus a number of international) stations which measure, *inter alia* gamma radiation, and are operated by universities, local authorities, environmental and other groups.

These developments will improve UK early warning capability and the mapping of any radioactive plume, while the CDF should help improve coordination. Nevertheless, some environmental groups see the system as having limitations. Firstly, while the CDF will accept data from a number of sources (including RIMNET and LARRMACC), DoE have yet to decide whether to include data from Argus. Secondly, concerns have been expressed over the dissemination of information held in the CDF. Current plans are that RIMNET data will be analysed by DoE and published as digests or summaries. Environmental and other groups suggest that important details can sometimes be overlooked in the process of preparing summaries, regional averages, etc. and believe that they should be allowed direct (electronic) access to the raw data so that they can carry out their own analyses. However the CDF was not designed to allow direct access by non-governmental organisations, although data can be made available in printed form. DoE are planning to review ways of increasing accessibility once the system is operating later in 1993.

Fallout predictions can also be made from radiation monitoring data (e.g. from RIMNET) combined with meteorological (e.g. wind, rainfall) data. Since Chernobyl, the MO has developed the NAME (Nuclear Accident Model) computer model which uses a wide range of weather information (e.g. weather radar, surface and satellite observations, and computer predictions) to model the progress and likely deposition from a radioactive plume. NAME can also modify its predictions in the light of observed deposition patterns.

Preventive measures to protect the public. Since 1986, the NRPB's guidance on levels of radioactivity in food has been superseded[2] by statutory EC 'maximum admissible levels', which lay down the levels of food contamination requiring action in any future emergency. The EC limit of 1,250 Bq/kg for all radionuclides in meat is similar to the current UK limit of 1,000 Bq/kg for radioactive caesium, and thus has few implications for current practice. However, the current EC limit of 500 Bq/l for radio-iodine in milk is substantially lower than the 1986 NRPB DERL of 2,000 Bq/l for iodine-131 (Box 1). Had this limit been in force in 1986, it is quite likely that milk restrictions would have been triggered.

Preventing future emissions. While improvements to monitoring and contingency planning have incorporated experience after Chernobyl, no widely applicable methods have yet been developed to ameliorate the effects of radioactive fallout. The primacy of avoiding further releases is thus clear. Since Chernobyl it has become increasingly apparent that many of the 60 or so nuclear reactors of Soviet design still operating in Eastern and Central Europe do not conform to Western standards; an assessment by the International Atomic Energy Agency, focused attention on the 15 Chernobyl-type RBMK reactors and 10 first generation VVER 440/230 reactors. The main safety concerns relate to inadequate containment and emergency core cooling systems, although there are also doubts about standards of construction and operating methods (which may lead to premature ageing of the reactor).

Because of these concerns, there have been a number of recent initiatives to improve the safety of Soviet-designed reactors. The G7 group of countries have set up a 'Nuclear Safety Account', managed by the European Bank for Reconstruction and Development - this contains around 125 MECU (mostly from European sources, including £8.5M from the UK). The priorities of the fund are immediate operational safety and 'near-term technical improvements'. The fund has recently (June '93) announced its first award for carrying out safety improvements on VVER 440/230 reactors at the Kozloduy site in Bulgaria. G7 countries are also negotiating bilateral projects with nuclear operators in Central and Eastern Europe (e.g. the UK is providing £150,000 worth of emergency communication equipment to the Kozloduy site). Bilateral assistance is being co-ordinated by the European Commission (at the request of the 24 countries of the OECD), to ensure that the most appropriate action is taken for each site and that duplication of effort is avoided.

As part of their longer term strategy, the G7 countries commissioned the World Bank and International Energy Agency to examine the costs of three options - a 'high nuclear' scenario where existing nuclear plants are upgraded to allow them to continue operating to the end of their envisaged life, a 'moderate nuclear' scenario involving retirement of RBMK and VVER 440/230 reactors by the year 2000, and a 'low nuclear' scenario where the latter plants would be shut down by 1994/5. The reduced generating capacity from early shutdown would have to be compensated for by improved energy efficiency and a switch to fossil fuels. This report and the options contained within it will be discussed at the Tokyo G7 summit.

Environmental groups (e.g. Greenpeace) believe the Soviet designed reactors are fundamentally flawed and that no amount of money can bring them up to Western safety standards. They place the highest priority on improving energy efficiency (electricity use per unit of output is 3-5 times the average in OECD countries) and in developing alternative sources of power, so that the nuclear reactors can be shutdown as soon as possible. Nuclear operators in the West however, suggest that considerable improvements in safety can be achieved by retrofitting modern safety systems (either through multilateral or bilateral assistance) and improving regulatory regimes, and argue that such measures will provide the required 'breathing space' for the most cost-effective alternative approaches to be developed.

2. The EC Directive applies only to the sale and distribution of food contaminated with radioactivity. NRPB emergency reference levels will still be used to guide Government decisions on the necessity for various counter-measures outside this specific area.