CHAPTER B – CONCEPT DESIGN IN RELATION TO THE ENVIRONMENT

1. INTRODUCTION

Chapter A of Volume 3 includes a brief overview of the design of the EPR. This chapter summarises the design of the European Light Water Pressurised Reactor (EPR) in relation to the environment, i.e. the interface of the design with the environment. The diagram presented below illustrates the interface of the EPR with the environment, including water, air, and land compartments.

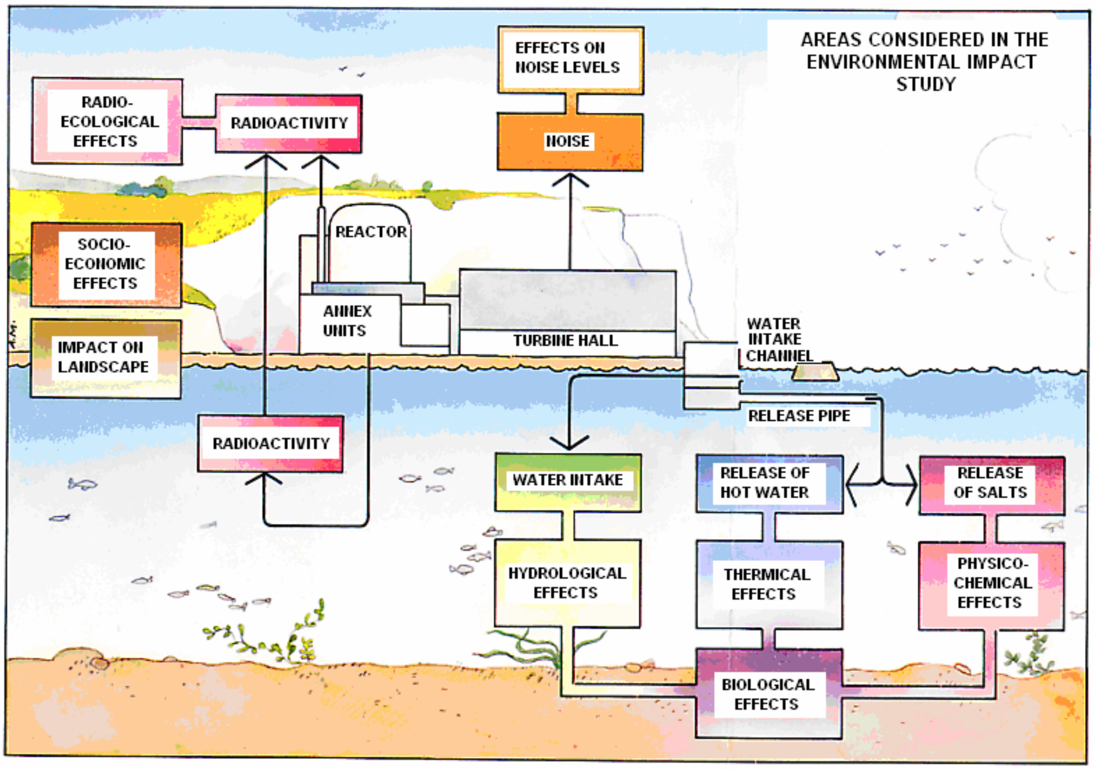

Figure B1-a Areas Considered in the Environmental Impact Study for Flamanville 3

Environmental impacts associated with the design are addressed in Chapter D.

The design of the EPR is addressed in detail in other volumes of this Pre-Licensing Application. In those documents the relationship of the design to the environment is presented by process area. However, since this volume is focused on the environment, the components of the design that affect the environment are summarised by the environmental aspect affected. The affects of the design on the following environmental aspects are addressed:

- Marine environment including hydrology, water quality and biota;

- Terrestrial environment including ecology, soils and geology, and non-radiological waste;
- Freshwater, both surface and groundwater;
- Air and climate;
- Noise and vibration;
- Landscape; and
- Radiological effects.

2. MARINE ENVIRONMENT

2.1. SEAWATER REQUIREMENTS

The EPR plant in Flamanville pumps water from the sea via a pumphouse located alongside the intake channel. The seawater is used to cool the condenser and auxiliary systems. It is also used for the production of demineralised water by desalinisation. To avoid corrosion and deposits in the primary and secondary systems, a nuclear power plant needs chemically pure water.

The mass flow of sea water required is around 67m^3/s for the EPR unit at Flamanville. The maximum temperature for the cooling source water is 26ºC at Flamanville.

2.1.1. Filtration and electrochlorination

If seawater is used, it must be filtered and treated with sodium hypochlorite. The filtration unit for the Flamanville 3 EPR is located near the pumping station. It is divided into pre-filtration (using fixed grids and trash rakes), followed by fine filtration (using drum and chain filters). The filtration system has four independent channels.

The cooling circuits in the Flamanville 3 EPR Unit are protected against the growth of biofilm and biological fouling by injecting sodium hypochlorite into the cooling-system water. Sodium hypochlorite is produced in situ from the electrolysis of seawater. The plant producing sodium hypochlorite for the Flamanville 3 EPR Unit will be situated in the pumping station above the central water intake.

2.1.2. Cooling water

The annual volume of sea water required for cooling is 2.1 billion m^3. For the EPR Unit, the pumping station’s nominal intake of approximately 67 m^3/s is distributed as follows:

- 61 m^3/s for the circulating water system (CRF), via two pumps with a nominal flow rate of 30.5 m^3/s,
- 2 m^3/s for the essential services water system (SEC system [ESWS]) supplying the nuclear steam-supply system auxiliaries, via four pumps with a nominal flow rate of 1 m^3/s (only two pumps operate at any one time)
- 2.80 m^3/s for the service-water circuit for the conventional auxiliaries, comprising four pumps, each with a nominal flow rate of 1.4 m^3/s. In normal circumstances, only two operate at any one time,
- 0.04 m^3/s for the system for treating the circulating water system water by injecting with sodium hypochlorite from seawater electrolysis, via one pump with a nominal flow rate of 0.04 m^3/s,
- 0.56 m^3/s for the circuit supplying the pumps washing the drum and chain filters (two pumps for the drum filters and two for the chain filters),

- 0.14 m^3/s for the water in the ultimate cooling system, via one pump with a nominal flow rate of 0.14 m^3/s.

2.1.3. Desalination water

The desalination unit functions 24 hours a day, 7 days a week, producing 85 m^3/h, or approximately 2,000 m^3/day, of demineralised water. The annual volume of seawater required by the desalination unit to produce the demineralised water for the EPR Unit is estimated at 400,000 m^3.

2.2. THERMAL DISCHARGES

In the case of Flamanville 3, the EPR warm water discharges are cooled with water drawn from the sea. The cooling water is discharged back into the sea after use. The degree to which the seawater is heated depends on the unit's power and the cooling water's flow rate, which varies according to the tide and the number of pumps in use. Under normal operating conditions, the rise in temperature between the water inlet point and the tunnel discharge outlet does not exceed 12ºC. During extreme conditions when the tide is low and the pumps are fouled, the outlet temperature may be 14°C above the inlet temperature.

The EPR warm water discharges are released into an outfall structure and then through an underwater 700-metre-long tunnel equipped with an outlet diffuser. The pool, length of tunnel, and diffuser help minimise the thermal impact of the discharge. Onsite measurements and computer modelling have shown for the two existing Units at Flamanville, at approximately 50 metres from the waste outlet points, the temperature of the discharge is reduced by half.

2.3. CHEMICALS ASSOCIATED WITH RADIOACTIVE EFFLUENT

The table below shows the maximum amounts of chemicals associated with radioactive effluent that will be discharged under normal operating conditions.

Chemicals	Expected performance excluding contingency (kg)	Maximum additional annual discharge (kg)
Boric acid (H_3BO_3)	2,000	7,000
Lithium hydroxide (LiOH)	Less than 1	4.4
Hydrazine (N_2H_4)	7	14
Morpholine (C_4H_9ON)	345	840
Ethanolamine (C_2H_7ON)	250	460
Nitrogen (expressed as N) excluding hydrazine, morpholine and ethanolamine	2530	5,060
Phosphate (PO_4^{3})	155	400

Table B2-a Maximum Amounts of Chemicals associated with Radioactive Effluent

Expected performance excluding contingency and maximum annual additional discharge for chemicals associated with radioactive effluent

The following notes provide additional information related to the above table:

- Boric acid: the proposed treatment of the primary water facilitates recycling. The use of boron enriched with boron 10 significantly reduces the volume of discharge in normal circumstances.

- Morpholine: forms ethanolamine by thermal decomposition. This in turn, is decomposed in a series of reactions, finally forming glycolates, formiates, acetates and oxalates. The estimated maximum annual amount discharged for each of these substances is listed below:

	Acetates	Formiates	Glycolates	Oxalates
Annual amount (kg)	1.53	1.9	0.19	0.127

Table B2-b Maximum Annual Discharge of Acetates, Formiates, GLycolates, and Oxalates

- Nitrogen: nitrogen (excluding hydrazine, morpholine and ethanolamine) in the secondary-circuit water is present only in the form of ammonium ions. When collected in the sumps and transferred to the storage tanks, it may be converted into nitrates (or possibly nitrites) on contact with atmospheric oxygen. In the environment, it is stable in the form of nitrates.

- Because the discharge environment is seawater, the sodium level associated with phosphates is not specified: it is discharged in concentrations that are negligible compared with the concentration in the receiving environment.

2.4. CHEMICAL DISCHARGES NOT ASSOCIATED WITH RADIOACTIVE EFFLUENT

Chemical discharges not associated with radioactive effluent arise from effluent generated from the conventional parts of the site, mainly:

- effluent from demineralised-water production (the main desalination unit and the supporting demineralisation station),

- effluent from biological fouling treatments (seawater chlorination).

- water collected from rainwater drains and black and grey wastewater (effluent from the purification stations),

- water contaminated with oil, and water used in production in the Turbine Hall.

2.4.1. Chemical effluent from the demineralisation station and desalination unit

The demineralisation station and desalination unit discharge iron, total suspended solids, chlorides, sodium, sulphates, detergents and brine.

The maximum annual amounts of discharged chemicals resulting from supplying the EPR Unit are shown below. They are calculated assuming that the desalination unit runs continuously, that pre-processing in the current demineralisation unit runs for several hours per day and that the regeneration cycles operate for 40 days per year.

Substance	Maximum Annual Additional Discharge (kg)
Chlorides	3616
Sulphates	11725
Sodium	13523

Table B2-d Maximum amounts discharged during the production of demineralised water for the EPR Unit

Brine is discharged into the intake channel at a rate of 150 m^3/h at a concentration of 70 g/l.

2.4.2. Discharge of black and grey wastewater, water contaminated with oil and rainwater

Chemicals discharged into the sea from the sewage network are treated in the purification station. This treatment ensures that the BOD_5 (5-day biological oxygen demand) of the discharged effluent is less than 35 mg/l.

Waste water that could contain hydrocarbons is treated in the on-site oil filters. The hydrocarbon concentration in the discharged water is below 5 mg/l.

2.4.3. Discharge from anti-fouling treatments

Chlorination is carried out once the temperature of the seawater reaches 10°C. The process involves discharging both residual oxidants into the sea (both in the free state and as chlorine compounds) and trihalomethanes (as bromoform). Chlorides from cleaning the processing equipment are also discharged into the sea.

The standard processing method for Flamanville is chlorination using a concentration of 0.5 mg/l of active chlorine. Injection is sequential, once every 30 minutes to each cooling channel.

Realistic values for the expected discharge from the EPR Unit, based on experience of the two production Units operating at Flamanville, are shown in the table below.

	Residual oxidants	Bromoform
Chlorination	0.14	0.0027

Table B2-e Realistic concentration in the outfall structure (mg/l)

Expected performance excluding contingencies for the chemicals from electrochlorination

A change to the water quality may cause excessive biological fouling, requiring exceptional chlorination at 1 mg/l (10 days each year per unit, non consecutive) to treat the various sections of the service-water circuits.

The estimated discharge from treating circuits against biological fouling is as follows:

	Maximum concentration in the outfall structure (mg/l)	
	Residual oxidants	**Bromoform**
Normal chlorination	0.5	0.02
Exceptional chlorination, at 1 mg/l	1	0.04
Shock chlorination at 6 mg/l	0.72	0.0244

Table B2-f Oxidant and Bromoform Discharge from the EPR Unit

The annual mass of discharged chlorides is estimated at 2,600 kg.

3. TERRESTRIAL ENVIRONMENT

3.1. LAND

The EPR unit and ancillary facilities requires 70 hectares for construction and operation based on the layout of Flamanville 3. Seismicity, liquefaction, flooding and related characteristics must be considered on a site specific basis.

The construction of the EPR will require moving earth for levelling the site and excavations for buried structures. Embankments may be required for flood protection or other factors. The infrastructure for the main buildings will also require reinforcement. The material excavated during construction will be reused on-site to the extent practical.

Excavated materials will be utilised as far as practical to shore up trenches and as infill around buildings. Concrete used in construction will probably be produced in an on-site concrete batching plant that recycles crushed rubble from rock blasting as aggregate, if applicable.

3.2. CONVENTIONAL WASTE

Waste produced during the construction phase will be stored in a temporary location specifically created on the building site. The materials extracted during the earth-moving works, excavated material and rocks, will be reused as much as possible on the site as fill and in the making of concrete after crushing.

Other waste on site will be managed as practical according to the waste hierarchy: reduce, reuse, or recycle.

Conventional waste produced during the operational stage is also subjected to a strict management procedure so as to reduce its volume. For example, the quantity of waste produced annually by the Flamanville EPR unit is estimated at 600 tonnes. Conventional waste may include normal industrial waste (i.e. cardboard, paper, wood and metals), and special waste or hazardous industrial waste (i.e. aerosol spray cans, solvents, oils, paint residues, and rubble.

At Flamanville, conventional waste is stored at an on-site transfer station for resorting and repackaging. The waste is packed in drums and is stored for no longer than 90 days. Certain types of waste that accumulate slowly and for which there is a national disposal strategy, may be stored for longer periods (fluorescent tubes, electronic components, etc.). For this type of waste, the storage period does not exceed one year.

3.3. FLORA AND FAUNA

The effects of the EPR on terrestrial flora and fauna are site-specific and not directly related to the conceptual design. (Radiological issues are addressed in section III.D.7)

4. FRESHWATER

4.1. CONSTRUCTION

During the construction period, freshwater is required for the construction activities. This water may be provided by surface water sources such as rivers as is the case for Flamanville or groundwater. In addition, water will be required for sanitary and other purposes which were supplied by the mains in the case of Flamanville.

The construction of new freshwater supply infrastructure will be probably required at a UK site. Freshwater supply infrastructure was already in place at the Flamanville site for the existing Units 1 and 2. Due to a wide range of site-specific factors such as geology and material selection and construction methodology, it is not possible to predict accurately the impact of discharges during the construction phase. An assessment will be completed once a specific site is selected.

The maximum freshwater needs during construction are estimated at 612 m^3/day during the preparatory phase. The construction period is assumed to required 5-6 years, with the peak freshwater requirements during the first 12-15 months primarily due to rock crushing activities and concrete batching.

Freshwater needs are expected to peak again in construction years four and five due to the requirements of the demineralisation system. A desalination unit is planned for Flamanville (demineralised water manufactured from seawater by reverse osmosis). The desalination unit is expected to come on line in approximately construction year three. However, the unit is expected to be out of service for planned maintenance periods of 40 days per year. During this period, the site's demineralised water will come from the existing demineralisation plant, which produces demineralised water from fresh water. Peak freshwater use is estimated at 230 m^3 / day for 40 days per year. Freshwater will be needed to supply the demineralisation plant If a desalination unit is not included in the UK EPR.

Peak drinking water demands are expected to occur in construction years 3-5. Peak demands for drinking water are estimated at 2,500 – 3,500 m^3/month.

4.2. OPERATION

During operation of the EPR, freshwater will be required to meet process needs and sanitary and other uses. It is assumed that liquid effluent will be discharged to the sea.

4.2.1. Process water requirements

It is anticipated that water needs during operation of the Flamanville EPR will be primarily met by the desalination unit. Demineralised water will be produced by the desalination unit (operating continuously 24 hours a day/7 days a week).

Freshwater will also be required for the following:

- to supply the industrial water system, used in the turbine hall to wash the floors and reduce overheating in the secondary effluent system, etc.,

- the pumping station (spraying the packing glands, etc.),

- producing filtered water for washing the sand filters, and for regenerating and flushing the ion exchangers.

The requirement for filtered/demineralised water produced from freshwater for the EPR Unit is estimated at 25,000m^3 per year. The annual requirement for untreated freshwater is estimated at 115,000 m^3 of which 40,000m3 is for spraying the packing glands and 75,000m^3 for use mainly in the turbine hall. Thus the total freshwater requirement for the EPR Unit is approximately 140,000 m^3/year.

4.2.2. Other water requirements

The supply of water is intended to meet sanitation requirements (lavatories and showers) and catering, and to supply drinks dispensers. It also has a number of industrial uses, including:

- laundry,
- the demineralisation station (hydraulic seal on settling tank),
- flushing the electrolysers at the end of a run,
- Effluent Treatment Building (sealing the concrete cells),
- packing glands for the water circulation system pumps (backup),
- fire main (in addition to the fire fighting network),
- refrigeration equipment, air-conditioners,
- laboratory work.

The EPR Unit's average annual drinking water consumption is estimated at 30,600m^3 year.

4.2.3. Freshwater effluent

The sanitary sewage treatment system for Flamanville 3 is an existing community system. Effluent from the following sources will be discharged to a sanitary sewage treatment system:

- the rainwater collected on the site,
- water used in production (if water is contaminated by hydrocarbons it will first pass through an oil water separator),
- grey water and sanitary sewage.

Water collected that could contain oil (from transformers, turbine hall, oil and grease store, and storage areas that might be contaminated with hydrocarbons) is sent to a oil water separation system. This system has an interceptor that collects the oil before it flows into the rainwater drains.

In addition, polluted water (water from fires, or accidentally polluted with chemicals) may be collected and stored in a containment tank. The liquid in the tanks may be analysed and treated on site as far as possible, or transferred to another tank for shipping offsite for treatment rather than being discharged to the sanitary sewer.

5. AIR AND CLIMATE

5.1. CONSTRUCTION

Dust/particulates produced during construction will be from sources typical for a construction site of any large industrial facility. Dust will be produced during excavations and earth moving, rock crushing, and concrete manufacturing.

Air emissions will be produced during construction by exhaust from heavy diesel equipment and other transportation sources, concrete manufacturing and onsite generators. Approximately 292,000 m^3 of concrete will be poured during the main civil-engineering stage. The concrete will come from the concrete batching plants in the vicinity of the construction site.

During the testing phase formaldehyde may be produced. Insulation round the equipment and hot pipework undergoes thermal decomposition the first time the temperature rises, and releases formaldehyde into the steam in the reactor building. This may result in the formation of carbon monoxide which is discharged via the chimney by operating the reactor building ventilation system.

The quantities of formaldehyde and carbon monoxide discharged as gases into the environment after hot trials have been calculated by considering the worst case. The maximum quantities produced in the containment in the Reactor Building are approximately 1230g of formaldehyde and 1152g of carbon monoxide. Depending on the ventilation flow rate (normal or low), the operating time required to evacuate these quantities and reduce concentrations to acceptable exposure limits, and is estimated at 10 hours at normal flow and 52 hours at low flow.

Potential odour sources during construction include exhaust gases from the site machinery and from the formaldehyde released.

5.2. OPERATION

Potential sources of air emissions (non-radioactive) during operation include:

- sulphur and nitrogen oxides in the exhaust gases from engines of the backup electricity generators,
- formaldehyde and carbon monoxide emitted by the insulation when installations go back into operation after servicing,
- ammonia discharged as the temperature rises in the steam generators during start-up.

5.2.1. Sulphur and nitrogen oxides

There are four main backup electricity generator sets, each rated at around 7Mwe, and two final emergency backup sets rated at around 2Mwe. This is safety equipment, providing a backup power supply if the main supply is interrupted, so that the Units can be secured and the reactors cooled. These backup generators are tested periodically to ensure they are in good working order and at that time produce sulphur and nitrogen oxides.

5.2.2. Formaldehyde and carbon monoxide

When the plant restarts after maintenance, the temperature rises and the insulation in the reactor building undergoes some thermal decomposition. It produces steam containing formaldehyde within the containment in the reactor building, and this in turn may produce carbon monoxide.

In order to keep the concentrations of formaldehyde and carbon monoxide in the workplace air below the acceptable exposure limits, the discharged gases are evacuated via the chimney in the Unit by operating the reactor building ventilation system, at either normal or low flow rates, depending on the condition of the Unit.

The quantities of formaldehyde and carbon monoxide discharged as gases into the environment when the Unit is restarted after maintenance have been calculated by considering the worst-case scenario. Restarting the installation produces approximately 700g of formaldehyde and 660g of carbon monoxide in the containment in the Reactor Building. The operating time required to evacuate these quantities to comply with the average exposure limits depends on the ventilation flow rate in the Reactor Building containment. It is estimated at 8 hours at normal flow rates and 42 hours at low flow rates.

5.2.3. Ammonia

If the EPR Unit is shut down for longer than a week, laying up the steam generators wet prevents their fabric corroding and provides a biological barrier (a water shield) when carrying out work in the vicinity. In this case, the steam generators are filled with demineralised water, conditioned with hydrazine with added morpholine, ethanolamine or ammonia in the proportions defined in the chemical specifications for lay-up on shutdown.

Once the shutdown is over, the solution used for wet lay-up can be drained into the reservoirs or heated directly in the steam generators as the installation restarts. The gaseous effluent from this process is then evacuated using the turbine bypass to the atmosphere.

The rise in temperature generates gaseous ammonia from the wet lay-up solution and the emergency feedwater system for the steam generators. It is assumed that all the hydrazine present in the water is broken down into ammonia.

The quantity of discharged ammonia is estimated to be approximately 20 kg. The assumption is that this quantity is discharged during the first few hours of operation.

The chemicals discharged from the EPR Unit that may produce an odour are formaldehyde, ammonia and diesel exhaust gases.

6. NOISE AND VIBRATION

The primary noise sources during construction of an EPR are those typical of an industrial construction site and include excavation and earth moving, crushing and concrete batching plant.

While operating, primary sources of noise are the discharge stacks, the air entry and exit openings, the ventilation openings, the cold water production equipment, the steam pipes, the machine rooms, the pumphouses and the transformers.

Soundproofing will be implemented at primary noise sources to reduce or eliminate the sound effects of the EPR. Soundproofing of equipment includes covers, insulating walls, silencers, etc.

7. LANDSCAPE

The effect of an EPR unit on the landscape is primarily a site-specific issue. Within the coastal area, there is a potential effect on seascape, which is defined as the discrete area within which there is shared inter-visibility between land and sea.

8. RADIOLOGICAL EFFECTS

8.1. GASEOUS RADIOACTIVE EMISSIONS

8.1.1. Emission levels

Gaseous radioactive waste from the EPR is produced by:

- the ventilation of nuclear buildings;
- the degassing of radioactive fluid.

Depending on its origin, the gaseous radioactive emissions are:

- filtered[1] and released into the atmosphere via the discharge stack. This is the case for the gaseous emissions from the ventilation circuits; or
- retained in the treatment system to lower the level of radioactivity and then filtered and released into the atmosphere via the discharge stack. This is the case for the gases released by the degassing of the primary system's water.

The following tables provide the expected annual releases of radioactive gases into the atmosphere by the EPR unit after filtering.

Radionuclides	Expected performance excluding operating contingencies	Maximum release
Tritium	500 GBq	3000 GBq
Carbon-14	350 GBq	900 GBq
Iodine isotopes	0.05 GBq	0.400 GBq
Noble gases	800 GBq	22 500 GBq
Other FP/AP	0.004 GBq	0.340 GBq

Table B8-a Expected Annual Releases of Radionuclides into the Atmosphere by the EPR Unit after Filtering

[1] Filtration allows to retain more than 99% of aerosols and iodines and to convert them into solid waste.

Radionuclide category	Expected performance excluding operating contingencies	Maximum release
Kr 85	111.2 GBq	3127.5 GBq
Xe 133	504.8 GBq	14197.5 GBq
Xe 135	158.4 GBq	4 455 GBq
Ar 41	23.2 GBq	652.5 GBq
Xe 131m	2.4 GBq	67.5 GBq
Total noble gases	*800 GBq*	*22500 GBq*
I 131	0.0228 GBq	0.182 GBq
I 133	0.0272 GBq	0.2176 GBq
Total iodine isotopes	*0.05 GBq*	*0.4 GBq*
Co 58	0.000102 GBq	0.0867 GBq
Co 60	0.0001204 GBq	0.10234 GBq
Cs 134	0.0000936 GBq	0.07958 GBq
Cs 137	0.000084 GBq	0.0714 GBq
Total FP/AP	*0.0004 GBq*	*0.340 GBq*

Table B8-b Expected Annual Releases of Radionuclide Categories into the Atmosphere by the EPR Unit after Filtering

8.1.2. Mitigation measures

The EPR unit is equipped with a treatment system, which works almost entirely in a closed loop, thus allowing effective treatment and recycling of aerated gaseous waste. The expected waste according to energy produced (known as realistic waste) is therefore below that of the previous generation pressurised water reactors, except for carbon-14. As carbon-14 emissions are proportionate to the energy produced, they are consequently slightly higher for the EPR.

8.1.3. EPR design improvements

The assessment of EPR design-based improvements in terms of gaseous radioactive releases excluding tritium and carbon-14 is based on a detailed preliminary analysis of the origin of gaseous releases from in-service reactors for each isotope family, and a subsequent quantification of the impact of the EPR design.

The EPR has the following design characteristics:

- Gaseous waste treatment system derived from the Konvoi design: aerated effluent treatment system with an almost closed-loop design, which differs from the 1300 MWe units. In particular, this design allows better handling of activity peaks during cold shutdown. Its main characteristics are as follows:

- o common gaseous waste treatment system and reactor boron and water make-up tank blankets, significantly reducing gaseous volumes released during normal operation (constant gas balance during water movements),
- o continuous nitrogen sweeping of tank blankets and recombination of hydrogen, allowing retention of gaseous effluents from aerated or hydrogenated coolants,
- o gas recycling, reducing gaseous volumes released during normal operation,
- o gas radioactive decay (xenon and krypton isotopes in particular) in active carbon beds, ensuring a decay period of 40 hours for krypton isotopes and 40 days for xenon isotopes (half-life of 5.25 days for Xe-133),
- o recycling for certain forms of iodine and aerosols, theoretically favoured in heat exchangers with vapour condensation, in desiccators and in liquid compressor rings,
- o discharge via exhaust stack upon reaching a threshold pressure that can be adjusted depending on the gases to be handled (adaptation to system storage capacity).

- No releases from the reactor building during the cycle (no pneumatic valves in the reactor building), except those associated with purging system operation for in-service reactor building maintenance.
- Nuclear auxiliary building, safeguard auxiliary building and reactor building ventilation systems able to switch to iodine trap. In 1300 MWe units only certain rooms in the nuclear auxiliary building can be connected to iodine trap ventilation system after connecting to a very high efficiency filter system. In the EPR, all rooms are divided into cells (two for the reactor building, three for the nuclear auxiliary building, one for the safeguard auxiliary building) associated with ventilation lines connected to a very high efficiency filter system and able to switch to iodine trap ventilation system.
- In the EPR, the implementation of a metallic liner on the inner wall of the reactor building limits the infiltration of radioactive gases into the annulus (depressurised by the annulus ventilation system, consisting of three extraction lines equipped with very high efficiency filters and pre-filters).

Depending on the condition of the primary system, potential improvements (essentially due to the new gaseous waste treatment system design) are variable, but on average they are estimated at approximately 20% for inert gases and iodine isotopes, and 15% for other gaseous releases.

8.2. RADIOACTIVE LIQUID EFFLUENT

8.2.1. Discharge levels

Radioactive Components

Liquid radioactive waste from the EPR is grouped into two categories according to its source:

- waste from the primary system, which contains dissolved fission gases (xenon, iodine, etc.), fission products (caesium, etc.), and activation products (cobalt, manganese, tritium, carbon-14, etc.), and also chemical substances such as boric acid and lithium hydroxide. This waste can be recycled;

- waste from the systems connected to the primary system, including:

  - effluents which are radioactive and free from chemical pollution,

  - radioactive and chemically charged effluents,

  - effluents with a very low level of radioactivity collected by the floor drains [2].

After being systematically collected, this waste is treated to “retain” most activity in solid form. It is then channelled to storage tanks where it undergoes both a radioactive and chemical test before being discharged to the sea.

The following table shows the expected annual and maximum discharge of radioactive substances released into the sea by the Flamanville 3 EPR unit.

Radionuclides	Expected performance excluding operating contingencies	Maximum release
Tritium	52 000 GBq	75 000 GBq
Carbon-14	23 GBq	95 GBq
Iodine isotopes	0.007 GBq	0.05 GBq
Other FP/AP	0.6 GBq	10 GBq

Table B8-c Annual Radioactive Substances released into the Sea

[2] The floor drains constitute a network of underground pipes which collect material leaks, drainage operation waters and water used to wash the floors.

The fission and activation products in radionuclides discharged in liquid form are listed below.

Radionuclides	Expected performance excluding operating contingencies	Maximum release
Ag 110m	0.0345 GBq	0.570 GBq
Co 58	0.1242 GBq	2.070 GBq
Co 60	0.18 GBq	3.000 GBq
Cs 134	0.0336 GBq	0.136 GBq
Cs 137	0.0567 GBq	0.945 GBq
Mn 54	0.0162 GBq	0.270 GBq
Sb 124	0.0294 GBq	0.490 GBq
Te123m	0.0156 GBq	0.260 GBq
Ni 63	0.0576 GBq	0.960 GBq
Sb 125	0.0489 GBq	0.815 GBq
Other (Cr 51)	0.0036 GBq	0.060 GBq
Total	*0.6 GBq*	*10 GBq*

Table B8-d Fission and Activation Products in Radionuclides Discharged in Liquid Form

Chemical Substances Associated with Liquid Radioactive Waste

Chemical products must be added to the water of certain systems. This mainly concerns:

- boric acid, lithium hydroxide and hydrazine for the primary system;
- hydrazine as well as morpholine (or ethanolamine or ammonia) for the secondary system;
- sodium phosphate for the auxiliary cooling and heating systems.

These products are necessary either to control the nuclear reaction (boric acid) or to condition water so as to reduce the corrosion of the equipment. (These chemicals were addressed previously in Section 2.)

8.2.2. Mitigation measures

Non-recyclable chemical waste combined with radioactive elements is treated in the EPR Effluent Treatment Building and is sent to the site's tanks for monitoring before being discharged offshore through the underwater tunnel. The design and operating options adopted for the EPR reactor allow for a significant reduction of this type of waste in comparison to that of the second generation pressurised water reactors. The following kinds of waste are reduced:

- boric acid, by using boron enriched with isotope 10 and greater recycling,
- lithium hydroxide by implementing a system which optimises the injection and recovery of the lithium hydroxide,

- hydrazine by implementing a method which destroys the hydrazine in the tanks prior to discharge,

- and phosphates by implementing measures which limit the transformation of phosphates in the systems.

These chemical substances are checked regularly in the waste contained in the tanks for monitoring before discharge.

8.2.3. EPR design improvements

Control of liquid tritium production

As the EPR is characterised by a significant power capacity and by high combustion rate fuel, the Boron-10 concentration sufficient to control reactivity is important. Consequently the approach adopted for the EPR involves controlling the tritium production rate so as to have the same specific production rate of an existing 1300 MWe unit (present fuel management scheme).

The main design characteristics permitting such control are the following:

- significant use of burnable gadolinium poison rods: reduction of Boron-10 concentration and therefore of tritium production,

- use of Boron enriched up to 30 to 40 % in Boron-10. This characteristic leads to a lower Boron concentration without decreasing the number of Boron-10 atoms responsible for most of the tritium produced. Since the lithium concentration decrease with Boron content, the tritium produced via neutron capture by Li-6, decreases as well.

Due to the characteristics of tritium, the management strategy for the tritium produced in the EPR reactor consists of limiting the tritium activity in the primary system through primary coolant recycling and through controlled release of the activity produced. If the unit performed significant recycling of primary liquid effluent distillates, release values would be reduced, but this would pose problems, namely regarding the presence of tritium in the pool water purification pits and tanks, or in the secondary system in case of sealing problems. The controlled discharge of tritium, therefore, ensures an activity release rate allowing good diffusion without having a noteworthy impact on the aquatic environment.

Gadolinium poisoning. Increasing the gadolinium load reduces the Boron-10 concentration, which constitutes the main source of tritium production. On the other hand, this reduces the natural length of the corresponding operating cycles, with significant economic impact due to the associated production loss.

An optimisation approach has been applied to the uranium dioxide 18-month management scheme, leading to a 180 ppm reduction in boron concentration, i.e. improvement amounting to 6 TBq, with significant economic impact due to the reduction of the natural cycle length by three EFPD (Equivalent Full Power Days).

Lithium concentration. The optimisation of primary coolant chemistry (pH) via lithium content constitutes another approach to control tritium production. The change in lithium content has to be assessed against technical requirements (preservation of primary pH and boron-lithium coordination) and radiological protection objectives (lower generation of corrosion products).

The possibility to operate with high lithium content (6 ppm) as previously suggested (based on international operational experience feedback [OEF]) and considering the fuel management schemes adopted is still realistic. Nevertheless, the primary optimisation strategy currently adopted consists of finding an operating point close to 4 ppm, i.e. close to a 'low lithium' primary coolant chemistry.

A second optimisation strategy currently pursued aims to achieve operation at constant pH since the beginning of life, with lithium content optimised at approximately 3 to 4 ppm. The conditions come close to standard 'low lithium' chemistry (generating less tritium) and make use of two effects: no Li threshold at start of cycle and lower Li content due to lower boric acid concentration resulting from Boron-10 enrichment.

Volume Reductions due to Design Modifications

Process drains: From experience, the process drains (demineralising treatment gain approximately 10^3) amount to 30% of the total activity release, with 80% of this contribution associated with unit outage. The recycling of aerated primary liquid effluents constitutes a fundamental advantage of the EPR (in existing plants they become liquid waste). This recycling is possible due to gaseous waste processing system’s compatibility with aerated gaseous effluents. A detailed analysis of the contribution of the various operations during unit outage has enabled the quantification of deviations associated with EPR design changes. This quantification has shown an improvement of approximately 35% for this release path, i.e. 10% of total activity release. The improvement for the most marginal part of the process drains during non-outage has not been quantified.

Floor drains: Based on experience assuming a treatment without gain (equal to 1), the floor drains amount to 60% of total activity release. Due to the EPR design (improved selective drainage, greater differentiation of floor drains), only the most active effluents are treated with an evaporator. The other floor drains, with no activity or low activity, are released after simple filtration. The improvement associated with this optimisation is difficult to quantify and will depend on the criteria used to choose between evaporator or filtration treatment. The EPR design incorporates the methods used by the most efficient units, thus simplifying operation.

The approach adopted for this preliminary analysis is a global, non-theoretical approach. Its purpose is to provide a comparative analysis of 1300 MWe and EPR units under equivalent conditions It is not supposed to provide an assessment of absolute activity release values (whether for existing plants or the EPR). Therefore, after the detailed analysis and quantification phase, a macroscopic approach has been adopted based on the annual release values for existing 1300 MWe plants.

The EPR will therefore yield an improvement of liquid activity release values (excluding tritium and carbon-14) of at least 10% when compared to the most efficient 1300 MWe units.

8.3. RADIOACTIVE SOLID WASTE

The reduction in the volume of solid radioactive waste is one of the objectives adopted at the design stage which aims to lessen the unit's impact on the environment.

Concerning fuel, the EPR uses the same types of enriched uranium elements as previous generation reactors but it does so more efficiently due to its neutronic design and the use of higher burn-ups: it therefore consumes less fuel (17%) and produces less irradiated material - and therefore waste (26%) - for the same amount of energy produced.

The spent fuel is stored in an interim storage facility pending a final decision about either reprocessing, if it is economically acceptable and allowed by UK law at that time, or the setting up a final geological waste disposal facility.

The production of waste during operation is limited to 80 m^3 per year at the Flamanville EPR. Short-lived low level waste, a by-product of the operating process, is sorted, treated and stored in the unit's Effluent Treatment Building so as to reduce the volume of waste as much as possible (compaction) and to ensure the radioactive material is confined through suitable packing. The waste is then sent, after monitoring, to an approved storage facility or to an incineration and fusion facility.