06

445.72 +
4422

European Communities

EUROPEAN PARLIAMENT

Working Documents

1977 - 1978

16 March 1978

DOCUMENT 576/77/ANNEX

OPINION

of the Committee on the Environment,
Public Health and Consumer Protection

on the need for Community measures in connection with the removal of radioactive waste as part of Community energy policy

and on the proposals from the Commission of the European Communities to the Council for

- a draft Council resolution on a Community plan of action relating to radioactive wastes
- a draft Council decision on the establishment of a high-level Committee of Experts to assist the Commission on matters concerning the implementation of a plan of action on radioactive wastes
  (Doc. 255/77)

Draftsman: Mr L. NOE'

122

On 16 March 1977 the Committee on the Environment, Public Health and Consumer Protection appointed Mr Noe' draftsman of an opinion for the Committee on Energy and Research on the need for Community measures on the dismantling of nuclear power stations and the hazards and expense involved in the final disposal of radioactive waste within the framework of the Community energy policy.

It discussed this subject at its meetings of 28 April, 24 June and 26 September 1977.

The European Parliament was meanwhile asked for its opinion on a communication from the Commission to the Council on a Community plan of action in the field of radioactive wastes.

On 26 September 1977 the Committee on the Environment, Public Health and Consumer Protection again appointed Mr Noe' draftsman of an opinion for the Committee on Energy and Research.

It decided to incorporate this opinion on the communication from the Commission within its original opinion.

It considered this opinion at its meetings of 20 October, 19 December 1977 and 26 January 1978 and adopted it unanimously on 26 January 1978.

Present: Mr Ajello, chairman; Mr Jahn, vice-chairman; Mr Noe', draftsman; Mr Alber, Mr Brown, Mr Edwards, Lady Fisher of Rednal, Mr Schyns, Mr Spicer and Mr Veronesi.

INTRODUCTORY STATEMENT

Apart from nuclear power-stations, the generation of electricity using nuclear fission as the heat source also requires other installations for the various operations at different stages in the fuel cycle.

Some of these operations take place prior to the generation stage (extraction of the ore and production of uranium oxides, conversion, enrichment, reconversion and production of fuel), others are carried out subsequently (reprocessing of the irradiated fuel, temporary and then final storage of radioactive waste).

Apart from atmospheric pollution, which is often serious during periods of operation, conventional power-stations create no waste problems (at most there might be some difficulty with ash deposits in the case of thermal power-stations); with nuclear power-stations, on the other hand, the main problem is the disposal of irradiated fuel which is discharged from the reactor when spent and difficulties arise depending on how it is dealt with.

This report will examine the foreseeable repercussions on the environment of all the operations mentioned above.

Since there are various ways of carrying out some operations, we intend to examine in general terms those which can reasonably be foreseen, in order to assess their relative effect on the environment, without giving any value judgments, this being the responsibility of the Committee on Energy and Research.

1. - Alternatives in the nuclear combustion cycle

Let us consider three possibilities:

1.1 - nuclear energy without reprocessing spent fuel;
1.2 - recycling of plutonium and uranium;
1.3 - the thorium option.

1.1 Nuclear energy without reprocessing spent fuel

1.1.1 The first alternative corresponds to the idea put forward last spring by President Carter, which has, however, been rejected at least in part by the US Congress.

1.1.2 Under this scheme, irradiated fuel would be deposited for a certain length of time in suitable cooling tanks.

1.1.3 A decision on how and where to store the irradiated fuel definitively would be left until a later date.

1.1.4 This is not a simple matter; a Vice-Chairman of ERDA, acting on Carter's policy advice, set up within his own organization an examination of the containers and sites to receive the irradiated fuel, after an initial period in the cooling tanks, pending a definitive decision - after a period of not more than twenty years - whether to reprocess the fuel or to store it definitively in more suitable places under more suitable conditions.

1.1.5 Without going into details here, the solution to the problem of definitive storage presents far fewer difficulties in the United States than in Europe, given the availability in the USA of wide uninhabited spaces which sometimes, as in New Mexico, have large salt deposits in the sub-soil, in other words, an impermeable environment which is ideal for the proposal under discussion.

1.1.6 Furthermore, the wide availability of natural uranium in the United States and its substantial other fuel resources (coal) would make a policy of this kind far more acceptable in America than in Europe; such a policy would involve, as we shall see, much greater consumption of natural uranium for the generation of an identical quantity of energy.

1.2 Recycling of plutonium and uranium

1.2.1 For some time the Community has advocated in the Member States the practice of reprocessing irradiated fuel discharged from nuclear power-stations with the dual aim of

(a) preparing long-lived radioactive waste in such a way that it can be kept in storage for an indefinite length of time with the least possible risk to the environment;

(b) recovering from the used fuel the low-enriched uranium and plutonium. The uranium reclaimed in this way can then be used to produce new fuel while the plutonium can be used in two ways: it can either be stored before being used as fuel for reactors, or be used to replace enriched uranium in the fuel for the light water reactors at present in use.

1.2.2 This practice was, moreover, shared by all countries in the world, including the United States, at least until the recent declaration by President Carter.

1.2.3 We feel that the Community and the largest industrialized countries, including Japan and the Soviet Union, will continue to follow this practice and it is possible that the United States will return to it after a pause for reflection.

1.3 The thorium option

1.3.1 The uranium-thorium cycle has, from the outset, formed part of nuclear energy research, particularly in the United States.

1.3.2 The experience gained in the last few years of the uranium-thorium cycle and, on a much wider scale, of the uranium-plutonium cycle led to the conclusion that from a technical and economic point of view the uranium-plutonium cycle was to be preferred.

1.3.3 Consequently, the knowledge available about the uranium-thorium cycle is at present very limited and the development of this cycle is much less advanced, especially as far as fabrication and reprocessing of the fuel is concerned.

1.3.4 In the uranium-thorium cycle, thorium, which is a fertile material, is transformed into a fissile isotope of uranium (uranium 233), which can be used for energy production.

1.3.5 The fabrication and reprocessing of the fuels used in the uranium-thorium cycle poses certain technical problems which have not yet been resolved at the industrial level and reliable sources have said that the uranium-thorium cycle cannot reach industrial maturity in less than twenty years, even if this development were allocated sufficient funds.

2. Sources of radioactive waste and effluents

Radioactive waste deriving from the nuclear industry mainly consists of radionuclides produced by fission and consequently known as 'fission products', which accumulate in the fuel elements, plutonium and other transuranium elements during irradiation within the reactors.

Radioactive waste also includes the so-called activation products, consisting of elements which become radioactive when exposed to the neutron flux of a nuclear reactor.

All these radionuclides are present in radioactive waste, to varying degrees according to their source.

If we exclude military applications and others on a modest scale such as those by research centres, universities and hospitals etc., virtually all radioactive waste today derives from the industrial processes which constitute the fuel cycle and in particular, within this cycle, from the chemical reprocessing of irradiated fuels.

The attached diagram gives a simplified picture of the entire nuclear fuel cycle, showing the estimated quantities of radioactive waste produced each year at each stage of the fuel supply process for a nuclear power plant with a light water reactor of 1,000 MWe.

The diagram shows that the processes prior to the irradiation of uranium in nuclear reactors produce only limited quantities of radioactive waste (this is also true of thorium); in addition, this waste has an extremely low radioactivity level and virtually negligible radiotoxicity. However, during and following irradiation there is an increase in both the activity level and radiotoxicity; the production of plutonium for fast reactor fuels gives rise to waste having a low level of activity but considerable radiotoxicity.

Radioactive waste is generally classified according to its specific radioactivity, viz.:

- high-level, exceeding 10^4 Ci/m^3 [1]
- medium-level, between 10^4 and 0.1 Ci/m^3
- low-level, between 0.1 and 10^{-6} Ci/m^3.

The relative radiotoxicity of a radioactive substance is also defined as the volume of drinking water in m^3 in which the activity of this substance in Ci must be diluted in order to arrive at the maximum permissible concentration.

[1] Ci = curie: unit of radioactivity equal to 3.7×10^{10} disintegrations per second

To obtain a clearer understanding of the problems involved and the quantities of waste produced at each stage of the fuel cycle, we shall consider the main stages of the cycle one by one.

A separate section will deal with the shutdown and final decommissioning of nuclear power stations, when relatively large quantities of active and contaminated material arise. However, its level of activity remains low compared with that of irradiated fuel.

2.1 Plants for uranium production and enrichment, conversion and fuel production

If uranium is to be used in nuclear reactors, it must be fabricated into fuel elements which, in large modern power stations, consist of rods of ceramic oxide clad in zircaloy or stainless steel (depending on the type of reactor).

During the mining and extraction of uranium, its enrichment in U-235 and fabrication into bundles of rods, waste is produced which contains merely the natural decay products of uranium. However, where the uranium has been recovered from the reprocessing of irradiated fuel, it also contains fission products.

Natural uranium contains approximately 14 radioactive nuclides in mutual equilibrium and of two main types (U-238 and U-235).

It might be added that it is the activity of these radioisotopes which is used in the search for ore containing uranium.

During the processing of the ore the other chemical elements are separated from the uranium: the activity of the uranium ore decreases while that of the other materials increases.

The extraction and grinding of uraniferous ore does not produce liquid waste. It does, however, produce dust which gives off the gas radon, which, together with its radioactive decay products represents one of the main sources of problems for work in mines, especially for excavation in underground galleries.

For the next stage in the preparation of uranium concentrates (the so-called 'yellow cake'), **wet** - way chemical processes are used producing low-level waste which may be both solid and liquid.

The former consists of the ore residue from which the uranium has been extracted and accumulates in large quantities near the plant (the percentage of uranium in uraniferous ore is generally extremely low, approximately

0.1%). This material continues to emit radon-222 for thousands of years; however, if properly dried and buried - several feet underground - it represents no danger for the outside environment.

Concentration and purification plants produce a volume of liquid waste varying between 2 and 4.5 m^3 per tonne of processed ore and containing, apart from traces of uranium, uranium decay products with maximum activity of approximately 10^{-3} Ci/m^3.

Plants for converting uranium into hexafluoride and gaseous diffusion plants for the enrichment of uranium produce relatively small volumes of liquid radioactive waste with a low level of activity and amounting to a few cubic metres per tonne of processed uranium. This waste contains traces of uranium and decay products with a maximum concentration of 10^{-3} Ci/m^3, where there is no recycled uranium, and mainly derives from the decontamination of various equipment.

The solid waste originating from these plants mainly consists of contaminated items of equipment which, for various reasons, have been discarded.

The recycling of uranium recovered from fuel reprocessing has not so far been undertaken at industrial level, one reason being the wish to avoid contamination of isotopic enrichment plants by traces of fission products and transuranium elements.

In some cases preference has been given to the mixing of such uranium with uranium of different isotopic composition, either as UF_6 or directly at the nitric stage, thereby confining the problem of waste containing residual fission products to the fabrication stage alone.

The volume of radioactive waste from fuel element fabrication plants is less than that from the plants mentioned above, and in the case of new uranium elements has an even lower level of activity.

Liquid waste consists mainly of dilute nitric and hydrofluoric acid solutions containing uranium isotopes and, in cases where fabrication occurs some considerable time after the uranium has been purified, radioisotopes which have reformed from the decay of uranium.

In cases where new fuel elements are fabricated from thorium, the problem of radioactive waste is exactly the same. The quantities and activity concentrations in the waste are similar - the only difference being the radionuclides, which are those of the natural decay chain of thorium and have the same level of activity as those of the uranium decay chain.

2.2 Reactors

As a consequence of the fission process in a nuclear reactor, fission products originate within the fuel elements and contain isotopes of over 30 elements. Most of these isotopes are radioactive and these, together with primary radionuclides and decay products, represent a total of about 200 radioactive forms. These fission products weigh very little (about 900 kg per operational year in the case of a power station of 1000 MWe), but have an extremely high level of activity, mainly beta and gamma; the most significant of these products, in terms of both the quantity produced and, above all, their radiotoxicity, are Sr^{90} (t 1/2[1] = 28.8 years), Cs^{137}(t 1/2 = 30 years), Kr^{85} (t 1/2 = 10.3 years) and I^{131} (t 1/2 = 8 days).

In addition to fission, a process of neutron absorption always occurs in uranium which generates, through successive captures, the so-called transmutation products, the most important of which are plutonium, americium and curium. These elements, which do not exist in nature and are therefore also called 'synthetic actinides', all emit alpha rays and have a high degree of radiotoxicity, rendering them dangerous even in extremely low concentrations.

The process of neutron absorption in the other materials present in a reactor such as structural materials, coolant, corrosion products etc., together with other types of nuclear reactions, produce numerous other radionuclides, called activation products; most of these products may generally be treated as fission products.

When the reactor is operating, the fission products and actinides are enclosed within the fuel rods and are not, therefore, released into the coolant, except in cases of leaks in the cladding of the rods themselves.

Liquid and solid waste thus consists almost exclusively of activation products, the quantity of which mainly depends on the type of materials used and the degree of purity maintained in the coolant. In general, liquid waste also contains significant quantities of tritium, formed either by ternary fission (about 10^{-4} atoms/fission in thermal flux) and then diffused through the fuel cans into the coolant, or by nuclear reaction with boron which, in chemically controlled pressurized water reactors, is continually present in the coolant to control reactivity.

Gaseous waste, on the other hand, which is invariably of limited quantity, frequently contains, in addition to activation products, small quantities of fission gas which escape through micopores which form in

(1) t 1/2 = half-life, i.e. time required for the activity to reduce by half

the fuel element cans during irradiation.

The radioactive waste produced during the normal operation of a power station mainly results from the purification of the primary coolant, and consists of spent resin, washing solutions of the latter and various filters, in addition to the inevitable losses of coolant from the tanks. This waste may be either liquid, solid or gaseous, and its activity level varies considerably.

There are also other types of waste which are produced by the auxiliary services of a power station, such as the air used for ventilation and cooling in all hot areas, liquids deriving from the decontamination of machinery, the active laundry, the laboratories etc.. The concentrations of this waste too may vary considerably.

Finally, another category of radioactive waste consists of activated or contaminated equipment and machine components, maintenance materials, various tool, laboratory materials etc..

However, all this waste produced within the power station is always subjected to special processing to prevent it from contaminating the outside environment.

Gases which often contain solid (dust) and liquid (aerosol) substances are filtered and, where they contain iodine, krypton and xenon isotopes, are also subjected to special retention processes which prevent them from being fully released, at least until they have decayed. However, up to approximately 500 Ci of these isotopes may be released each year by a power station of 1000 MWe, thereby discharging a small percentage of natural radioactivity into the environment, representing less than the existing variations of natural radioactivity between different areas within a given region.

Liquid waste is always filtered, concentrated or purified with ion-exchange resins to reduce the volume of radioactive materials; this process produces, firstly, a purified liquid which can either be reutilized in the power station or disposed of outside, provided that its radioactive content does not exceed the permissible limits, and, secondly, a concentrated liquid (sludge) or resins and contaminated filters.

The quantity of radioactivity released into the environment is extremely low (a few Ci per year depending on the type of radionuclide it contains); however, concentrates are produced which, depending on the type of plant, may total 100 m^3 per year at medium and low level (max 500 μ Ci/g) with overall radiation of approximately 200 Ci per annum.

Solid waste may be classified as compactible and combustible or non-compactible and non-combustible.

A 1000 MWe power station produces high-level solid waste to the extent of a few m^3 per year with a total activity of approximately 5 Ci per year.

2.3. Reprocessing plants

Spent fuel discharged from power stations after irradiation in the reactor is at present placed in cooling tanks, which ensures the natural decay of radionuclides with short half-lives.

During the first year, about 98% of the initial radioactivity of the fission products decays spontaneously.

Cooling facilitates the subsequent operations of handling the fuel elements, particularly as regards their transport and reprocessing.

Following the recent crisis concerning the reprocessing of industrial fuels, which was mainly of a political nature, provision has been made for medium-term storage of fuel elements either in the power stations' cooling ponds, whose storage capacity has been appropriately increased, or in suitable disposal tanks. With an open uranium cycle of this nature, the problem of disposing of radioactive waste is postponed at least 10 to 20 years.

Under such a system, only limited quantities of liquid or solid radioactive waste would be produced, as a product of the continuous process of purifying the water from these tanks.

However, the purpose of reprocessing irradiated fuels is not only to recover the uranium and plutonium suitable for further use, but also to prepare the radioactive waste so that it can be finally disposed of with minimum danger for the environment. It is therefore logical to conclude that the reprocessing of spent fuels must be postponed for some years; medium-term storage (for about ten years) would not give rise to serious technical difficulties or economic repercussions.

However, long-term disposal of the fuel elements themselves is technically difficult and, above all, would present certain dangers if extremely rigorous conditions were not complied with.

In reprocessing, the fuel elements are dismantled, the fuel dissolved and uranium and plutonium, inter alia, are recovered from the solution by solvent extraction.

These operations produce two categories of radioactive waste: the first, containing an extremely low radioactive content, may be disposed of by being discharged into the environment in full compliance with existing standards; the second, which contains a quantity of radioactivity with a very long half-life, must be isolated from the biosphere for extensive periods (some such radionuclides have half-lives of hundreds of thousands of years). The latter constitutes the high-level radioactive waste which has become a new problem at industrial level, as it must be confined within strict limits over very lengthy periods. The problem of its disposal is not only industrial but also political; public acceptance of the danger represented by the existence of such waste is today considered a vital condition for the effective development of nuclear energy.

However, it must be pointed out that the quantity and, above all, the volume of this waste could be greatly reduced: its disposal is not, therefore, either a technical or an economic problem.

For example, following appropriate processing, the high-level waste produced in supplying all the electrical energy consumed by one individual throughout his life is equivalent in size to about 100 aspirin tablets.

As regards the quantity of radioactive waste produced by a reprocessing plant, the quantity of fuel discharged each year by a 1,000 MWe power station creates approximately:

(a) - First category (low-level waste):

- liquid: 40 m^3 per day containing one millionth of the activity of the fuel discharged;

- solid: 100 m^3 per year containing one millionth of the activity of the fuel discharged;

- gaseous: 200 m^3 per minute containing one tenth of one millionth of the activity of the fuel discharged (mainly from the ventilation plant).

During the chemical treatment of the spent fuel, tritium and fission gases (Kr^{85}, I^{129}) are released, which may either be discharged into the atmosphere in small quantities, or placed in cylinders and left to decay. Approximately 0.1 m^3 are produced per year (compressed to 150 atm) with total activity of 0.25 MCi.

(b) - Second category:

- high-level liquid waste (already concentrated): 8 m^3 per year containing approximately 1.2% of the activity of the fuel discharged;

- medium-level solid waste: 50 m^3 per year containing approximately 1/100,000 of the activity of the fuel discharged;

- solid waste contaminated with plutonium: 1 m^3 per year containing approximately 1/10 of one millionth of the activity of the fuel discharged.

High-level liquid waste mainly derives from the solutions used to treat the irradiated fuel, following the first cycle of uranium and plutonium extraction. The aqueous solution retains practically all the fission products, small residual quantities of uranium and plutonium (up to approximately 0.5% of the original quantity) and all the remaining actinides; total activity is approximately 80 MCi beta + gamma.

Medium-level solid waste mostly consists of sections of the cans and structural parts of fuel elements produced during the dismantling and chopping of irradiated elements which, even after several successive washings, still contains traces of irradiated fuel; its radioactivity is approximately 0.8 MCi beta + gamma. In addition to this waste there are spent resins, filters, sludge etc. and all solid waste produced in the plant during the processing of active affluents.

A final category of solid waste which is to some extent alpha-contaminated (above all by plutonium) consists of all the tools, gloves, paper etc. which have come into contact with plutonium, particularly during the purifying stage. Taken together, this waste may contain about 1 kg of plutonium.

2.4. Fuel fabrication plants

The uranium and plutonium recovered from the reprocessing of used fuels may be recycled in the reactors together with fresh material.

Whereas the recycling of uranium alone inevitably produces low-level radioactive waste, the recycling of plutonium produces waste which, because of the presence of the plutonium itself, contains alpha-activity and has a half-life of approximately 25,000 years.

Its level of activity, in terms of radiotoxicity, is more closely comparable with that of waste from reprocessing plants than that from fabrication plants.

The recycling of plutonium involves the fabrication of oxide fuel elements of mixed uranium and plutonium oxide. If the recycling is carried out in thermal reactors, it is estimated today that the annual refuelling of a water reactor containing 500 to 700 kg of Pu produces 10 to 50 m^3 of solid or solidified waste containing 5 to 10 kg of plutonium. This represents a considerable production of alpha-active waste, and the recycling of plutonium at industrial level calls for both the development of optimum fabrication techniques to reduce the production of waste, and the use of suitable techniques to reduce the volume of the waste itself.

The quantity of alpha-active waste is even greater in the fabrication of mixed oxide elements intended for fast reactors, as the annual refuelling of a 1,000 MWe fast reactor involves more than twice as much plutonium as in the previous case. However, we lack reliable information on waste resulting from the fabrication of fuel elements for fast reactors.

The refabrication of thorium fuel elements is based on the recovery of U-233, which is produced by conversion from Th-232.

The use of U-233 raises serious problems during fabrication, owing to the high activity level of U-232, a by-product of the reaction of absorption of Th-232, which is always to be found with U-233.

In order to avoid the problems of refabrication, it is today proposed to adopt an open thorium cycle, in other words without reprocessing and refabricating the fuel.

However, there is a lack of reliable data on the production of radioactive waste from the fabrication of thorium fuels.

2.5. Shut down and decommissioning of nuclear power stations

The final decommissioning of a nuclear power station calls for the removal of the reactor core and the dismantling of all structures, including those which have become activated and contaminated during operations.

Broadly speaking, the decommissioning of a power station may be carried out in three successive stages: the first, which consists of removing not only the fuel but also all radioactive waste which has accumulated in the power station during operations, is completed immediately after the decision to close down the plant. The other two stages may be implemented at a later stage, depending on the future use to be made of the site. If another power station is to be built on the same site, it may be preferable to postpone the subsequent stages so that most of the activity can decay.

Any such postponement is facilitated by the presence on the site of a nuclear authority, which makes it possible to maintain the closed plant under strict surveillance.

The second stage consists of the dismantling of activated and non-activated buildings other than the reactor building. During this stage only a small part of the total radioactivity is removed, even though most of the site occupied by the plant is cleared.

The third stage consists of the complete dismantling of the reactor building and the primary circuit: this is the stage which poses the most difficult and complicated technical problems.

It has been estimated that, one year after the closing down of a 1,000 MWe reactor which has operated for thirty years, the level of activity of the most active parts breaks down approximately as follows:

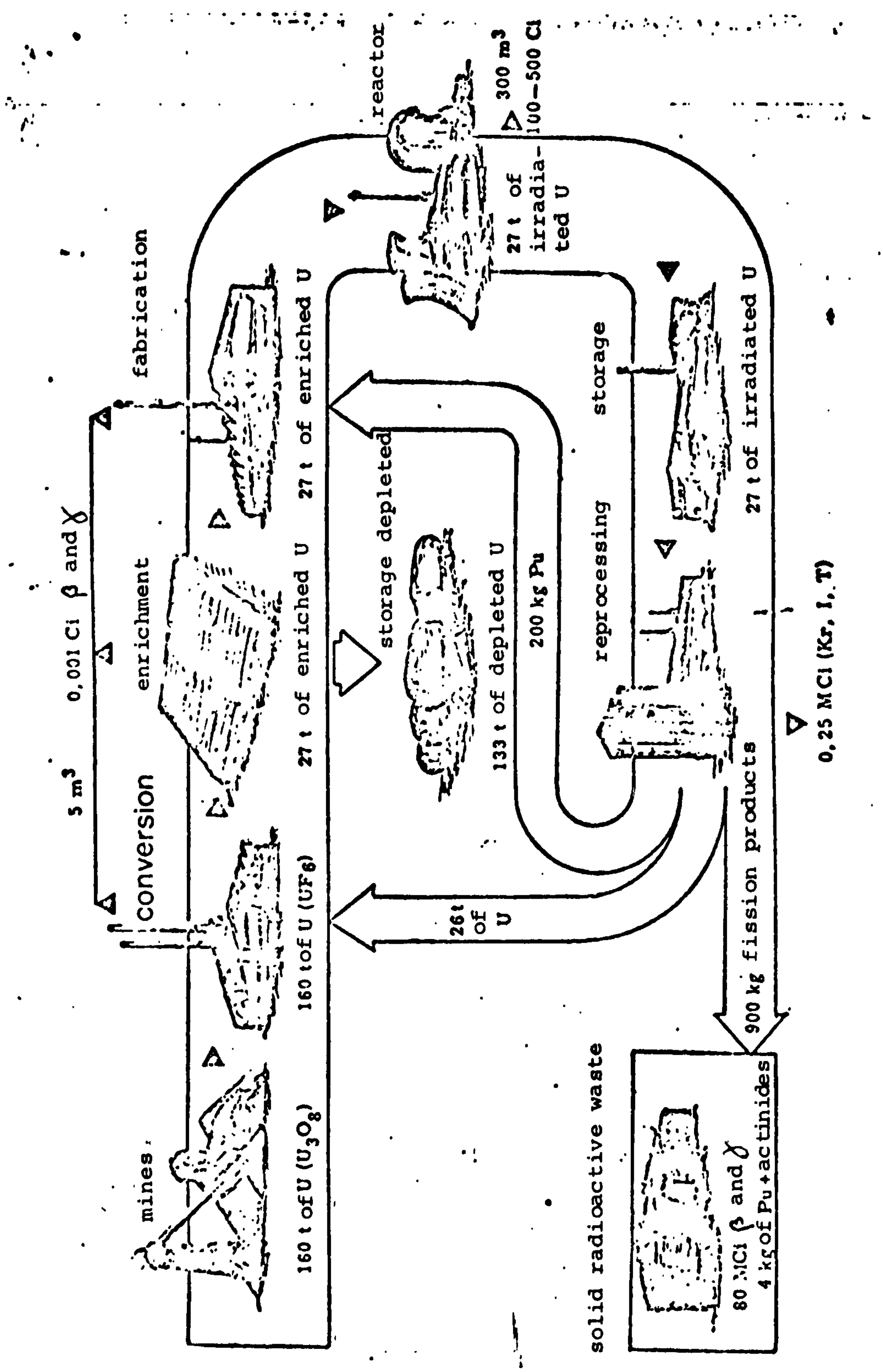
- Pressure vessel and internal components	700t of steel	10^6 Ci
- Primary circuit components	1000 t	medium
- Contaminated civil structures	1000 t	low-medium
- Contaminated auxiliary systems		low-medium
- Liquids from decontamination	10^4 m^3	medium
- Miscellaneous materials		low

Studies carried out by international bodies have not indicated the existence of insuperable technological problems; similarly, the subsequent stage of disposing of the material removed would appear feasible and not unduly expensive.

The decommissioning of a large power station has yet to be carried out, although small research reactors have been decommissioned in various countries. One example is the American Elk River reactor (22.5 MWe), the entire decommissioning of which was wholly successful, and its site cleared of all radioactive waste.

Fig. 1 - Fuel cycle for a light water reactor

The quantities given below have been calculated on the basis of the requirements and annual refuelling of a 1,000 MWe power station.



3. Management and disposal of wastes

3.1 Treatment of radioactive wastes

3.1.1 Reactor wastes

In general, the wastes produced in a reactor will receive specific treatments to reduce their final volume and to make them compatible with the conditioning technique. The waste which contains the largest amount of activity, although dispersed in a very large volume, stems from the purification system for the water of the primary system. After chemical pretreatment and partial dehydration, these substances (about 300m^3/year for a 1000 MWe light water reactor) are solidified in cement, bitumen or, more recently, in plastic resins. The final product is compacted in drums of 100/200 litres or in concrete blocks of about 1m^3 (for higher activities). Reactors also produce large quantities of dry wastes (cleaning rags, clothing, plastic sheets) ca 100m^3/a for 1000 MWe. which, according to the type of contamination they contain, can be incinerated or compacted to reduce the volume by factors of 100% and 10% respectively in order to facilitate final incorporation in concrete or bitumen.

3.1.2 Reprocessing wastes

The low and medium active liquid waste from reprocessing plants is generally treated and conditioned in the same way as liquid waste from reactors.

The other important types of waste from the reprocessing of irradiated fuel:

- Liquid high level waste (HLW)
- Solid middle level waste (cans and structural materials)
- Transuranium contaminated solid waste (TRU - waste or alpha-waste).

The liquid high level waste containing the bulk of the fission products is, at present, stored in leak-tight tanks. Special care in the design and construction as well as particular engineered safeguards have made tank storage a very satisfactory intermediate solution for this type of waste for a period of 20-50 years.

However, for final disposal this waste must be solidified and then placed in an environment completely isolated from the biosphere. Present schemes envisage the following main phases:

- treatment to remove the acidity (denitration)
- solidification in highly resistant glass
- loading in stainless steel canisters
- possible further storage for a determined period
- final storage or disposal in stable, impermeable geological strata.

The vitrified waste in its stainless steel canister prevents the release of all enclosed radioactive isotopes. It will, however, continue to emit intense gamma radiation and considerable decay heat for very long periods of time. Fission products maintain a primary role for several centuries (ca 800 years in terms of radioactivity and ca 400 years in terms of radiotoxicity) after which, the quantity of actinides present will determine how much longer it has to be kep in isolation. Solid waste made up of sections of cladding and the structural parts of the reprocesses fuel elements are less radioactive than the liquid high level waste and can be incoporated directly in concrete or embedded in low-melting metal alloys.

3.1.3 Wastes from enrichment, conversion and fuel element fabrication plants

The only active material contained in the wastes from these plants in fuel cycles without plutonium recycling, is uranium and its decay isotopes and thus, if suitably disposed, they will have no practical impact on the environment. At most these wastes might give concern because of the chemical toxicity of uranium and its compounds rather than because of their radioactivity.

Where plutonium is recycled, Pu conversion plants and factories producing plutonium fuel elements will produce wastes with high alpha activity due to plutonium contamination. In order to prevent the uncontrolled use of plutonium in weapons, the dispersion of this toxic substance into the human environment and, to a lesser degree, the loss of valuable fuel, the primary aim of waste treatment consists of recovering as much plutonium from the wastes as practicable by physical or chemical processes. The residual waste will contain such low quantities of plutonium that misuse can be ruled out.

These residues can therefore be fixed in concrete, glass or other substances for final disposal.

3.1.4 Decommissioning wastes

None of this waste is, by nature, easily released to the environment and the main problem probably resides in the difficulties of remote dismantling and cutting of activated and contaminated equipment in order to transport them to a disposal site in shielded containers.

If a reactor is decommissioned after a serious accident, plutonium can be present in the plant.

The highest contamination with alpha-emitters occurs in fuel reprocessing plants. Here in particular the equipment must be thoroughly decontaminated before dismantling a plant.

3.2 Storage and disposal of radioactive wastes

3.2.1 Disposal of conditioned low and medium active wastes

A number of disposal methods for low and medium active wastes have proven satisfactory

- trench burial (Infratom, Cap de la Hauge/France, DRIG/UK, Idaho, Oak Ridge/USA and others)
- final storage in salt mines (ASSE II/FRG)
- sea dumping (OLCD experimental programme).

3.2.2 Solidified high level wastes

High level waste is not yet conditioned industrially, and schemes for the final disposal of this waste are still under development: laboratory and inactive tests are being undertaken presently and it is thought that by 1980 preparations for the first test disposal in a salt mine will be completed.

The options presently under consideration for the final disposal of these wastes are:

- disposal in salt, clay and crystalline rock formations
- disposal on or under the sea bed.

Research and development on this subject has been slowed down considerably by legal and political problems. The main requirement for a final disposal method is the complete isolation of all radioactivity from the biosphere. The geological sites under consideration should have the following characteristics in common:

- a thick impermeable layer to prevent access of ground water
- extremely low probability of any perturbation in more than 100,000 years
- no conceivable incentive for future generations to disturb (mine) a repository.

In order to assess the long term effectiveness of the conditioning and possibly correct unforeseen errors, it is likely that the vitrified wastes will be stored in repositories from which they can be retrieved for examination after some 50 years.

Disposal in layers of rock or sediment under the sea could provide ultimate isolation as good as that of land-bound repositories. It will however be difficult to effect recovery for the purpose of short-term checks. Since there are many areas of uncertainty about submarine geology further investigations into undersea disposal methods will have to be made.

3.3 <u>The alternative solution: final disposal of irradiated fuel elements</u>

3.3.1 Technical aspects

Only fairly recently important efforts have been devoted to this alternative and projects are still at the conceptual stage. Irradiated LWR elements cannot be placed into a final storage or repository immediately, as they require a relatively long cooling period. During this time (5-10 years) they must be allowed to decay in a storage pool. However, as the cans containing the fuel elements could fail due to corrosion, the elements could be enclosed in sealed containers after the initial cooling period. Should the fuel element still release more heat at this time than can safely be removed in a dry container, empty space within the container could be filled with a low melting metal alloy.

After intermediate storage of 50 to 100 years these containers would be transferred to deep geological strata.

3.3.2 General aspects

Fundamentally, the amount of activity to be handled and stored is certainly higher for a 'throw-away' fuel cycle than for a Pu-recycling system, assuming that both systems have extracted the same amount of energy from the original fuel. The depleted fuel element repositories will after only about two centuries contain more actinide (Pu & Am) activity then fission product activity, whereas 99% of these isotopes could have been burnt in fast breeder reactors.

In respect of the overall volumes to be disposed of the alternative of not reprocessing irradiated fuel presents no major advantages.

Therefore, the 'throw-away' cycle, which provides for no recycling of material recovered from reprocessing, does not promise appreciable advantages in waste management. Its main argument, the improved safeguarding of fissile material, is of no relevance in this context.

4.1. General comments and the state of the art

The processes outlined above do not eliminate all activity from liquid or gaseous waste discharged into the environment. In some cases the gaseous waste contains radionuclides with very short half-lives (a few minutes) which may consequently be discharged, without being treated, after a short period of retention, as is the case for power reactors. In other cases, in the absence of proven techniques, some contaminated waste is released under controlled conditions which take into account the geographical location of the site, as in the case of reprocessing plants.

The radioactivity in liquid waste discharged into surface water is reduced to extremely low levels corresponding to the natural level in the water.

4.2. Radionuclides released into the environment by reactors and reprocessing plants

4.2.1. Nuclear power reactors

The gaseous effluents from reactors contain oxygen and nitrogen isotopes with very short half-lives which can be released after a decay period which virtually eliminates any activity.

Traces of the fission gases, xenon, krypton, iodine and tritium are occasionally present in waste following diffusion through the fuel element. The latest generation of reactors possess effective retention systems for all these effluents, with the exception of tritium, which may be spread through both gaseous and liquid waste. Carbon 14 represents a separate problem for which processing techniques do not exist, and remains the subject of serious studies. Activity levels in liquid waste from internal processing are generally extremely low (one picocurie per litre) and derive from fission or activation products.

4.2.2. Fuel reprocessing plants

The industrial reprocessing plants in operation today discharge into the environment fission gases contained in gaseous waste and fission products contained in discharged liquid waste. The problems of environmental contamination stem mainly from gaseous wastes, as the activity in liquid waste can be reduced to extremely low levels.

Newly-designed plants may not release liquid waste at all as the water can be recycled. The gaseous fission products contained in the fuel are released during preliminary processing. Up to now krypton, xenon and tritium have been disposed of by burning, while processing techniques have been perfected for iodine which reduce activity to approximately one thousandth. In the case of high-capacity plants beginning operations in the next few years, the granting of a licence to operate will in all probability require the total or partial elimination of krypton emissions, for which proven techniques exist for industrial applications.

Tritium and carbon C14 continue to pose more serious problems, as processing techniques in this field are still at the development stage.

4.3. Effects on the environment of the activity released

The most radiologically significant radionuclides released from reactors and reprocessing plants are those with medium and long half-lives, which may directly injure human health or, if allowed to accumulate, may cause an increase in the environmental radioactivity.

In all cases the waste discharged, whether on a routine or irregular basis, is always examined by the authorities in order to establish its radiological effects. For the reasons given above, the isotopes discharged in surface waters are of little significance, as their activity can be reduced to a negligible level.

The most important radionuclides discharged in gaseous waste, in terms of both concentration and half-lives are tritium and krypton. Tritium may be discharged as tritiated water vapour and inhaled as such. Krypton is less dangerous, being a chemically inert noble gas which is not absorbed to any great extent. Permanent contamination of the biosphere is also caused by iodine 129 and carbon 14. Current in-depth studies indicate that the uncontrolled release of radionuclides into the environment through the latter or through tritium would lead to the imposition of rigorous standards.

5. Risks to health from radioactive wastes

Of the anxieties of informed public opinion which sometimes find radical expression among groups demonstrating against nuclear power, the fear of the dangers to health to which present and future generations would be exposed is certainly one of the most important.

Even those who accept the safety of nuclear installations often express strong reservations about the ability to prevent risks and damage arising from the enormous quantities of radioactivity which, through the laws of physics, are the end product of the fuel cycle.

It must be admitted that these fears are well-founded inasmuch as the correct management of radioactive wastes is one of the most important problems in the protection of man and the environment from radioactivity. The problem is to find the appropriate technologies for handling, treating, storing and eventually finding a final natural site for the enormous quantities of radioactivity which result from reprocessing.

Far be it from us to minimize this problem: we must on the contrary stress very strongly that often national and even international programmes have given proportionately less attention to this sector than to the development of increasingly advanced nuclear reactors. However, we cannot accept wholesale - because it is untrue - the view held in certain quarters that in both theoretical terms and in terms of technological feasibility no adequate solutions can be found for the problem of radioactive waste from the nuclear fuel cycle.

Indeed, we would hasten to stress, with the support of the valuable study carried out by a group of international experts and published by the OECD in Paris in only the last few weeks, that on the theoretical level - that is to say the feasibility in principle, in reasonable economic terms - the problem of radioactive waste has certainly been solved, as we will see below.

We would also stress that the basic technology to put these theoretical solutions into practice exists and only requires research and development to make it more reliable and more economic.

The time has undoubtedly come in several countries to move into the demonstration stage of these theoretical and technological solutions. We must insist that the tempo be speeded up before the expansion of nuclear energy forces us to adopt irreversible solutions. We must use this period when nuclear energy still only produces a fraction of our energy production to carry out the demonstration stages for all steps in the waste management process.

Demonstration plants should therefore be designed, constructed and put into operation for the packaging of high level waste and waste containing alpha-emitters. Similarly, definitive disposal programmes must be implemented with limited quantities of radioactive waste for checking and collecting statistics.

These activities should preferably be coordinated and encouraged in an international context, because this would ensure better use of available resources and through the use of international teams would achieve a very high overall safety level. It should also be added that public opinion is more favourable to international programmes.

It is therefore the duty of all those who can influence the development of these programmes to make every effort at administrative and political level to ensure that not even one year is lost, to ensure that all the existing capabilities are coordinated, in order to move on from the research stage to the practical demonstration stage, under international guarantees and with international economic aid.

We will now consider some of the questions which require more detailed explanation.

5.1. Accidental escapes from reprocessing plants

For those who are unfamiliar with these matters, we should explain that reprocessing plants can be dangerous if the liquids used in the process (almost all highly radioactive) escape from the proper ducts through operational error or technological breakdown and leak into the sewers, the earth or the environment, causing contamination which is difficult to remove, rapidly becomes impossible to contain locally and spreads over large areas. As a result, surface and deep waters become contaminated, and through the various uses of water and the biological and food cycles, radioactivity reaches man and contaminates him.

These health risks can clearly be contained through correct plant management. Theoretically, accidental leaks cannot be excluded, but they must and can be prevented in the same way as any other technological accident which might have consequences on the external environment.

It should be pointed out right away that the problem of accidental leaks from reprocessing plants is less serious and more easily mastered than the same problem **where** nuclear reactors are concerned. In reprocessing plants the approach should be the same as the classical method in use for reactors:

- a safety analysis should be carried out considering all the possible causes or opportunities for malfunctioning or breakdown, to make provision for their removal and also reduce their consequences to a minimum by providing adequate protection with a sufficient degree of redundancy;
- accident analysis should be carried out which in a purely hypothetical manner should consider the occurrence of accidents which have nevertheless been excluded by the safety analysis described above. The accident analysis studies the hypothetical development and the hypothetical consequences of these accidents and provides details of the structural, operational and topographical precautions which would make it possible to reduce and eventually contain the accident entirely.

As can be easily ascertained from those acquainted with the modern science of industrial safety, the approach to the prevention of accidental leaks of radioactive substances from fuel cycle plants is no different from the problems of containing other highly toxic substances.

What should be stressed is that although there is an abundance of publications and guides, including international ones, on safety and accident analyses for reactors, there is a lack of publications and guides on similar analyses for fuel plants: here is a field to which attention should be drawn in the appropriate quarters.

5.2. Risks deriving from deposits of nuclear waste

While reprocessing plants present dangers from the processing liquids which may get out of control, deposits of nuclear waste present similar dangers, although generally less serious, since no processes or operations are carried out with the deposits and the aim is specifically to preserve the radioactive material in a stable condition.

A fundamental distinction must be made here between highly radioactive liquid deposits and deposits of solidified substances which are also highly radioactive. It is clear that the greatest potential danger arises from radioactive liquid substances, because if for any reason they escape from the deposit they can rapidly spread in the environment, which is not the case for solid substances, particularly if they present the right characteristics.

Here then is a major distinction, from which we would draw a recommendation of vital importance. We believe that reprocessing wastes can be stored in liquid form (which is the end product of the chemical process) only for a limited time, because preserving them in this form indefinitely would increase the environmental and health risk.

Efforts should therefore be directed towards operations involving the solidification of this waste and its preservation in appropriate deposits. Risks are thus reduced and more time is made available for finding a definitive solution without incurring possible criticism from public opinion or health authorities.

Solidification technology is available and some demonstration plants and plants on industrial scale already exist or are under construction.

Almost all operative schemes have now adopted the following stages in waste management:

- deposit on the site of the plant reprocessing highly active liquid wastes for a sufficiently long 'cooling' period, before passing to the subsequent stages;
- solidification on the site of the plant of highly active liquid wastes;
- controlled deposit on the site of the plant of the solidified products;
- transfer to the long-term repository, national or international or transfer to the site of final disposal.

The above procedures concern highly active wastes but a word should be said about low level wastes for which the above operations are excessively complex and unnecessary both from a technological and a health point of view. For these wastes, storage on the production site should take place after suitable packaging and for the period of time laid down by the authorities before transfer to the disposal sites which, depending on the circumstances, can be in trenches near the surface, in pits, by sinking in special areas of the ocean where there is no danger of the material returning to the surface, or, lastly, in deep cavities such as disused mines, caves and tunnels.

5.3. Risks deriving from the final storage of spent fuel

We will now consider the final stage in the correct management of radioactive wastes and residues: this is disposal or - as it is incorrectly called - final storage.

By the term disposal we mean the placing in appropriate sites of the waste material with no intention of recovering it and with the following guarantees deriving from our scientific knowledge:

- that this material will not come into contact with subterranean water;
- that it will not be uncovered by geological occurrences before the radioactivity is spent;
- that any movement, however limited, of the radioactive materials in the geological formations used will be such that the danger of the return of the radioactivity to mankind is negligible.

It should never be forgotten that man comes into contact with radioactivity every day, breathing air containing radon and other naturally radioactive products, consuming food and drink containing naturally radioactive potassium and so on.

The long definition we have given of disposal requires some comment.

As a general rule, siting will be in deep and stable geological formations with a well-known geological history making it possible to predict that they will remain unchanged for hundreds of thousands of years, just as they have remained for millions of years in the past.

We are all aware that geology is accustomed to dealing with extremely long periods of time compared with the duration of human life or human civilization. It is not therefore impossible, indeed it is not very difficult to find in the depths of the earth's crust formations providing the above guarantees and capable of receiving materials with extremely long life such as plutonium, thus permitting complete extinction of the radioactivity.

Indeed, a natural example of this possibility recently came to light in the studies made of the 'Oklo phenomenon' in Gabon. Recent research has shown that 1800 million years ago, when the earth was still young, there occurred locally a kind of nuclear reactor with fission chain reactions which continued for a long period of time. Now these nuclear reactions produced plutonium. The important point is that this plutonium remained trapped in the surrounding geological formations until it decayed completely and disappeared, as has been demonstrated by recent sophisticated methods of analysis. So nature itself succeeded almost 2000 million years ago in producing a nuclear reactor, in 'dismantling' it and in disposing of its waste. We have proof that this waste did not move from the original site and, over the geological eras, disappeared completely.

In the definition of disposal we stressed the need for waste to be kept <u>isolated</u> from subterranean waters to prevent radioactivity reappearing in surface water. We also stressed the need for <u>geological stability</u> in the formations, which must be unaffected by phenomena connected with the presence of major faults or readjustments in the earth's crust. Lastly, we pointed out that for these geological formations, such as clay, (in which contact with water is prevented by its very low permeability) <u>environmental assessments</u> should be carried out to provide suitable guarantees.

We have paid special attention here to final disposal in deep formations in the earth's crust because this appears today to be the most attractive and safe prospect from a technological and health point of view. For the sake of completeness, we should add that there are theoretical alternatives to these solutions consisting of siting on special areas of the sea bed, siting in geological formations below the sea bed, siting in the icecaps, the launching of waste into space in missiles to beyond the field of gravity of the earth or the sun and lastly, the nuclear transformation of the waste itself by bombarding it with neutrons in special nuclear reactors.

This list merely gives an idea of the variety of studies and alternative solutions which are under examination. It is not intended to detract from what appears to be the optimum solution at the present time and on which we have dwelt at greatest length: siting in deep geological formations.

After this description of the risks deriving from wastes we feel we should insist on the fact that these are not qualitatively different from the well-known dangers from all ionizing radiation.

The difference arises from the enormous quantities of radioactivity (curies) with which we have to deal; and also from the need to solve the problem of disposal in our own generation without leaving a dangerous legacy to future generations. We enjoy the benefits of energy from nuclear sources, it is our duty not to lay an excessively heavy economic and health burden on succeeding generations.

To this end, we must direct the focus of the various nuclear programmes, of the many international projects and of public and political opinion towards those small and medium-scale operations demonstrating the definitive disposal of high-level wastes which are at the heart of the correct management of wastes from the nuclear programmes of the Community countries.

By the end of the 1980's the nuclear programme will be on such a scale that valid solutions from the technological and health points of view will have to have been found some time previously. If we are to be prepared when that time comes we will have to speed up our work in this field.

6. CONCLUSIONS

6.1 The complexity of the technical problems, and in particular the philosophical, political and often 'metaphysical' nature of the major debate on nuclear energy for the most part lead to unproductive dialogues between opposing factions without any tangible results and to the certain detriment of society as a whole.

6.2 Believing that it had a duty to make every effort to avoid this trap, the European Parliament's Committee on the Environment, Public Health and Consumer Protection has tried to adopt a more selective and specific approach and to take account, in a realistic manner, of all the facts available.

6.3 Thus, it fully realizes that:

- The use of nuclear energy for the generation of electricity is a well-established technique - so much so, in fact, that the main problems involved are already making themselves felt or will soon do so. These problems should therefore be taken seriously in every Member State of the Community, and should be investigated by the European Parliament, regardless of the basic arguments for or against nuclear power. Moreover, the Committee on the Environment welcomes the initiative taken by the Commission of the European Communities with a view to stimulating a wide-ranging public debate on this matter, to which it hopes to be able to give active support.
- It is valuable to make a distinction between the problems connected with the desirablity of the non-proliferation of nuclear arms and those connected with the impact of nuclear power on the environment. Both of these aspects are important, but their political, philosophical and even technical implications are sufficiently different for them to be treated separately. Indeed, it is desirable that such a distinction should in fact be made if attention is to be focused on environmental problems and not diverted to even more complex issues which are even less capable of objective evaluation.

6.4 Within the limits of this voluntary restriction on the scope of its deliberations and debates, the Committee on the Environment considered the problems raised by:

(i) the extraction and processing of uranium and thorium ores;

(ii) the operation of nuclear power-stations in normal running conditions;

(iii) the risks and consequences of possible accidents;

(iv) the processing and possible recycling of irradiated fuels; and

(v) the disposal of radioactive waste.

6.5 Its conclusions and recommendations are as follows:

(i) The extraction and processing of uranium and thorium ores would not seem to represent an important problem in any of the territories of the Member States of the Community. However, studies on the protection of workers and the environment should be followed through in those countries where uranium mining is fairly extensive.

(ii) Attention should be drawn to two distinct aspects of the operation of nuclear power stations under normal running conditions, namely radioactive pollution and thermal pollution. As regards radioactive pollution, credit must be given to industrialists for the fact that, over the years, the radioactivity of liquid and gaseous effluents has been reduced to levels comparable to or lower than those occurring in nature. However, it should not be forgotten that it is very important to continue to study the long-term consequences of radiation and its effects on health. Thermal pollution cannot be ascribed entirely to nuclear power, although nuclear power-stations at present discharge considerably more waste heat into cooling water than conventional coal- or oil-fired power-stations. There has so far been no real cause for alarm, mainly thanks to the efforts of producers of electricity; however, considerable problems could well arise in the relatively near future. The economic disadvantages of discharging waste heat from power-stations directly into the atmosphere seem small by comparison with the disadvantages connected with the use of rivers. It is strongly recommended that work should be directed towards this end.

(iii) The risks and consequences of possible accidents represent the most complex aspect of any study of the advantages and disadvantages of nuclear power, not only for technical reasons but also, and in particular, for psychological reasons. However, in recent years much energy has been devoted, both in the United States and in Europe, to the clarification and objectification of this problem. Thus, it is now considered very important to ensure that, in all Member States of the Community, present and future safety rules and criteria for the selection of sites guarantee the same degree of safety. This is not the case at present.

(iv) The main risk to the natural environment from the reprocessing of irradiated fuels and, possibly, the recycling of uranium and plutonium, derives from the effluents discharged by reprocessing factories, particularly in the event of accidents or human error.

(v) A compulsory requirement for preliminary studies on the construction of nuclear power-stations should be the use of designs which will facilitate the <u>dismantling of a factory</u> when the need arises. When dismantling is necessary, steps should always be taken to ensure that 'burial techniques' which might lead to radioactive contamination of the geological strata are not used.

(vi) As regards the <u>final disposal of radioactive waste</u>, and in particular of long-lived substances, the committee stresses the need to intensify the efforts to find optimum solutions from the point of view of the protection of the environment for future generations.

Although acceptable solutions admittedly exist, the importance of the problem and in particular the fact that it will persist over an exceptionally long period of time, call for greater efforts and for research work geared increasingly to long-term safety.

In this connection, work should continue on the studies and tests designed to find ways and means of <u>industrializing the solidification</u> (vitrification for example) <u>of waste</u> and research into geological formations suitable for final disposal should be extended.

It would seem worthwhile to keep abreast of the research into methods involving the disposal of radioactive waste at sea, but no irreversible decisions should be taken, at least not for a great many years.

As regards the disposal of waste in space by means of rockets, it will be sufficient to consider the proposals put forward by the relevant specialists. We should also follow with interest the research on incineration in reactors with a view to reducing the radioactive life of waste to a minimum; this research continues despite the difficulties which such transmutation processes involve.

6.6 In this connection, we believe that the Commission's communication to the Council on a Community plan of action in the field of radioactive wastes (Doc. 255/77) will represent a useful basis for action and is deserving of support. Credit is due to the Commission for its efforts to achieve more collaboration between the Member States in the Community framework. Such collaboration cannot fail to further the protection of health and of the environment.

6.7 Your committee asks the Committee on Energy and Research, as the committee responsible, to take account of the above conclusions and recommendations in its motion for a resolution if it has not already done so.