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for the STOA Panel

Executive Summary and General Conclusions

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POSSIBLE TOXIC EFFECTS FROM THE NUCLEAR REPROCESSING PLANTS AT SELLAFIELD AND CAP DE LA HAGUE

1. Introduction

The principal aim of this report is to assist the Committee of Petitions of the European Parliament in its consideration of Petition 393/95 brought by Dr. W. Nachtwey. The Petition expresses concerns about radioactive discharges from nuclear reprocessing plants at Sellafield in the UK and La Hague in France, and their possible adverse health effects. Six years after the Petition was introduced, the Petitioner's main concerns remain relevant. This report concludes that reprocessing discharges are a valid matter for the Committee's consideration. It also concludes that, on balance, the Petitioner's concerns over radioactive discharges from Sellafield and La Hague are justified.

The report presents evidence and data on:

- radioactive discharges from the Sellafield and La Hague sites;
- resulting nuclide concentrations in environmental media including foodstuffs;
- radiation doses from nuclide discharges to critical groups near the sites;
- adverse health effects near the two sites; and
- resulting collective doses from nuclide discharges.

The report also examines a number of current issues in radiobiology concerning health effects from exposure to ionising radiation, in particular genetic and in utero effects.

In addition, in accordance with contract specifications, the report examines other major factors that might influence future decision-making on reprocessing. It provides information on the legal framework, the operational history of the plants and the economic case for reprocessing compared with available alternatives for spent nuclear fuel management. The report also makes policy-related recommendations that take into account current knowledge and uncertainties in risk assessment and the availability of alternatives to reprocessing in spent fuel management.

2. Reprocessing Status and Issues

Only 5% to 10% of world annual spent fuel arisings is submitted for reprocessing, with the rest stored pending final disposal in a repository. The largest centres in the world for commercial reprocessing remain Sellafield in the UK and La Hague in France. Reprocessing involves the dissolution of the spent fuel in boiling concentrated nitric acid and subsequent physico-chemical separations of uranium and plutonium. Multiple waste streams are created by these physical and chemical processes. While some wastes are retained and conditioned, considerable volumes of liquid and gaseous wastes are released to the environment. Reprocessing operations release considerably larger volumes of radioactivity than other nuclear activities, typically by factors of several 1,000 compared with nuclear reactors.

3. International and European Legal Framework

The report provides a brief overview of Major International Bodies that play a role in the development of international nuclear standards and the main International Conventions relative to nuclear reprocessing are presented.

The OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic, to which the European Commission is a Contracting Party, is of particular relevance to reprocessing activities. The OSPAR Commission has declared its commitment to the application of the precautionary principle, the polluter-pays principle, and to the application of Best Available Techniques (BAT) and Best Environmental Practice (BEP), including, where appropriate, Clean Technology. At the Sintra Meeting in 1998, Ministers agreed to reduce marine pollution *"with the ultimate aim of achieving concentrations in the environment near background values for naturally occurring substances and close to zero for man-made synthetic substances."* They emphasised the importance of the Precautionary

Principle in this work. It is notable that the commitment is to achieve concentrations in the environment close to zero, not merely concentrations in discharges. At the Copenhagen Meeting in June 2000, the OSPAR Commission voted unanimously (with the abstentions of the UK, France and the European Commission) that discharge authorisations be reviewed *"with a view to, inter alia: implementing the non-reprocessing option (for example dry storage)."*

The Euratom Treaty provides the basis for the European regulation of the nuclear sector. Article 34 requires Member States to obtain the opinion of the European Commission before they carry out *"dangerous experiments."* According to the Commission, France has not requested the Commission's opinion under Article 34 concerning activities in La Hague nor has the UK as regards activities in Sellafield.

Conclusions on "Dangerous Experiments"

The Member States UK and France apparently have not complied with Article 34 of the Euratom Treaty, since they have never requested the European Commission's opinion under the article concerning any of their activities at Sellafield and La Hague.

Article 35 of the Euratom Treaty grants control rights to the European Commission for the verification of operation and efficiency of monitoring equipment at nuclear facilities. However, only one verification mission was carried out at Sellafield (1993) and La Hague (1996). These are considered to be outdated. Furthermore, the Commission is apparently highly dependent on information provided by Member States. It is equally doubtful whether the Commission is in a position to determine, as required under Article 37, whether the reprocessing activities are liable to result in the radioactive contamination of the water, soil or airspace of another Member State. In addition to the dependence on Member States' information, the Commission spends only extremely limited manpower into the evaluation of nuclear projects (2 person-months in the case of reprocessing plants).

Conclusions on European Commission Responsibilities under Article 35 of the Euratom Treaty

The Commission's verification activities make ineffective use of its control rights over monitoring equipment. Statements by the Commission on monitoring at Sellafield and La Hague are not backed up by credible data. It is noted, however, that the Commission is currently reviewing its verification activities.

The Commission is apparently not in a position to guarantee that the Basic Safety Standards are respected concerning the La Hague and Sellafield facilities and to determine whether the reprocessing activities are liable to result in the radioactive contamination of the water, soil or airspace of other Member States.

4. Risk Assessment of Radioactive Releases

Radioactive discharges from both sites are very large and indeed rank among the largest anthropogenic sources of radioactivity to the world. As such they constitute a reasonable subject for enquiry by the Committee. Nuclides released to air and sea result in the contamination of food chains via a number of pathways. Individuals may also receive radiation doses from immersion in radioactive aerosols, inhalation of radioactive gases and particulate matter, and ground shine from nuclides deposited on land.

Various computer models have been designed to estimate radiation doses from nuclide releases to members of critical groups living near nuclear facilities. These calculated doses are used to regulate discharges from nuclear facilities.

However, this approach protects individuals and not populations. The use of collective doses has therefore been stipulated by various international bodies, including the European Commission in the Basic Safety Standards Directive (96/29). Crucial theoretical underpinning for collective dose was provided by the scientific community's adoption of the Linear No-Threshold model for radiation's adverse health effects. This states that there is no level of radiation exposure below which there is no effect: risks continue with declining doses until zero dose. Even the smallest possible dose, i.e. a photon passing through a cell nucleus, carries with it a risk of cancer. Although this is an extremely small risk, it is still a finite risk.

Collective dose estimates strongly depend on the size of the population considered and the time scale used. Opinions vary as to which populations and time scales should be used. Given the very long term half-lives of some radionuclides released by reprocessing plants (e.g. iodine-129, 16 million years) and their global distribution, there should be no time limits and dose evaluations should be global. There is no reason why future generations or distant populations should be any less protected than current generations in the vicinity of the facilities.

Comparisons of doses from nuclear activities with those induced by natural background radiation are flawed because, inter alia, these omit to indicate the health impact of background radiation itself. It has been estimated that natural background radiation results in about 6,000 to 7,000 UK cancer deaths per year in the UK with a similar figure for France.

Conclusions on Dose Estimates

In order to evaluate the risk of large releases of radionuclides into the environment, in addition to critical group dose estimates, collective dose calculations should be carried out and taken into account during decisions on the continued operation of reprocessing plants.

5. Case Study Sellafield

Between 1965 and the end of year 2000, about 26,000 tonnes of spent gas graphite fuel were reprocessed by the B205 line at Sellafield. About 3,000 tonnes of spent light water reactor fuel have been reprocessed at THORP since 1994. Based on current contracts and annual throughput rates, both plants are expected to shut down within the next 10 years or earlier.

Although gaseous releases of most nuclides from Sellafield have not varied to a marked extent since the 1970s, iodine-129 emissions have increased 10-fold. Radioactive marine releases of carbon-14, strontium-90 and caesium declined markedly in the early 1980s, while in the mid 1990s increases occurred in releases of carbon-14, cobalt-60, strontium-90, technetium-99 and iodine-129. Over the same period, actinide (mainly plutonium) discharges have declined markedly.

Internal BNFL documents suggest significant increases in nuclide releases in the future at Sellafield. For some *"worst case"* scenarios, the operator predicts for *"levels approaching or above the limits"* for sea discharges of over half the currently authorised radionuclides. A similar situation is expected for aerial releases.

Conclusions on Sellafield Releases

Increases of releases of key radionuclides from Sellafield in the late 1990s and expected future discharges are inconsistent with obligations under the OSPAR Convention.

The deposition of plutonium within 20 km of Sellafield attributable to aerial emissions has been estimated at 160-280 GBq (billion becquerels), that is two or three times plutonium fallout from all atmospheric nuclear weapons testing. In addition, significant quantities of radionuclides can become airborne in sea spray and be transported inland by the wind. The average activity due to actinides from the sea may occasionally exceed the international limit of 1 mBq/m^3.

It has been estimated that over 40,000 TBq (trillion becquerels) of caesium-137, 113,000 TBq of beta emitters and 1,600 TBq of alpha emitters have been discharged into the Irish Sea since the inception of reprocessing at Sellafield. This means that between 250 and 500 kilograms of plutonium from Sellafield is now adsorbed on sediments on the bed of the Irish Sea. The migration of undersea deposits of actinides to coastal environments represents a long-term hazard of largely unknown proportions.

Technetium-99 (half-life 214,000 years) discharges have led to particular concern. In 1997, technetium concentrations in crustacean – particularly in lobster – reached 13 times the European Council Food Intervention Level (CFIL) in the vicinity of Sellafield. Some technetium concentrations above CFIL limits have also been found in molluscs (winkles, mussels, limpets and whelks). Recent environmental surveys along the Norwegian coast indicate a six-fold increase in technetium concentrations in seaweed since 1996. Concentration factors are greater than 1,000 for some biota such as macrophytic brown algae, worms and lobsters and are particularly high for some seaweeds (around 100,000). In 1999, a number of high concentrations of various radionuclides were also recorded in fish, shellfish, sediments and aquatic plants, some exceeding CFILs several times. Large uncertainties remain in the field of transfer of technetium in the biosphere.

Conclusions on Radionuclide Concentrations in the Sellafield Environment

Marine discharges at Sellafield have led to significant concentrations of radionuclides in foodstuffs, sediments and biota. Discharges lead to current concentrations in some foodstuffs, which exceed European Community Food Intervention Levels (CFILs). The transfer of technetium to the biosphere is of particular concern, because of its long half-life (214,000 years), its mobility in seawater and the high concentration factors in plants. Large uncertainties remain as to the transfer mechanisms and environmental fates of many radionuclides.

During the 1970s and 1980s, peak doses to critical groups in the Sellafield region possibly reached 2.5 to 3.0 mSv per year (as compared to a dose constraint of 0.3 mSv in the UK and 1 mSv in the EU). Latterly, doses to marine-related critical groups have declined to about 0.2 mSv per year.

A recent study commissioned by the German Federal Office for Radiation Protection, using German statutory dose assessment assumptions, calculated that annual doses from consumption of contaminated foodstuffs were more than 5 times the annual limit imposed by the European legislation and about 20 times the annual dose constraint used in the UK and Germany. Most of the dose was received via the technetium contaminated seaweed fertiliser/animal feed/meat consumption pathway. The conclusion of the German study was that the Sellafield reprocessing facilities would not be "licensable" in Germany. European legislation does not prescribe specific assumptions in dose assessment models. The European Commission has responded that *"the guidance currently being produced on realistic dose assessments will comment on this issue."*

Conclusions on Doses Induced by Sellafield Discharges

Discharges to the Sellafield marine environment have led in the past to doses to critical groups exceeding 10 times current UK and 3 times EU limits. The doses calculated by the UK administration from current environmental radionuclide concentrations reach respectively 2/3 and 1/5 of the UK and EU limits. These doses remain problematic, considering that doses from past discharges and from direct radiation are ***not*** included. Doses calculated under German statutory dose assessment assumptions exceed UK and EU dose constraints. In addition, German dose limits for organs (also used in the US but not in the rest of the EU) would also be exceeded by the ingestion of relatively small quantities of seafood from Sellafield. The Sellafield reprocessing plants would not be licensable in Germany. Also very large uncertainties in dose estimates remain, with differences between 5th and 95th percentiles often exceeding several orders of magnitude. This raises the question of whether "realistic" assessments should be used rather than "conservative" dose assessments.

The risk potential of certain hazards at Sellafield is very large. Liquid high level wastes currently stored at Sellafield contains about 7 million TBq (2,100 kg) of caesium-137, which is about 80 times the amount released through the 1986 Chernobyl accident. Assuming a 50 percent release of caesium-137 in an accident at Sellafield, population dose commitment would range up to tens of millions of person-Sv resulting in over a million fatal cancer cases.

Conclusions on Hazards Posed by Liquid High Level Waste at Sellafield

The hazard potential of liquid high level wastes in particular is very high. A serious accident might lead to large releases of radioactivity and on the long term globally to over one million fatal cancer cases.

Higher incidences of childhood leukaemia than expected were first identified near Sellafield in 1983. The cause or causes of the observed increases in childhood leukaemia near Sellafield have not been determined, nor is it known whether a combination of factors is involved. The UK Committee on the Medical Aspects of Radiation in the Environment (COMARE) has stated: *"As exposure to radiation is one of these factors, the possibility cannot be excluded that unidentified pathways or mechanisms involving environmental radiation are implicated."*

Various hypotheses, including paternal preconception irradiation and population mixing have been advanced without being conclusive. Possible explanations for the discrepancy between observed cancers and estimated low doses include erroneous dose assessments (in particular foetal doses) and uncertainties as to the parameter of "dose" and what it measures.

Besides childhood leukaemia, other areas of concern have arisen, including reports of increased incidence of retinoblastoma in children and a statistically significant increase in stillbirth risk in the Sellafield region.

Conclusions on Health Effects from Reprocessing at Sellafield

More than fifteen years of research has established that the excess incidence of childhood leukaemia around Sellafield is statistically significant and is continuing. The cause or combination of causes of the observed leukaemia increases are not known. Many uncertainties remain. Radiation exposure due to radionuclide releases from Sellafield cannot be excluded as a cause for the observed health effects.

6. Case Study La Hague

Between 1966 and the end of 2000, about 21,000 tonnes of spent fuel have been reprocessed at La Hague. Most waste generated at La Hague has remained unconditioned – in other words they were not stabilised and packaged for long term or permanent storage – for many years, and some is stored under very unsatisfactory safety conditions, including over 9,000 m^3 (or 39,000 containers equivalent) of plutonium contaminated sludge.

In 1999, the total radioactivity released by La Hague to the environment was 15,000 times higher than that released by a nearby nuclear reactor. While releases of some radionuclides (e.g. technetium-99, plutonium) have decreased or remained constant, releases of other radionuclides from La Hague have significantly increased over the past decade. These include liquid discharges (iodine-129 x 5; tritium x 3) as well as gaseous releases (carbon-14 x 8; krypton-85 x 5; tritium x 3). Also, some important radionuclides are not measured at all, including chlorine-36, technetium-99, and strontium-90 aerial emissions.

Conclusions on La Hague Releases

Releases of radioactivity from La Hague to the environment are several orders of magnitude larger than releases from a nuclear reactor. Releases of some radionuclides have decreased in the past while liquid and gaseous discharges of other key radionuclides have increased significantly. A further group of radionuclides is not being measured in effluents. Increases of radioactive releases from La Hague in the 1990s and expected future discharges are in violation of obligations under the OSPAR Convention.

There have been numerous accidents at La Hague, some involving significant radioactive releases. For example, as a consequence of a severe discharge pipe break in 1980, doses to individuals of the critical group (fishermen) exceeded the annual EU limit of 1 mSv by 3.5 times. Main potential hazards at La Hague are linked to the risk of fires and explosions in the storage pools, in the vitrification plants or in the effluent treatment plants, and to the risk of dispersion of the caesium-137 stocks in the spent fuel pools, or of the separated plutonium stocks.

Conclusions on Accidental Releases from La Hague

Past accidents at La Hague include at least one accident that led to population doses significantly exceeding EU limits. Accidents are estimated to be responsible of 36% of the leukaemia risk level for the 0-24 year age category around the La Hague site. The hazard potential of the La Hague spent fuel stores is very large. The accidental release of a fraction of the caesium inventory in the cooling pools could cause up to 1,5 million fatal cancers.

Concentrations of most of the nuclides measured in samples taken in the La Hague environment reached their peak during the 1980s. Nuclide concentrations have decreased on average unequally, depending on nuclides and samples, by factors between 5 and 50 if compared to 1997 levels. These developments do not reflect the large increases in releases of some radionuclides (in particular tritium, iodine-129 and carbon-14). However, there is a notable lack of complete series of data and redundant measurements. Occasionally, there have been samples taken that exceed EU Community Food Intervention Levels (CFILs), in particular in crabs. While most of the samples are taken and measured by operators, it is remarkable that the highest readings were obtained by independent measurements.

Conclusions on Radionuclide Concentrations in the La Hague Environment

Radionuclide concentrations in the La Hague environment have generally decreased since the 1980s. However, a comprehensive trend analysis is difficult or impossible because of missing data on some key radionuclides. The sampling and analysis should be significantly extended in order to guarantee redundancy and a thorough analysis of the impact of the large increases in releases of some radionuclides during the 1990s.

Calculated doses from routine radionuclide releases of the La Hague reprocessing plant generally remain small and well within the EU limits. However, the uptake of radioactivity taken into account in critical group scenarios is very small and can be reached with very small amounts of higher contaminated foodstuffs. Doses can increase accordingly through the consumption of such foodstuffs. The cumulative effective doses induced by the consumption of seafood, as calculated under German statutory dose assessment assumptions, significantly exceed German and EU dose constraints. It is questionable whether the current French practice of dose assessment can be considered conservative.

Conclusions on Doses Induced by La Hague Discharges

Calculated doses from routine releases at La Hague generally remain well within EU limits. However, doses calculated under German statutory dose assessment assumptions exceed German and EU dose constraints. The La Hague reprocessing plants would not be licensable in Germany. The current French dose assessment practices do not appear to be conservative.

In 1983, morbidity was found to be higher than expected in the greater La Hague area for men in case of leukaemia and respiratory organs, and for women in case of leukaemia and lung cancer. Moreover, mortality data show an increased rate of cancers for the digestive organs in the Department. In 1995, a study identified an excess of leukaemia cases among persons aged 0-24 years living in the canton about 10 km from the La Hague plant. In 1997 case control study, the authors claimed "convincing" evidence for a causal role in childhood leukaemia for environmental radiation exposure from recreational activity on beaches and fish and shellfish consumption.
In 1999, the GRNC (Groupe Radio-écologique Nord-Cotentin) reported that the contribution to doses from nuclear facilities was low, as regards the increased incidence of leukaemia revealed in earlier epidemiological studies. While GRNC calculated individual doses up to six times higher than the operator values, these did not exceed 6% of the EU annual limit. The report stated that the result was an average estimate and that uncertainty margins were not quantified. The quantification of these uncertainties is currently underway.
In June 2001, a new study confirmed earlier findings on leukaemia in the La Hague region. The study indicated that the increased incidence was continuing, and provided more data to allow statistical significance to be established for the increases in leukaemia in the La Hague area.

Conclusion on Health Effects around La Hague

A statistically significant increase in the incidence of leukaemia in the La Hague area has been established. This increase is continuing. There is, as yet, no conclusive evidence for a causal link to radioactive releases from La Hague. However, these cannot be ruled out as a factor contributing to the health effects observed.

The assessment of doses and their effects are surrounded by many uncertainties. These include errors in assumptions on parameters, errors in computer codes, measurement errors and paucity of environmental monitoring. GRNC has identified more than 4,000 parameters, including 200 critical parameters, in its methodology to assess dose impact.
On the question of iodine-129 releases, WISE-Paris has quantified the differences between the theoretical activity in spent fuel and the activity discharged to sea and air. Large gaps are observed in the beginning of the 1990s, as only 50% of the theoretical values were reported discharged. In the worst case, the committed collective dose from non-attributed iodine-129 in the period 1989-1999 would be about the magnitude of a serious nuclear accident such as the Windscale fire (Sellafield) or the Kyshtym (Russia) waste explosion in 1957.
The Precautionary Principle is clearly laid down in various binding international agreements (e.g. Agenda 21, EC Treaty). In 1992, Agenda 21 pointed out that radioactive wastes are among *"the contaminants that pose the greatest threat to the marine environment."* The Earth Charter of March 2000 calls notably to *"place the burden of proof on those who argue that a proposed activity will not cause significant harm, and make the responsible parties liable for environmental harm."*

Conclusions on Uncertainties and the Precautionary Principle

Many uncertainties remain regarding dose assessments. In addition, error margins may be large and might modify assessed doses significantly. Under these conditions, the continued release of large quantities of radionuclides into the environment from Sellafield and La Hague violates the Precautionary Principle.

7. Comparative and Cumulative Analysis

Differences exist in effluent treatment between Sellafield and La Hague. Carbon-14 which is the major contributor to collective doses, for example, is partially removed from air emissions at Sellafield while all of it is released at La Hague. Its abatement is not considered cost effective by Cogema.
In 1999, a representative year, releases from La Hague and Sellafield were broadly comparable. In general terms, La Hague discharges were marginally greater than those from Sellafield, except for iodine-129 and tritium air emissions and technetium-99 liquid discharges.
Until 1992, Sellafield and La Hague released a total of some 1.2 tonnes of iodine-129 to the environment. This is several hundred times that

released at Chernobyl. In the period 1993-1998, a further 1.7 tonnes of iodine-129 were discharged (of which 80% from La Hague). Iodine-129 discharged from La Hague and Sellafield in 1999 alone was eight times greater than that released by the fallout from all nuclear weapons testing.

Conclusions on Comparative and Cumulative Analysis

In 1999, radioactive releases to the environment from La Hague and Sellafield were broadly comparable. Iodine-129 discharged from La Hague and Sellafield that year was eight times greater than the total iodine-129 released by the fallout from all nuclear weapons testing.

The estimated global collective dose of a decade of radioactive releases from Sellafield and La Hague (77,000 manSv) corresponds to about 1/7 of the collective dose from the Chernobyl accident, or to a Kyshtym scale accident every year. This raises the question of the justification of these releases as required under the radiological principles of the International Commission on Radiological Protection.

Also, in conventional cost-benefit studies, monetary values are attributed to a human life. When applied to untruncated global doses from 10 years' of Sellafield and La Hague releases, very large sums are obtained (£ 1.8 and 5.9 billion – respectively 2.9 and 9.4 billion Euro): the amounts that therefore could be spent on abatement measures comfortably exceed annual operating profits at each site.

8. Alternative Options

Non-reprocessing options, and available dry storage technologies in particular, are considerably less expensive than reprocessing. In addition, their social and political acceptability are much greater than reprocessing. Nuclear utilities are increasingly moving towards dry storage solutions, including utilities in the US, Canada, Germany, Russia and many eastern European countries. Direct disposal options also significantly reduce waste volumes to be disposed, due to the large volumes generated by reprocessing.

General Conclusions

Reprocessing of spent nuclear fuel at Sellafield and La Hague constitute the world's largest man-made releases of radioactivity into the environment, corresponding to a large-scale nuclear accident every year. Some of the radionuclides released in great quantities have half-lives of millions of years. Concentrations identified in recent years in the environment repeatedly exceeded EU Community Food Intervention Levels (CFILs).

The 1990's trend to large increases in the discharge of certain key radionuclides at Sellafield and La Hague and planned increases in releases constitute a violation of the letter and spirit of the OSPAR Convention.

Accidental radionuclide releases from Sellafield and La Hague could be two orders of magnitude larger than the Chernobyl disaster releases and could lead globally in both cases to over one million fatal cancers in the long term.

The European Commission does not effectively use its verification rights. The Commission is highly dependent on information provided by Member States and is therefore apparently not in a position to guarantee that the Basic Safety Standards are respected in the La Hague and Sellafield facilities. It is doubtful whether the Commission is in a position to determine whether the reprocessing activities are liable to result in the radioactive contamination of the water, soil or airspace of another Member State.

Operational and/or accidental releases from Sellafield and La Hague have led in the past to population doses that exceed current EU limits. Reprocessing alone accounts for about 80% of the collective dose impact of the French nuclear industry. In the UK, about 90% of nuclide emissions and discharges from the UK nuclear programme result from reprocessing activities.

In the surrounding regions of Sellafield and La Hague a statistically significant increase in the incidence of leukaemia has been established. While research on the causal relationship with environmental radiation has not been conclusive, it cannot be ruled out that exposure to radiation is an initiating or at least a contributing factor.

There are great uncertainties involved in the assessment of population doses and subsequent health effects. The release of large quantities of long lived radionuclides at Sellafield and La Hague therefore violates the Precautionary Principle, laid down, inter alia, in the European legislation, Agenda 21 and the Earth Charter of March 2000.