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Radioactivity studies in Lowestoft: the first fifty years

G. J. Hunt

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RADIOACTIVITY STUDIES IN LOWESTOFT: THE FIRST 50 YEARS

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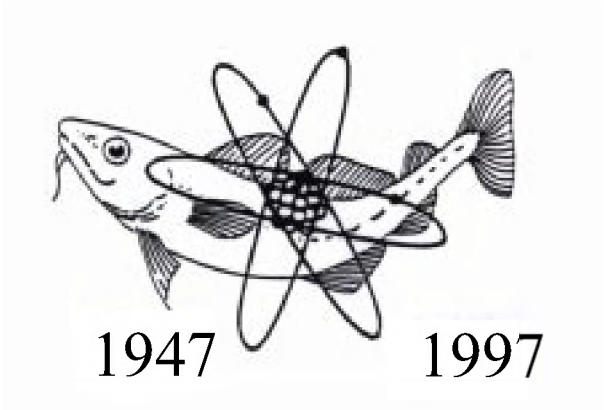

LOWESTOFT
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1. INTRODUCTION

A brief history is presented of the radioactivity studies by scientists of the Ministry of Agriculture, Fisheries and Food (MAFF) at Lowestoft. 1997 marks the golden jubilee of the start of this work, which was set up to investigate the potential effects of radioactive waste discharges to the Irish Sea from Sellafield.

The events are described in the context of the developing UK nuclear industry, and in particular the discharges from Sellafield and their behaviour in the Irish Sea and further afield. International activities have stemmed from the Sellafield studies as well as those in connection with sea disposal of solid radioactive wastes. Much of the work has been driven by the need to provide advice to Ministers in a developing statutory climate; scientists were involved in all aspects: regulatory control and advice; environmental monitoring and radiological assessment; and pioneering radioecological R&D.

2. THE EARLY SELLAFIELD-RELATED STUDIES, 1947 TO 1952

The beginnings of radiobiological work in Lowestoft date from the early days of the British post-war atomic programme. The Atomic Energy Research Establishment had been set up at Harwell in 1946 by the Ministry of Supply (MOS) to cover the development of all uses of atomic energy under the directorship of Dr John Cockcroft (Gowing, 1974). In the same year, Risley was established as the headquarters for furthering the production of fissile material. In 1947, work began at Sellafield which had been selected as the site for production reactors; it was renamed "Windscale" to avoid confusion with the uranium factory at Springfields. The site at Drigg had also been a late possibility. Such were the post-war pressures that weapons development was the driving force. Perhaps ironically, when the formal decision was taken by Ministers to proceed with nuclear weapons in January 1947 (although the decision was only announced to Parliament and the public in May 1948), it was one of the coldest winters on record, with severe fuel shortages. The prospect of a new abundant source of energy was clearly in the background, but at that time was of somewhat lower priority.

The MOS considerations of the Cumberland factory included the potential need to discharge liquid wastes, and Fisheries Division of the Ministry of Agriculture and Fisheries (which joined with the Ministry of Food in 1956 to become MAFF) was drawn in because of potential effects of the waste on fish and on people eating them. One of the initial MAF contacts was F. T. K. Pentelow, who later became Chief Inspector of Salmon and Freshwater Fisheries. His opening minute on the file [MAF, 1947], dated 1 May 1947, begins:

> *"This morning I went to see Dr Cockcroft, Director of Atomic Energy Research, Ministry of Supply and Mr A. T Fisher of the Atomic Energy Research Station at Harwell. Dr Cockcroft told me that it is expected that in about three years time an effluent containing radioactive substances will be discharged into the sea from the MOS factory at Drigg, Cumberland ....."*

> *"The questions put to us are how will this affect fisheries and what is the limit of tolerance of radioactivity on fish? I could of course answer only that I did not know and that we should have to find out ....."*

The matter was clearly extremely urgent. Within two weeks, after discussions in MAF, including with Michael Graham, Director of Fisheries Research, it had been agreed that a new project under MAF control should be set up and new scientific staff recruited. The question of whether the cost should be recovered from MOS arose (times have not changed that much) but it appears that H.M. Treasury later approved the posts for MAF. The project was to be steered by a small technical committee of experts from the Departments involved.

There then appears to have been a delay of several months; MOS were clearly firming up their wider proposals, including a final choice of site in Cumberland. On 17 July 1947 a meeting was held at senior level in Shell-Mex House, London (the base of MOS) to bring together the parties interested in the effluent disposal problem. Present, *inter alia*, were Dr John Cockcroft; Sir Ernest Rock Carling of the Ministry of Health, later chairman of the International Commission on Radiological Protection (ICRP); and Dr John Loutit of the Medical Research Council (MRC) and soon to be Director of the MRC Radiobiology Unit at Harwell. The small technical committee was endorsed; Mr P. Dunn of MAF said that as interdepartmental arrangements were being made to deal with the effluent problem there was no need for his Minister to object in principle to the atomic energy project in Cumberland. (Formal authorisation procedures were not introduced until the Atomic Energy Authority Act, 1954).

Developments then took place rapidly. The technical committee met on 1 August 1947. Michael Graham, who clearly took the new responsibilities very seriously, attended personally. Fisheries Department agreed to provide one Scientific Officer, one Experimental Officer and two Scientific Assistants together with necessary equipment; the location of the work was still undecided but was proposed as one of the MOS sites. The option of a site at Lowestoft seems to have been considered later, but it was clearly preferred by Michael Graham, and agreed in mid-August 1947. The existing Laboratory site on the Esplanade was impracticable and an alternative was sought.

On 20 August 1947 a small party met on a site on Hamilton Dock, Lowestoft. The party included Michael Graham, F. T. K. Pentelow and Captain Sutton, with representatives from MOS and the Ministry of Works. We read:

> "*It was found practicable to use a four roomed building at the north end of the west side of the dock, provided some restoration could be made of the partial demolition that had been carried out .....*"

Such was the urgency that the contractor agreed to start work the next day, and a target of 15 September 1947 for commencement of experiments was agreed. Meanwhile Michael Graham had been recruiting staff to do the work. Fred Morgan, a wartime colleague of Graham, was recruited to be in charge at the new Laboratory, assisted by Margaret Ryle, Mary Beavan, Tom Davis and Tony Downing. They arrived during September 1947; on 10 September Michael Graham held a project meeting and issued a list of staff responsibilities. The project got underway.

The Laboratory on Hamilton Dock became known as the 'Fisheries Experimental Laboratory', a title consistent with the need-to-know nature of the atomic work at that time. Figure 1 shows a photograph of the laboratory, which was extended several times during its existence, taken about 1980. The original building is the dark part at the far end. Figure 2 shows Wally Parnell, technician, in the laboratory not long after the start of work there. The initial intention was to study the effects of the proposed effluent on brown trout, and later marine fish, looking at radiosensitivity and the rate at which the fish became hazardous to eat. The radionuclide of immediate interest was ^{90}Sr, but when MOS could not supply tracer material (until May 1948, causing some amusement after the perceived urgency) the effects of irradiating fish directly using a framework containing radium needles was designed. This experiment started in February 1948, and showed that fish were much less sensitive than mammals; stronger irradiation, carried out at the Norfolk and Norwich Hospital in summer 1948 indicated an LD50 (30 d) of about 1200R (≈12 Gy). The tank studies proceeded and showed by 1949 that, broadly, there was a wide margin of safety between the likely concentration of effluent in the Irish Sea and that necessary to harm the fish. Data on human tolerance intakes were available from the Medical Research Council; particular unknowns about fish uptake which might also affect humans were the behaviour of other fission products than ^{90}Sr, and the effects of fish migration in the Irish Sea. Further tank studies were planned and, to study migration, large numbers of tagged fish were released off the Cumberland coast, using the *RV PLATESSA*. A base in Whitehaven was set up making use of rooms on one of the upper floors of the Tax Office in Lowther Street. The work to be done was seen as:

(i) how long will fish stay in the contaminated area?
(ii) how active will they become during this time?
(iii) how soon will they be caught after leaving the contaminated area?

Dye release experiments conducted off Sellafield ('operation seanuts') (Seligman *et al.*, 1948) had provided information on dilution and the extent of potential contamination. There was much collaboration with Sellafield, especially with John Dunster who was studying the effects of all of the potential pathways back to man and developing recommendations for MOS on safe levels of effluent release.

Figure 1. The Fisheries Radiobiological Laboratory (formerly Fisheries Experimental Laboratory), Hamilton Dock, Lowestoft, 1947-1982

Figure 2. Wally Parnell, technician, at work in the recently-opened Fisheries Experimental Laboratory

By 1951 the Windscale factory had become operational; pipelines had been laid and effluents were accumulating for disposal. In December 1951, estimates of the amounts of the principal radionuclides which could be safely released from the factory in respect of the fish pathway were submitted from Lowestoft to MOS. John Dunster amalgamated them with those of his and for other pathways in his now-declassified report (Dunster, 1952) on initial discharge limits, which embodied a succession of safety factors. After discussion with MAF and the Ministry of Housing and Local Government (MHLG), discharges from Windscale began in May 1952.

3. DURING DEVELOPMENT OF THE NEW NUCLEAR INDUSTRY, 1953 TO 1970

Commencement of the Windscale discharges were, it proved, only a new beginning for the Fisheries Experimental Laboratory. It was widely understood that much experience was needed to affirm the initial radiological estimates, and that on this basis the cautious discharges were recognised to be 'experimental'. Extensive monitoring programmes were put in hand, both by Windscale and Lowestoft. The fish tagging work continued and was analysed by Harry Hill, who had joined the Fisheries Laboratory staff in 1950, returning in 1952 after National Service. Alan Preston joined the Hamilton Dock staff in 1952. It became clear that an important pathway to man was the consumption of the edible seaweed *Porphyra* which strongly absorbed ^{106}Ru; the weed was harvested in Cumberland and transported to South Wales where it was made into laverbread and eaten. Extensive work was done on investigating and quantifying this pathway by Mary Hampson (née Beavan), Basil Hampson who had replaced Tony Downing, Doug Jefferies who joined in 1951, Alan Preston and others. This work eventually lasted for 20 years until transport difficulties made the use of Cumberland *porphyra* for laverbread uneconomic, and the pathway declined in importance. The developing knowledge of this and other pathways enabled modifications to be made to the Windscale discharge limits as the operations proceeded.

Even before the commencement of the Windscale discharges, the Hamilton Dock laboratory had begun to take on a control as well as research function, in support of MAF's interests in protection of fisheries and food. The control function gradually became more formalised. The UK Atomic Energy Authority (UKAEA) was formed from relevant parts of MOS in 1954, and under the Act of Parliament disposals of radioactive wastes from UKAEA premises became formally authorisable by MAF and MHLG. These two Ministries were empowered to appoint inspectors to ensure that the conditions of authorisation were fulfilled. Fred Morgan and Alan Preston became inspectors under the Act, to be followed later by others. The time of the more senior laboratory staff was increasingly taken up by statutory duties, the need to provide advice on authorisations and reports of monitoring and inspection activities (MAF, 1954). In 1956, in the knowledge that the Nuclear Industry would be developing, and further radioactive wastes would require to be disposed of, the Government set up a Panel to investigate the disposal of radioactive wastes under the umbrella of the Radioactive Substances Advisory Committee. This Committee had been set up under the Radioactive Substances Act, 1948, whose main purpose was to control the use of radioactive substances rather than disposal of radioactive wastes; disposals were subsequently covered, on an interim basis for the UKAEA sites, under the Atomic Energy

Authority Act, 1954. Fred Morgan was appointed to the new Panel, which consisted of a number of eminent figures of the day. The deliberations of the Panel led to the first Radioactive Waste White Paper, Cmnd 884, published in 1959 (United Kingdom - Parliament, 1959).

In October 1957 the whole of Britain was shocked by the news of the fire at Windscale no. 1 pile, and the need for a 6-week local milk ban which followed. Though the main effect was through agricultural pathways, the Lowestoft staff played a part in the overall monitoring effort, and the experience of basing laboratory work in Cumberland proved an asset. Continued use was made of the Tax Office premises in Whitehaven, but analytical facilities there were limited and a large number of samples accumulated at Lowestoft. Monitoring of the marine environment, including seaweed, showed that compared with the consequences of the gaseous releases, the effects of the cooling water discharged to sea were relatively small.

Within MAFF, the rapid developments in the Nuclear Industry as well as the Windscale Fire had indicated a need for a review of responsibilities. A MAFF office notice was issued in March 1958 announcing arrangements for co-ordination of Agricultural and Fisheries interests, and the setting up of an advisory Panel. The terms of reference of the new Panel on Disposal of Radioactive Wastes (PDRW) were:

> "*To advise the Minister of Agriculture, Fisheries and Food on matters arising out of his statutory responsibilities under the Atomic Energy Authority Act, 1954 for the granting of authorisations for the discharge of radioactive waste*".

The Panel was to be chaired by the Chief Scientific Advisor (Food) and attended from Lowestoft by Mr R. S. Wimpenny, for a short time Director of Fisheries Research, and Fred Morgan. The first meeting was attended by Morgan and Dr Cole, who became Director of Fisheries Research from 1958 to 1974. From the minutes we read that:

> "*The panel was very concerned about the prospect of an expanding commitment both on inspection and monitoring work with little apparent prospect of obtaining further staff Dr Stableforth [the Director of the MAFF Veterinary Laboratories] and Dr Cole both emphasised the danger of research being sacrificed to cover pressing routine work*".

This dual role with responsibilities both for radiological control and R&D, became one of the strengths of the work at Hamilton Dock but at the same time a difficult role to balance against the necessary research effort and the demands from London for dissemination of results. It was to the PDRW that the reports of statutory inspections and monitoring activities were made on a half-yearly basis from 1958 until 1984; the successor to PDRW, the Nuclear Inspectors Review Group (NIRG), also met on this basis until 1996, giving effectively a 38-year run.

Publication of Cmnd 884 in 1959 was an important milestone, bringing together the needs for control of radioactive wastes from the UKAEA, the new nuclear generating industry, and smaller users. The recommendations were to be given effect in a Radioactive Substances Bill, to cover *inter alia* the authorisation of radioactive waste disposal. The Bill became the Radioactive Substances Act, 1960 (RSA60) which came into effect on 1 December 1963. Radioactive waste disposals from UKAEA and Nuclear licensed sites in England and Wales were to be authorised by both MAFF and MHLG; authorisations for smaller users would require sole authorisation of MHLG. Inspectoral powers in support of these responsibilities were given to Ministry representatives. Prior to RSA60, a few authorisations were granted to non-UKAEA sites under the Nuclear Installations (Licensing and Insurance) Act, 1959. Interfaces developed between MAFF inspectors and opposite numbers in both MHLG (later the Radiochemical Inspectorate of the Department of the Environment (DoE)) and the Nuclear Installations Inspectorate (NII).

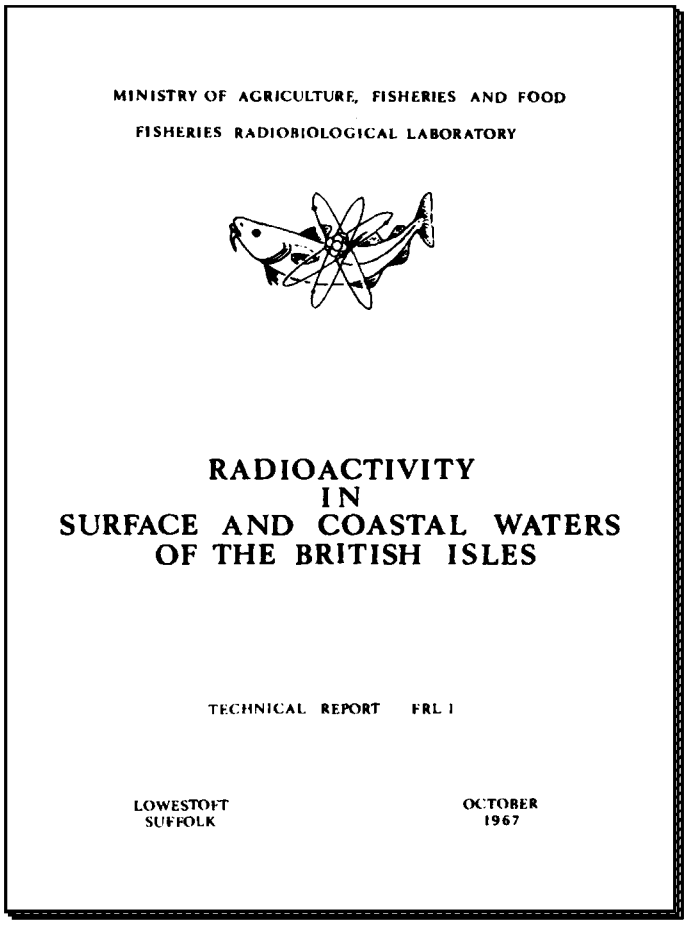
In practice, RSA60 gave statutory effect to many of the expanding responsibilities at Lowestoft. The new Central Electricity Generating Board (CEGB) nuclear power stations (the first of which was at Berkeley, Gloucestershire and came into operation in 1962) required pre-operational surveys and assessments of doses to the public from future discharges. The 'critical pathway' approach to limiting public radiation exposures, exemplified by the continuing surveys of the *Porphyra*/ laverbread pathway, had become well established during the 1950s. The importance of quantifying the pathways by means of site-specific surveys of peoples' habits and consumption rates was clear, particularly in respect of the variable fisheries pathways, and these surveys were carried out at the new sites. Habits surveys are an essential feature of the Lowestoft work to this day.

Increasing advice, nationally and internationally, was also provided on the sea dumping of solid radioactive wastes. This work dated from 1948, when Dr Cockcroft had approached MAF for advice on disposal of laboratory waste from Harwell (MAF, 1948). An interdepartmental working party was set up, and wastes were dumped in the Atlantic, at a number of different sites, from 1949. Low-level wastes were also dumped in the Hurd Deep in the English Channel from 1950 to 1963. In the early 1960s the International Atomic Energy Authority (IAEA) began to develop recommendations on sea dumping of radioactive wastes. Other European countries became interested in this disposal route, and in 1967 the European Nuclear Energy Agency (ENEA - from 1972 the NEA) member states agreed to co-ordinate dumping operations along guidelines in conformity with the IAEA recommendations. Throughout this period, Lowestoft scientists contributed to decisions on dumpsites, packaging and procedures.

With this burgeoning statutory work, inevitably less time was available for R&D, but nevertheless it continued, much of it driven by the needs of the new industry. Radionuclide uptake studies by Fred Morgan, Basil Hampson and others continued during the 1950s, covering a wide range (particularly the metabolism of caesium in a variety of fish/shellfish) and was extended in the late 1950s to cover radionuclides from the power stations; ^{65}Zn was recognised to be a particular problem likely to affect the oyster fishery near Bradwell. Studies were also carried out in the freshwater environment by Roy Chilvers at Aldermaston Court. Work on radiation effects continued; Alan Preston studied the effects on white/red blood cells in plaice and on plaice semen. By the mid-1950s it had become clear that there was a continued need for the work of the Hamilton Dock laboratory, and its nature had become more widely known. Instead of the original title of the 'Fisheries Experimental Laboratory', around 1957 it became the 'Fisheries Radiobiological Laboratory' (FRL), which title was kept for another 24 years.

An even greater repercussion of the increased statutory activities was the amount of work awaiting publication. There was a continual demand from London for internal reports as part of the PDRW process, and external publication was of much lower priority; in any case, the obsessive secrecy surrounding early work clearly prevented much publication during the 1950s. In the 1960s, with the new nuclear sites and the increasing discharges from Windscale, as well as the fallout from nuclear weapons tests which FRL also began to monitor, public concern began to increase. It was recognised that the monitoring data which FRL obtained independently of the Nuclear Industry could be of considerable reassurance. Under Dr Cole's direction, and Alan Preston's leadership of FRL from 1966, the first "FRL report" was compiled and published in 1967. It contained data covering mainly 1963 to 1966, with Windscale *Porphyra* data from 1959. The front cover of the report (FRL 1) is shown in Figure 3. The compiler of the report was Neil Mitchell, (Mitchell, 1967) who had been recruited in 1965. In the foreword to FRL1, Dr Cole said:

> *"In this report, the first of a series dealing with the work of the Fisheries Radiobiological Laboratory, Lowestoft, Neil Mitchell describes the arrangements made by the Ministry of Agriculture, Fisheries and Food to ensure the safe disposal of radioactive waste to surface waters and the sea. He shows clearly that the discharge of radioactive wastes in this manner is completely safe. The greatest care is exercised to ensure that at each and every one of the sites where radioactivity is present in wastes the most stringent precautions are taken to safeguard the public. It is our policy to publish the results of our surveys, so as to assist in creating an informed climate of public opinion in which the peaceful uses of nuclear energy may be fully exploited."*


MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

FISHERIES RADIOBIOLOGICAL LABORATORY

RADIOACTIVITY
IN
SURFACE AND COASTAL WATERS
OF THE BRITISH ISLES

TECHNICAL REPORT FRL 1

LOWESTOFT
SUFFOLK

OCTOBER
1967

Figure 3. The cover of the first FRL report

This awareness of the need for openness in nuclear matters came well before similar efforts by others. It is noteworthy that the cover of FRL1 carried the radioactive cod motif, which was designed by Neil Mitchell and Alan Preston; a redrawn version is still in evidence today.

With the expanding nuclear programme had come requests from the Scottish Office for advice on the effects of discharges of radioactive waste from Scottish nuclear establishments. The results of monitoring were included in the annual reports. Particular interest was at Dounreay, where radioactivity on fishing nets and accumulations from spume in the rocky inlets were potential critical pathways. Figure 4 shows FRL staff at work near Dounreay in the 1960s. Monitoring was also carried out in connection with nuclear submarine operations at naval establishments both in England and Scotland, including the US base in the Holy Loch.

During the late 1960s the R&D work of the laboratory continued, driven by the needs of the statutory responsibilities. The following were amongst the projects carried out. The importance of uptake of radioactivity onto silt and variations with particle size in determining both sediment inventories and dose rates over exposed sediments was recognised and investigated by Doug Jefferies *et al.* A radioecological study involving uptake of radionuclides by shellfish near the new power station at Bradwell was undertaken by Preston, Jefferies *et al.* Studies of the freshwater environment continued, with pre- and post-operational assessments in connection with the new nuclear power station at Trawsfynydd; Preston, Jefferies, Dutton *et al.* also studied the variations of radionuclide uptake by fish in waters of different potassium and calcium content. Radiological studies of the Northern Irish Sea were carried out by Jefferies *et al.* using *RV CORELLA*, producing inventory data and contour maps. Uptake studies were carried out in tank experiments with ^{134}Cs by Jefferies, Ken Hewett *et al.*, and later on a range of activation products by Jan Pentreath *et al.* Doses to fish and their effects were studied by Dennis Woodhead, Charlie Barker *et al., inter alia* involving an experiment in which plaice tagged with thermoluminescent dosemeters (TLDs) were released off Windscale, and showed that doses received were much lower than likely to cause harm. Monitoring at Dounreay led to a study by Fred Morgan *et al.* of computer-assisted predictions of concentrations under different weather conditions. A comparison of radionuclide and stable element behaviour led to a survey by Preston *et al.* of trace metals in UK waters, sediment and biota. Important developments took place in radioanalytical and radiometric techniques, on which the whole work of the laboratory depended; radiochemistry was developed under Basil Hampson, Bernard Harvey *et al.* and radiometric and spectrometric techniques under John Dutton, Eric Reynolds *et al.* Figure 5 shows some of the counting equipment in routine use around that time. Figure 6 shows FRL staff operating gamma dose rate instruments in the field.

With the increased work the staff complement also grew. The original 5 staff of 1947 had grown to 11 in 1956, and by 1965 there were 42. There was continuing severe pressure on accommodation. Following the Windscale fire and the increases in monitoring both near Windscale and at the new power station sites, further

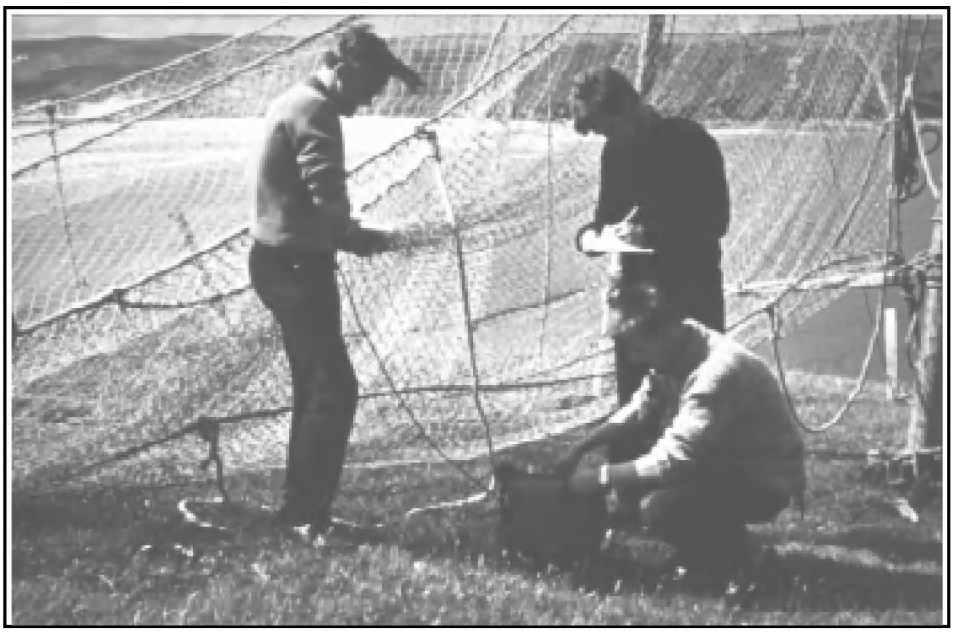


Figure 4. Dave Allington, Lloyd Woolner and Ian Huggins monitoring nets near Dounreay, circa 1963

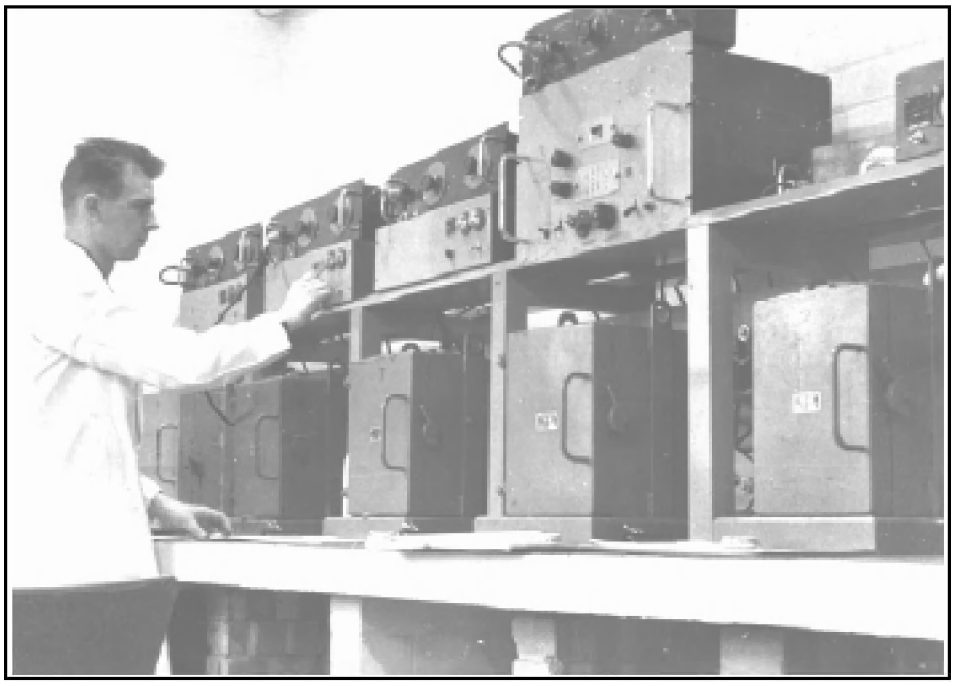


Figure 5. Ian Huggins with the bank of shielded GM detectors for beta counting. Note the stop-watches in use. The scalers such as being operated by Ian were transistorised and built in-house

Figure 6. Ken Firman (left) with 'Airmec' GM counter and Alan Moore with 'Gammagraph' high-pressure ionisation chamber, near Lytham, circa 1963

Figure 7. Fisheries Radiobiological Laboratory, Whitehaven, circa 1990. The part behind the wheel is an exrension added in the mid-1980s

accommodation was needed. Other parts of the Fisheries Laboratory had occupied the Grand Hotel, Pakefield, in 1955, and in 1959 the Ministry of Works proposed that to deal with the radioactivity accommodation and other pressures, the nearby Palais de Danse should be acquired and converted (Lee, 1992). This, however, would have taken too long to achieve, even though it was eventually put in hand for other Fisheries Laboratory needs. Instead, an extension to the Hamilton Dock Laboratory was built, and completed in 1961. To assist with the volume of samples at their main source in Cumberland and to avoid continued use of temporary accommodation at the Tax Office, in 1961 a small laboratory (Figure 7) was provided on the quayside at West Strand, Whitehaven; this laboratory was extended during the mid-1980s and is still in use today. Meanwhile, in Lowestoft, the Hamilton Dock Laboratory was almost immediately outgrown; some of the radioactivity work was transferred to Vernon House in the Marina, Lowestoft, not far away. A further extension to the Hamilton Dock Laboratory was put in hand, and this was completed in 1967.

4. INCREASING PUBLIC AWARENESS: THE 1970S

In the early 1970s, public concern about nuclear power was still at a relatively low level. The Magnox stations were operational and a second generation of advanced gas-cooled reactors (AGRs) was under development. For the Windscale discharges, the *Porphyra*/laverbread pathway was initially limiting, and much work was expended in determining the doses to the critical group. However, by 1972 the use of Cumberland *Porphyra* had declined for reasons already given, and other pathways became more important. Increased discharges of γ-emitters and their ready adsorption to the sediments of the Ravenglass estuary indicated the possibility that, from surveys of occupancy habits, the Ravenglass salmon garth fishermen could have a limiting exposure. Fish and shellfish consumption pathways were also studied; in 1974, following a prolonged period of shutdown of Windscale operations, increased corrosion of magnox fuel took hold in the storage ponds and discharges of radiocaesium increased significantly. Discharges of alpha emitters had also increased at around this time. MAFF and DoE, the Authorising Departments, brought pressure to bear on British Nuclear Fuels Ltd (BNFL) (who had assumed responsibility for the site from UKAEA in 1971) for discharges to be reduced and the authorisation to be revised. FRL provided the technical data and dose calculations for these negotiations. However, the generous authorisation, which had been set mainly – but now less appropriately – on the basis of the *Porphyra*/laverbread pathway, and increased for alpha-emitters in 1970, was not being breached and the ICRP dose limit (0.5 rem $y^{-1} \equiv 5$ mSv y^{-1}) was not being exceeded by the critical group of fish/shellfish eaters. There was also a lack of political pressure, with the recent oil crisis and miners strikes showing a need for diversity of electricity supply, and the relatively low level of public concern at that time.

However, a source of technical pressure was brought to bear, particularly by John Hetherington and John Shepherd, who had been recruited to FRL as a result of the increasing statutory work; John Shepherd was replaced by Peter Jones in 1976, who took on

responsibility for inspections at the CEGB nuclear stations. The technical pressure on Windscale stemmed from the recommendations of ICRP Publication 9 (ICRP, 1965), in which was developed the principle of keeping 'all doses as low as readily achievable, economic and social considerations being taken into account' (ALARA). This principle was further developed by John Dunster and others in ICRP Publication 22 (ICRP, 1973), showing the importance of 'collective dose' as a measure of detriment and suggesting cost-benefit analysis as a technique to judge the need for expenditure to reduce doses; 'readily' was adjusted to 'reasonably' as being closer to ICRP intentions. The radiocaesium discharges from Windscale had begun to be measurable in fish over a wide area; combining concentrations with landings statistics, it was possible to calculate the collective dose, and (by cost benefit analysis) the expenditure which was justified on control measures. These arguments were put forward, but initially, as has been referred to, without a great deal of success. Eventually, by 1976, taking account also of the need to control pond chemistry and visibility to allow decanning, BNFL decided to install an ion-exchange treatment plant. This plant became known as the site ion exchange effluent plant (SIXEP) and it came into operation in 1985. During the 9 year interim, control was provided by the use of skips of zeolite which were installed in the pond from 1976. The cost benefit approach was taken forward by John Hunt who joined in 1977; using this technique it was possible to estimate the optimum number of zeolite skips which should be installed per year to control the radiocaesium discharges until SIXEP became operational. Similar techniques were pursued thereafter.

By the mid-1970s, there were increasing signs of public anxiety about the potential environmental effects of nuclear power, and the subject was chosen for its sixth report by the Royal Commission on Environmental Pollution, chaired by Sir Brian Flowers (United Kingdom - Parliament, 1976). This report was wide-ranging and led to the second Radioactive Waste White Paper in 1977. In the course of their studies, the team visited FRL. Their comments are worth recording verbatim:

> *"We have visited this laboratory and we were struck by the range of work undertaken and by the thoroughness with which the laboratory discharges its responsibilities. The staff not only conduct research on how radioactivity is distributed in the environment and returns to give radiation doses to certain critical groups, but also inspect the sites and determine the levels of discharges that should be authorised. It appeared to us that this dual role of research and inspection had been fruitful in helping to identify useful areas for future research and in bringing expert scientific knowledge to bear directly on control problems."*

FRL were also heavily involved in the Windscale Inquiry of 1977. BNFL had applied for planning permission to build the Thermal Oxide Reprocessing Plant (THORP), and the application was called in for determination by the Secretary of State for the Environment, who appointed Mr Justice Parker to conduct a Public Inquiry. Among many other witnesses, Neil Mitchell, who had taken over leadership of FRL in 1972 when Alan Preston was promoted to Deputy Director of Fisheries Research, was called to present evidence on assessment methodology and the wide range of monitoring data published in the FRL reports. In his report (Parker, 1978) Mr Justice Parker endorsed the tribute to FRL paid by the Royal Commission. He also called for more rapid publication of the monitoring data.

The second Radioactive Waste White Paper, 'Nuclear Power and the Environment', (United Kingdom - Parliament, 1977) was the Government's response to the Flowers Report. *Inter alia* the Department of the Environment (DoE) was to take on the responsibility for Radioactive Waste Management Policy, and for co-ordinating related R&D and environmental monitoring. These new responsibilities were to be exercised in close collaboration with MAFF. Further advisory work for FRL stemmed from this, with more committees to service and also the need for Inspectors to scrutinise operators' construction and other documentation which went to the Nuclear Installations Inspectorate, to ensure that waste disposal aspects had been properly considered.

Throughout the 1970s there was a need to provide increasingly developed scientific advice in connection with sea dumping of solid radioactive waste. Lowestoft staff were involved with the UK regulatory aspects, of drawing up codes of practice and carrying out inspections of the packages against these codes prior to disposals, as well as assessment and modelling tasks to support the international discussions. The London Dumping Convention (LDC), signed in 1972, prohibited the disposal of high level wastes, to be defined by the IAEA. The provisional IAEA definition was based on a fairly simple assessment model, but a review was carried out in 1978 to which particularly John Shepherd at Lowestoft contributed. The modelling took account of a number of potential oceanographic processes and pathways back to man. Lowestoft scientists also contributed to the IAEA advisory meetings which resulted in the revised definition (IAEA, 1978). Sea dumping by the UK and other European countries continued in compliance with IAEA recommendations within the Nuclear Energy Agency (NEA) framework, which was revised in 1977, becoming the 'Multilateral consultation and surveillance mechanism for the sea dumping of radioactive waste'. This mechanism included the need for periodic reviews, the first of which was carried out in 1980. It was quite clear, however, that by the late 1970s there was growing opposition to sea dumping of radioactive waste, and this led to the need for Lowestoft staff to provide increasing amounts of advice in response to questions raised both nationally and internationally.

Against this background of increasing public awareness and advisory duties, the 1970s were also a significant period for radioecological research at FRL. The increased discharges from Windscale, both of beta/gamma and alpha emitters, gave rise to new areas of investigation. The importance of uptake on sediments both in horizontal distributions and in cores was pursued by Jefferies, Hetherington *et al.*; it was realised that especially the fate of the long lived alpha-emitters, which would have an effect on future doses, depended significantly on sediment behaviour. This area of work was taken up later by John Talbot and then Jan Pentreath, who became responsible in 1978 for co-ordinating work on transuranics. Attention was also paid by Bernard Harvey *et al.* to the pore water of sediment cores in relation to the possibility of remobilisation. Laboratory studies also continued on the dynamics of uptake and loss by Pentreath *et al.*, and studies at the subcellular level by Paul Leonard. Radiation effects studies were continued by Woodhead and Barker, investigating *inter alia* chromosomal aberrations in cells derived from the tropical freshwater fish *Ameca splendens*. International collaboration also developed. Research vessel cruises by Jefferies, Ken Steele *et al.* which produced the contour maps of radiocaesium distributions in British waters and further afield were supplemented by Hans Kautsky *et al.* of the Deutsches Hydrographisches Institut. The plutonium in sediment studies referred to above were extended by radiochemical investigations of Brian Lovett and Don Nelson (a visitor from Argonne National Laboratory, USA); these showed that the oxidised state (Pu V/VI) was mobile, and existed to a greater degree in the water column, as compared with the reduced state Pu (III/IV) which was predominant in the sediment.

During the 1970s further pressure on accommodation grew. By 1979 there were 62 staff at Hamilton Dock. Much of the accommodation was sub-standard, particularly the oldest part of the building which had been in use since 1947. On the Grand Hotel site, land next to the 'Palais Block' had been acquired in 1965 (Lee, 1992) but development had been slow because of successive moratoria on Government building. In the 1970s plans were developed for a new block – the 'north extension' – to rehouse the Hamilton Dock staff and facilities and other laboratory, computing and conference facilities. The extension was ready for occupation in 1981, when most of the Hamilton Dock staff transferred to it. The new extension was opened by HRH the Duke of Kent on 26 May 1982 (Figure 8). The old building remained in use for some radiation effects and uptake studies into 1982 when this work was also transferred. The Hamilton Dock site was relinquished, and the building has since been pulled down. With the move from FRL, the radioactivity staff retained their section name of AEP (Aquatic Environment Protection) 1.

Figure 8. HRH The Duke of Kent and Alan Preston, Director of Fisheries Research, on the occasion of the official opening of the North Extension at the Pakefield site, 26 May 1982

5. THE 1980S: THE DECADE OF ACCOUNTABILITY

Work in connection with the Windscale discharges continued its dominance of activities at Lowestoft. The 1980s began with radiocaesium discharges still at a relatively high level despite control by zeolite skips. Regular meetings were held between BNFL senior management and DoE and MAFF, the Authorising Departments, at which Lowestoft was represented. The aim was to reduce the discharge limits and to expedite construction of the necessary treatment plant. Revision of the authorisation was, *inter alia*, endorsed in the third Radioactive Waste White Paper, Cmnd 8607 (United Kingdom - Parliament, 1982) which annexed, under Lowestoft influence, the current radiological objectives including a statement of ALARA. Following a review of safety at Windscale, the activities were reorganised into two separate operations: Windscale Works, with its reprocessing plants, and Calder Works comprising the power station. The whole site was to be referred to by its original place name of Sellafield. Inspection work at Sellafield and other nuclear sites continued, assisted by Bryan Smith who joined in 1980. Research into the critical pathways by Lowestoft and Whitehaven staff particularly in the Sellafield vicinity continued. The importance of molluscan shellfish in contributing dose to shellfish eaters (principally from ^{106}Ru and alpha-emitters) had been demonstrated in the annual monitoring reports, now authored by John Hunt since 1977. Further habits surveys were carried out, by Ken Hewett and later by Paul Leonard, looking particularly at shellfish eaters. These surveys identified more high-rate winkle consumers than hitherto, and the monitoring report for 1981 showed that on the basis of current advice on gut transfer factors, the critical group of fish and shellfish consumers could have received an effective dose equivalent of 69% of the ICRP-recommended 5 mSv limit.

In 1982, much effort by Lowestoft was put into preparing for the 'Sizewell Inquiry' into the proposed construction of a pressurised water reactor at Sizewell. The Inquiry itself, under Sir Frank Layfield as Inspector, lasted for a record 26 months from January 1983, and the Inspector's report, recommending approval, was published at the end of 1986 (Layfield, 1986). Neil Mitchell appeared at the Inquiry as a witness for MAFF. In preparation, radiological assessments were needed, not just of the effects of proposed liquid discharges in addition to those of the existing magnox 'A' station, but also of the additional effects of reprocessing the fuel at Sellafield. Much of the Lowestoft methodology had been revised since 1977 and it needed to be published; a special series of reports (the 'Sizewell Inquiry series') was set up as a vehicle and presented in evidence. These reports took much effort to produce in a short space of time but this proved well worthwhile.

Few group photographs of the FRL/AEP1 staff exist; the opportunity was taken in May 1983 when John Dutton, head of the analytical section retired (Figure 9).

Figure 9. FRL/AEP 1 staff, May 1983: Back row - Dave Denoon, Peter Jones, Keith Wink, Ian Simcoe, Paul Blowers, Bob Milliner, John Tipple, Les Patterson, Gerry Sutton, Reg Farman, Terry Dean, Pete Kershaw, Frank Eaglestone, John Mullen, Dick Read, Chris Gooch;
Middle row - Clyde Curtis, Mike Howes, John Francis, Dave Coles, Julie Spendlove, Derek Andrews, Eric Reynolds, Alan Moore, Brian Lovettt, Bill Camplin, Tom Widdop, Bryan Smith, Stan Patmore, Joe McHugh David swift, Carroll Baker;
Seated - Sue Brown, Sonia Gerrell, Linda Goldspink, Dave Allington, Betsy Corrigan, Jan Pentreath, John Dutton, Doug Jefferies, Ken Steele, Ian Huggins, John Hunt, Paul Leonard, David Weiss

In November 1983 occurred what became known as the 'Sellafield Beach Incident'. During a period of maintenance shutdown of the reprocessing plant, washings containing solvents were mistakenly transferred direct to the sea tanks. Attempts were made to return the liquid to storage along a thin pipe, but this would have taken a long time; as monitoring showed low levels, operators released some of the liquid to sea. However, the solvents contained non-homogeneous 'interfacial crud' with high levels particularly of ^{106}Ru. The weather was unusually calm; instead of dispersing, a slick of solvent appeared. By coincidence, an inflatable dinghy being used by Greenpeace divers to take samples became contaminated. Later, an onshore wind blew activity onto the beach. Extensive programmes of monitoring were swiftly set up, both by BNFL and Lowestoft, taking the form of monitoring strand lines for beta/gamma activity using portable probes. It became clear that small contaminated pieces of rubbish from the plant were also being detected. The DoE advised the public to avoid unnecessary use of local beaches. Lowestoft rapidly produced a series of reports, the first during December 1983, of the concentrations found in local marine materials. Whilst there had been a temporary small increase in radioactivity in some local shellfish, levels soon returned to normal, but the problem of the contaminated items remained. Extensive monitoring to remove these items continued both by BNFL and Lowestoft/Whitehaven. The Minister, Mr Michael Jopling, visited the Whitehaven Laboratory and Ravenglass and carried out some strand-line monitoring (Figure 10). There was considerable effort at Lowestoft to develop more suitable instruments to monitor areas of beach, particularly by Derek Andrews and Ian Huggins who designed effective large area hand-help probes. Advice on beach restrictions continued until May 1984. Interim changes were made to authorised discharge limits pending the review which was still ongoing prior to operation of SIXEP. A prosecution under the Radioactive Substances Act was instigated, and the trial took place in Carlisle in July 1985. Neil Mitchell appeared as a witness for MAFF. BNFL were found guilty on a number of charges, including failing to limit the discharges such that radiation exposures were ALARA.

Concurrently with the beach incident, further Sellafield-related work was needed from Lowestoft. In November 1983, Yorkshire Television screened a programme which suggested an increased incidence of cancer in the area near Sellafield. The Minister of Health set up an investigation under Sir Douglas Black. Lowestoft staff presented oral evidence, including monitoring data and dose assessments. The report (Black, 1984) made a number of recommendations, mainly for epidemiological studies, but also for regulatory needs and monitoring programmes. A Committee on the Medical Aspects of Radiation in the Environment (COMARE) was set up, and Lowestoft staff began to service this Committee by representation and provision of data, especially on Sellafield monitoring.

With the occurrence of the beach incident, together with the Lowestoft data showing the high percentage of dose limits received by shellfish eaters, as well as the Black Report, there was immense pressure on BNFL to further abate discharges, particularly of alpha emitters. In 1984, MAFF and DoE requested consideration of a number of options; after much high-level debate it was announced in Parliament that BNFL would construct a floc precipitation plant. This plant, which became known as the Enhanced Actinide Removal Plant (EARP), eventually became operational in 1994, at about the same time as THORP, with further Lowestoft involvement as we shall see.

Figure 10. Doug Jefferies (left) and the Minister, Mr Michael Jopling, MP, near Ravenglass in January 1984

As already mentioned, much effort had been in progress towards achieving reductions in the Sellafield liquid discharge authorisation. With the commissioning of the salt evaporator and SIXEP in 1985, it was possible to put proposals into effect. Crucial in the process were the doses to the critical group of fish/shellfish consumers per unit discharge, and the Lowestoft data were relied upon to ensure that the overall dose did not exceed the principal ICRP dose limit of 1 mSv y^{-1}. The new authorisation, with significantly reduced limits, came into effect in July 1986.

Authorising Departments' accountability was further tested in 1985-86 when the House of Commons Select Committee on the Environment made a study of Government policy on radioactive waste (United Kingdom - Parliament, 1986(a)). Whilst many of the recommendations centred on the lack of progress in solid waste disposal, it was recommended that liquid authorisations should be reduced and gaseous discharges should have numerical limits. The Government's response was published in the fourth Radioactive Waste White Paper, Cmnd 9852 (United Kingdom - Parliament, 1986(b)). This included a statement that a review of authorisations was underway; the aim was to complete it in 3 years and thereafter to keep authorisations under regular review. Current radiological protection objectives of ICRP were also endorsed, with a target for individual authorisations of 0.5 mSv y^{-1}. The need for regular reviews of authorisations put additional strain on the Lowestoft inspectors and assessments team.

In April 1986 the disastrous accident happened at Chernobyl, causing an airborne plume contaminated with fission products to sweep westwards across Europe. The Lowestoft laboratory was one of the first to observe this plume as it arrived over Britain, by means of dry cloth collectors which are used in the programme for monitoring airborne activity. However, this was only the beginning; rain out over the hills of north-west England and Wales, south west Scotland and in Ireland caused deposition, mainly of radiocaesium, which began to enter the food chain. Lowestoft staff were redeployed onto a vastly increased monitoring programme; as well as for radioactivity in aquatic foods, much support was provided for the terrestrial programme of the MAFF Food Safety (Radiation) Unit. Assistance was also provided with instruments for the live monitoring of sheep. In the marine environment the effects were fairly short-lived except for the enhancement of caesium-134 which was a useful label rather than of radiological significance. However, upland lakes were affected by increased levels of radiocaesium, and these persisted for several years because of slow clearance rates. An increased monitoring programme for fish from such lakes continued until the early 1990s. A special monitoring report by Bill Camplin, who had joined in 1982, and others (Camplin *et al.*, 1986) described the early Chernobyl-related monitoring; after this the data were incorporated within the regular Lowestoft monitoring reports.

Further accountability of the Lowestoft work was required for the public Inquiry into the proposed Hinkley Point 'C' power station, under the Inspector Mr Michael Barnes. The Inquiry lasted from October 1988 until December 1989; during 1987 and 1988, proofs of evidence were prepared by Lowestoft as part of a MAFF package. The Lowestoft evidence consisted of the data from habits surveys and dose assessments under different release scenarios, and was presented at the Inquiry by John Hunt. The eventual outcome of the Inquiry, published in 1990 (Barnes, 1990) was that planning permission should be granted, but the privatised nuclear industry have now decided not to proceed with further nuclear development for the time being.

Significant effort by Lowestoft during the 1980s was put into studies in connection with deep sea disposal of solid radioactive wastes. Dumping within the NEA mechanism had proceeded until 1982, with the need for provision of more defensive advice year by year, until in 1983 the operation was blocked by the National Union of Seamen. The Government set up an independent review chaired by Prof. F. Holliday. Lowestoft provided evidence for this review, which was published in 1984 (Holliday, 1984). The review team could find no evidence of harm to man or the environment from the operations, but recognised that there were international reviews in progress, and recommended that dumping should not continue until these were complete. One such review was of the suitability of the NEA dumpsite. Data for this review were contributed from the NEA Co-ordinated Research and Environmental Surveillance Programme (CRESP) which had been set up following the previous review, and it was heavily supported by Lowestoft on both oceanographic and radiological fronts. The modelling was a collaboration by scientists of the National Radiological Protection Board and at Lowestoft, particularly Bill Camplin. The review was published in 1985 (NEA, 1985), and recommended, essentially, that use of the dumpsite could continue. The other international reviews were within IAEA and LDC. The IAEA review was of the definition of high-level waste unsuitable for dumping at sea, and was also contributed to by Lowestoft, producing essential information, for example by Jan Pentreath with an extensive review of distribution coefficients and concentration factors. However the IAEA and LDC reviews became more protracted and have now been overtaken by the bans on sea dumping of radioactive wastes by OSPAR (which in 1992 replaced the Oslo and Paris Conventions on sea dumping and land-based disposals, respectively, in the North East Atlantic area) and LDC. The OSPAR ban included an option (now relinquished) for the UK and France to resume, subject to conditions, after 15-25 years; the LDC ban will be scientifically re-evaluated after 25 years.

On the international front, in addition to these sea dumping studies, came further needs in the late 1980s. The Commission of European Communities (CEC) set up

a project (the 'MARINA' study) to look at the radiological impact of radionuclides, both natural and anthropogenic, in northern European waters. Lowestoft contributed to this study, particularly with monitoring and collective dose information in respect of Sellafield discharges. In addition, the Paris Commission on land-based releases began to take a greater interest in radioactivity. A series of presentations, mainly in connection with Sellafield, was needed. This work has now become more formalised within the OSPAR Convention, and is still a regular commitment.

The 1980s were a period of significant change and achievement for R&D in radioactivity work at Lowestoft. AEP1, on transfer from FRL, Hamilton Dock, was in 1981 a large section with some 60 staff; in 1983 the research group was made into a section in its own right, AEP4, led by Jan Pentreath. Research vessel cruises continued to study distributions of radioactivity both in sea water and in sediments. In certain areas of the Irish Sea, sediments were found to be highly bioturbated, and *Maxmulleria lankasteri*, an echiuroid of up to 20 cm length, was found to significantly disturb the radionuclide profiles. Models of dispersion and sediment interactions were developed, leading in the Irish Sea to the MIRMAID model (MAFF Irish Sea Modelling Aid). Radionuclide speciation studies continued, relating the species seen in effluents to those observed in different environmental compartments, as further input to the modelling studies. The calculation of doses to Sellafield critical groups had highlighted the sensitivity to the assumed transfer factor across the human gut; a series of studies were carried out in which volunteers ate samples of Cumbrian winkles, providing urine for analysis. The results suggested a lower factor for gut uptake than used by ICRP, indicating lower doses actually received. Whole-body monitoring of high-rate fish consumers in Cumbria confirmed the information derived from habits and diary surveys. Research in the deep ocean in support of the dumpsite suitability studies also continued: sediment distribution coefficients were established; analysis of deep sea organisms showed no significant difference between those near and those remote from the dumpsite. Radiation effects work also continued, demonstrating the effects of different rates of irradiation on growth and behaviour of germ cells of *Ameca splendens*.

The latter part of the 1980s and early-1990s were marred by two untimely events in the radioactivity work at Lowestoft which caused consequential staff changes. First, in January 1988, Alan Preston, Director of Fisheries Research from 1980, died suddenly; this was a tragic loss to the whole Directorate. Harry Hill, who had also had experience of radioactivity work, became Director and Jan Pentreath succeeded to his post of Deputy. In turn, Dennis Woodhead became head of AEP4. The second event occurred in 1987, when Neil Mitchell became ill; he returned from sick leave in 1988 but again became ill in 1990 and died in early 1991. John Hunt deputised over this period and became head of AEP1 which took on the more externally recognisable title of the Fisheries Radiological Inspectorate (FRI).

6. THE 1990S: PRIVATISATIONS, AGENCIES AND ONE-STOP-SHOPS

By 1990, the Radioactive Substances Act, 1960 (RSA60) had been in operation for 27 years; whilst still fundamentally sound, it needed amendment to bring it in line with current philosophy and practice. In 1987 Her Majesty's Inspectorate of Pollution (HMIP) had been formed as a unified Inspectorate within DoE, and included the former Radiochemical Inspectorate. The Environmental Protection Act, 1990 mainly concerned Integrated Pollution Control but it also made amendments to RSA60 such that in England and Wales the Chief Inspector of HMIP held the power of authorisation, together with the Minister, MAFF for nuclear licensed sites. Other amendments related to the powers to recover charges and to issue enforcement and prohibition notices. The changes were subsequently consolidated in the Radioactive Substances Act, 1993.

In the midst of these changes, studies in relation to the Sellafield discharges still dominated the Lowestoft radioactivity workload. In 1990, the Sellafield authorisation of 1986 was revised, as intended, to take account of experience of operation of the new plants, particularly SIXEP. A further revision was due in 1993, to coincide with the operation of THORP as well as the floc treatment plant, EARP. BNFL submitted an application in 1992 and public consultation took place later that year. Following the responses, the Government decided in 1993 to undertake a second round of consultation addressing wider issues of justification. A decision to grant the authorisation was issued in late 1993, but this decision was challenged by Greenpeace and Lancashire County Council. A judicial review took place in February 1994, and affidavits had to be prepared at short notice by DoE and for MAFF by Lowestoft on their part in setting the authorisation. The Ministers' decision was upheld, but in his ruling Mr Justice Potts emphasised that the principle of justification should be considered as a routine part of the authorisation process. This further added to the work needed in subsequent authorisations.

The authorisation effort was considerable during this period. Not only was there the review and revision programme set by the 1986 White Paper, but also the revisions needed because of the contractorisations (e.g. Aldermaston, Devonport) and privatisations, for which in 1995 the five AGR power stations of Nuclear Electric Ltd were re-authorised. There was also much advisory work to be done; one example stemmed from the 1990 recommendations of ICRP (ICRP, 1991), which introduced a distinction between 'practices' and 'interventions', and the concept of constraints on optimisation. The NRPB carried out a wide-ranging consultation on proposals for the UK, and Lowestoft

staff contributed to these discussions; later, the conclusions were broadly endorsed in the sixth Radioactive Waste White Paper (Cm 2919) (United Kingdom - Parliament, 1995), to which Lowestoft staff also contributed. One of the areas of discussion was that the past Sellafield liquid discharges still contribute to the exposures of critical groups; in the ICRP-60 formulation this situation is an intervention, not a practice, and not subject to dose limits. However, the Government accepted that assessments of dose against dose limits should include the effects of past discharges.

Radioactivity R&D at Lowestoft during the early to mid 1990s included much work on natural radioactivity, particularly in relation to discharges from the Marchon works near Whitehaven, which were recognised to contribute to critical group doses, mainly via ^{210}Po. Discharges reduced significantly in 1992, but continuing assessments were carried out including radionuclide distributions. The metabolism of ^{210}Po was also studied, both in shellfish and in humans where gut transfer from the brown meat of crabs was found to be higher than assumed by ICRP. Other R&D included investigations before and after the increases in discharges of ^{99}Tc from Sellafield following the operation of EARP to treat stored medium-active liquors. The metabolism of ^{99}Tc in crabs was studied. Increased shore-based monitoring was carried out and in sea water as part of the EU collaborative Marine Science and Technology (MAST) programme. Monitoring has shown increased radioactivity concentrations, particularly in lobsters, due to the releases but these are of low radiological significance. Other R&D studies examined the contribution of radionuclides associated with colloids in effluents from Sellafield and showed that they are only likely to have a small effect on transport mechanisms. Radiation effects work continued and studied irradiation of invertebrates; exposure of a representative species of worm showed that the lowest dose rate causing an observable reduction in larval production was 1500 times that estimated for worms currently living in the seabed near Sellafield.

7. NEW DIRECTIONS

In the period from 1995, quite radical changes have come about which have significantly affected the radioactivity work at Lowestoft. In the Government's drive towards cost-cutting, deregulation, and one-stop-shops, it became unacceptable to have two organisations – both MAFF and HMIP – issuing authorisations and carrying out inspection and enforcement, however well-targeted this might be. Under the Environment Act, 1995, which also amended RSA93, the Environment Agency (EA) was formed in April 1996 and took on the sole authorising and enforcement role for radioactive waste disposal in England and Wales. MAFF became a Statutory Consultee, with powers of call-in and direction over EA. Within MAFF, there were concurrent pressures to rationalise, as well as the drive towards agencifying executive functions including Government science laboratories. A Fundamental Expenditure Review took place during 1995, which centred the core-MAFF functions both for terrestrial and aquatic interests in London with a new MAFF Radiological Safety Division. This Division was formed from the former Food Safety (Radiation) Unit who were joined *inter alia* by two inspectors from Lowestoft. During 1996, the Government 'Prior Options' review of Government science laboratories confirmed that the Directorate of Fisheries Research should become an Executive Agency. The change took effect on 1 April 1997, and the new Agency is called CEFAS, the Centre for Environment, Fisheries and Aquaculture Science. It is as part of this new Agency that the radioactivity work at Lowestoft will continue, involving radiological assessments; monitoring; analytical and radiometric expertise; and R&D.

All these changes, coming on top of each other in such a short space of time, could not have been anticipated 50 years ago. That they have coincided with the golden jubilee of the radioactivity work at Lowestoft underlines that, together with our celebration, there is the start of a new chapter, full of challenges in the continuing work which lies ahead.

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Figure 11. CEFAS Radioactivity staff, June 1997. Back row - Kins Leonard, Pete Kershaw, Dave Coles, Ian McMeekin, Dave Denoon, John Tipple, Dave McCubbin, Trevor Bailey, Mark Baldwin, David James; Middle row - Winston Hendrickson, Alison Gooding, Janet Ellis, Pamela Dann, Debbie smith, Lindsey Duckett, Heather Emerson, Alison Boggis, John Santillo; Seated - Keith Winpenny, Glenn Round, John Knowles, Bryan Smith, Bill Camplin, John Hunt, Dave Swift, Dennis Woodhead, Alan Young, Mike Howes

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