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TABLE OF CONTENTS

1	MONITORING OF LIQUID EFFLUENTS.....	5
1.1	SAMPLING ARRANGEMENTS.....	5
1.1.1.	GENERAL SAMPLING FOR LIQUID EFFLUENTS	5
1.1.2.	SAMPLING AND PREPARATION OF AVERAGE ALIQUOTS	6
1.2	CONDITIONING AND STORAGE OF THE LIQUID SAMPLES	8
1.3	MEASUREMENT TECHNIQUES CURRENTLY IN USE FOR RADIOACTIVE LIQUID EFFLUENTS	8
1.3.1	GROSS ALPHA AND BETA MEASUREMENT	8
1.3.2	MEASUREMENT OF GAMMA ACTIVITY BY SPECTROMETRY	9
1.3.3	MEASUREMENT OF TRITIUM BETA ACTIVITY BY LIQUID SCINTILLATION.....	9
1.3.4	MEASUREMENT OF ¹⁴ C BETA ACTIVITY BY LIQUID SCINTILLATION	10
1.4	MONITORING OF THE PRIMARY LIQUID EFFLUENTS CURRENTLY IN PLACE.....	11
1.4.1	DISTILLATES	13
1.4.2	CONCENTRATES.....	14
1.5	MONITORING OF SPENT LIQUID EFFLUENTS CURRENTLY IN PLACE	15
1.5.1	PROCESS DRAINS.....	15
1.5.2	CHEMICAL DRAINS.....	16
1.5.3	FLOOR DRAINS	16
1.6	MONITORING CURRENTLY IN PLACE PRIOR TO DISCHARGE	17
1.6.1	MONITORING OF THE OKER [LRMDS] STORAGE TANKS	17
1.6.2	MONITORING OF THE OSEK [SITE LWDS] STORAGE TANKS.....	22
1.6.3	MONITORING OF THE EFFLUENTS BEFORE GENERAL DISCHARGE.....	26
2	MONITORING OF GASEOUS EFFLUENTS	26
2.1	SAMPLING AND STORAGE ARRANGEMENTS.....	27
2.2	MEASUREMENT TECHNIQUES CURRENTLY IN USE FOR RADIOACTIVE GASEOUS EFFLUENTS	27
2.2.1	GAMMA SPECTROMETRY OF GASEOUS EFFLUENTS.....	27
2.2.2	GASEOUS HALOGENS	27
2.2.3	ALPHA/ BETA ACTIVITY MEASUREMENT OF AEROSOLS.....	30

2.2.4	MEASUREMENT OF BETA ACTIVITY FROM TRITIUM BY LIQUID SCINTILLATION COUNTING	30
2.2.5	MEASUREMENT OF BETA ACTIVITY FROM ¹⁴ C BY LIQUID SCINTILLATION COUNTING	31
2.3	MONITORING THE GASEOUS EFFLUENTS CURRENTLY IN PLACE	32
2.3.1	EXISTING 1300 MW(E) FLEET – FRANCE	32
2.3.2	KONVOI REACTORS – EXAMPLE OF GERMANY NECKARWESTHEIM	35
3	QUALITY ASSURANCE	38
4	CONCLUSIONS	38
5	REFERENCES	39

LIST OF FIGURES

FIGURE 1: THE OXIDIZER SYSTEM	11
FIGURE 2: REPRESENTATION OF THE PREPARATION OF THE 0KER [LRMDS] SAMPLES FOR RADIOLOGICAL AND CHEMICAL ANALYSES.....	21
FIGURE 3: REPRESENTATION OF THE PREPARATION OF THE 0SEK [SITELWDS] SAMPLES FOR RADIOLOGICAL AND CHEMICAL ANALYSES.....	25
FIGURE 4: GASEOUS C-14 SAMPLING SYSTEM DESCRIPTION.....	31

LIST OF TABLES

TABLE 1: MONITORING OF THE INTERIM HOLDUP TANKS OF THE PRIMARY EFFLUENT TREATMENT SYSTEM (TEP [CSTS]).....	13
TABLE 2: MONITORING OF THE DISTILLATES FROM THE PRIMARY EFFLUENT TREATMENT SYSTEM (TEP [CSTS]).....	14
TABLE 3: MONITORING OF THE CONCENTRATES FROM THE PRIMARY EFFLUENT TREATMENT SYSTEM (TEP [CSTS]).....	14
TABLE 4: MONITORING OF THE FRONT TANKS 8TEU [LWPS]	15
TABLE 5: MONITORING OF THE 8TEU [LWPS] CONCENTRATES	16
TABLE 6: RADIOLOGICAL MONITORING OF THE 0KER [LRMDS] TANKS	17
TABLE 7: CHEMICAL MONITORING OF THE 0KER [LRMDS] TANKS.....	20
TABLE 8: RADIOLOGICAL MONITORING OF THE 0SEK [SITELWDS] TANKS	22
TABLE 9: CHEMICAL MONITORING OF THE 0SEK [SITELWDS] TANKS	24
TABLE 10: MONITORING CARRIED OUT IN THE OUTFALL STRUCTURE	26
TABLE 11: MONITORING CARRIED OUT PRIOR TO PLANNED DISCHARGE OF THE HYDROGENATED GASEOUS EFFLUENT AND THE REACTOR BUILDING STORING TANKS	33
TABLE 12: MONITORING CARRIED OUT AT THE STACK OF EACH NUCLEAR AUXILIARY BUILDING	34
TABLE 13: MONITORING CARRIED OUT AT THE STACK – KONVOI REACTOR.....	37

Following the Pre Construction Environmental Report (PCER) for the UK EPR sent by EDF/AREVA in April and June 2008, the Environment Agency required additional information to be provided on a number of points dealing with the monitoring activities: actions A15 to A18 of CM-EPR-1. The purpose of the present document is to provide further details on the monitoring regime before discharge that could be implemented in the EPR by looking at arrangements currently in place in existing stations, both on the 1300 MW(e) French fleet and at a German KONVOI site. This answers requirement 2.6 of the EA P&I Document regarding information on "the sampling arrangements, techniques and systems proposed for measurement and assessment of discharges and disposals of radioactive waste". The document does not deal with monitoring of substances in the environment, as this is not covered by the above requirement and has been dealt with in Chapters 11 and 12 of the PCER.

We believe that the information in this document, along with the information provided during the site visits at the French 1300 MW(e) Penly and the German KONVOI KKI-2 sites in October 2008, provides the level of detail required on monitoring activities for the Generic Design Assessment.

Note: Although actions A15 to A18 are associated with requirement 2.6 of the EA P&I Document, i.e. measurement and assessment of discharges of radioactive waste, information about monitoring of chemical discharges is also given in the document.

1 MONITORING OF LIQUID EFFLUENTS

The purpose of this section is to present the monitoring activities of the liquid effluents both for radiochemical and associated chemical substances, from their production through to collecting, storing and discharge. Information concerning the operations relating to the monitoring of liquid effluent has been provided in PCER Sub-chapter 7.3 (radioactive effluents) and Sub-chapter 7.4 (chemical associated with radioactive effluents). In addition, the processes taking part in the management of the liquid effluents are described in PCER Sub-chapter 6.2. The aim of the current section is to provide additional details on the monitoring arrangements in place in existing stations and that could be implemented in the UK EPR.

1.1 SAMPLING ARRANGEMENTS

1.1.1. General sampling for liquid effluents

The general sampling methods for radioactive liquids and the arrangements and procedure for sampling of liquid effluents from the 0KER [LRMDS], 0TER [ExLWDS] and 0SEK [SiteLWDS] tanks (and therefore potentially radioactively contaminated) are described below [1] [2].

It is evident that the sampling arrangements are of utmost importance to obtain a representative sample. The following steps are considered as good practice for the sampling of liquids:

- ensure sufficient mixing of the tank to be sampled (see details below);
- ensure sufficient drainage of the sampling pipe;
- ensure a stable and laminar flow during sampling (isokinetic sampling). Indeed, if the flow is not laminar, particles can be exchanged between the different layers of fluid. In particular, a non-laminar flow would lead to loss of some or all of the gases present in the fluid sampled;

- ensure use of a clean container of adequate volume with the activity and the nature of the sample;
- ensure rinsing of the containers with liquid of the tank to be sampled, avoiding external contamination of the container;
- ensure maximum filling of the container to minimise contact of the sample with air and thus avoid potential volatilisation of some chemical substances;
- ensure adequate recording of the sample (date and time of sampling, exact point of sampling, number of the storing tank, volume of effluent discharged, operator's name and number of the Sampling/Analysis/Discharge file if there is any).

A representative sample of a batch discharge can only be obtained if optimum homogenisation of the tank to be sampled has previously been achieved. In other words, the physico-chemical characteristics of the tank to sample must be representative of the discharge. In general, this means that:

- if sampling on a pipe, the flow of the liquid must be identical to the flow during normal operation;
- if sampling a tank, the content must be homogeneous. This is achieved by mixing the content of the tank for duration proportional to the volume of the tank. Operating experience feedback was used in order to determine "adequate" mixing time, which can be considered as:

$$T_m = x \cdot V/Q, \text{ where}$$

- T_m is the mixing time of the tank (h);
- V is the volume of the tank (m^3);
- Q is the effective mixing flow rate (m^3/h); and
- X is a coefficient depending on the characteristics of the tank ($x = 1.5$ or 2).

Feedback provided by operating experience has shown that compliance to the points above provide a representative liquid sample.

These arrangements in place in French nuclear power stations are similar to those described for the sampling of batch discharges in the Technical Guidance Notes M12 [3] and M18 [4].

1.1.2. Sampling and preparation of average aliquots

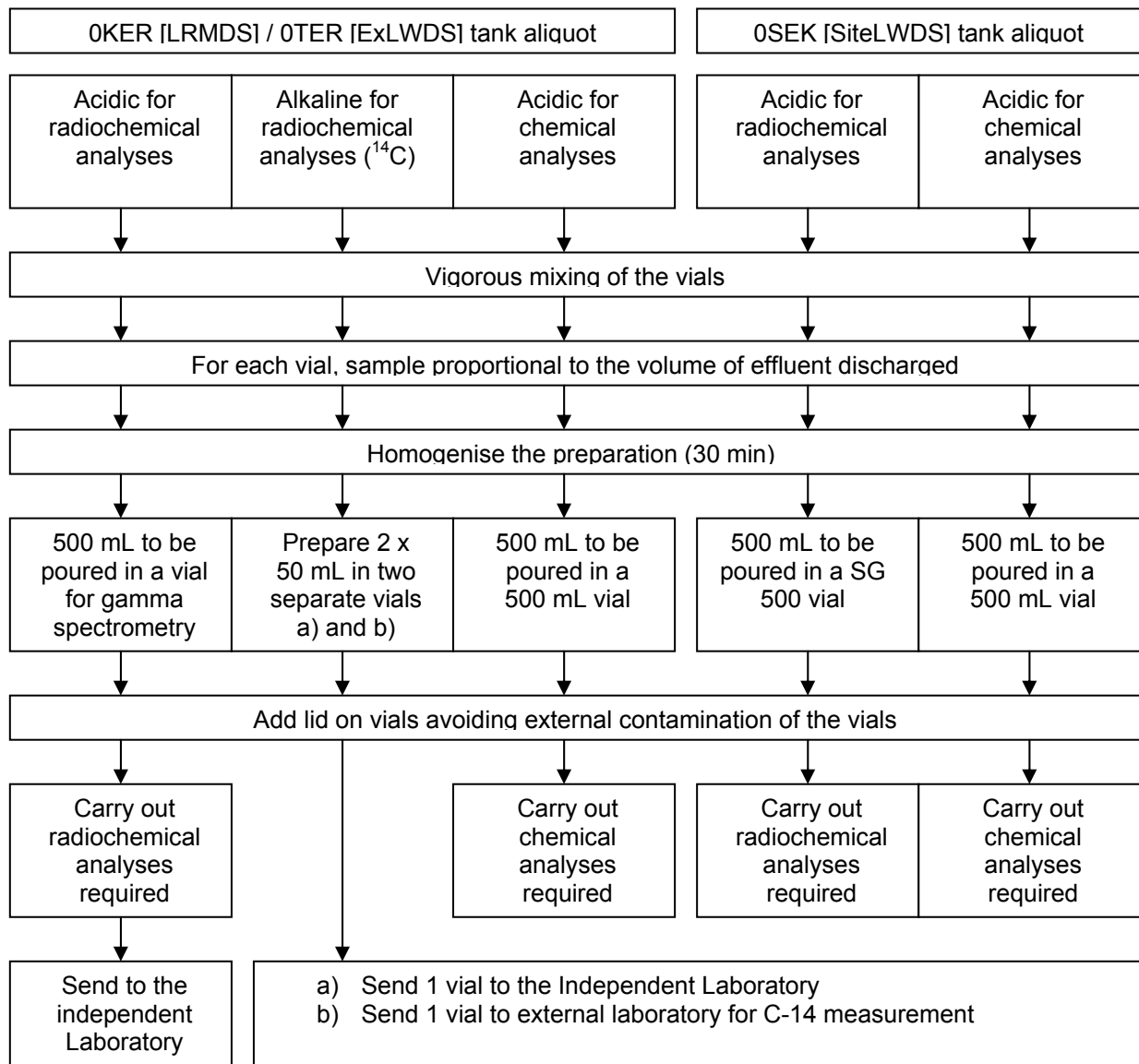
When they are required, composite samples described as "average aliquots" must be collected and be representative of the whole of the discharges undertaken during the period considered (month, quarter, semester ...). As such, the volumes of each sample added to the aliquot must be proportional to the volume of effluent discharged. The volume of effluent discharged is measured, either by a volume flowmeter fitted on the discharge line, or by difference of the level of effluent in the storing tank prior and after discharge. The flow rates are usually calculated: a gross estimation is first carried out to define the discharge conditions (maximum discharge flow rates to be used not to exceed the flow rate limits and added concentrations as defined in the discharge authorisation), and retroactive verification is also undertaken.

For each effluent added in the aliquot, records of the following must be made:

- volume discharged;
- volume of effluent sampled for making up the aliquot;
- the date of addition of this sample within the aliquot collecting vial.

The average aliquot used for the radiochemical analyses can either be prepared in one operation at the end of the period considered (month, quarter...), or the samples can be added throughout the period after every discharge. In the latter case, the final volume of the aliquot must be as defined for the radiochemical analyses. It is however compulsory that the average aliquot used for the chemical analyses is prepared at the end of the period considered, in order to minimise opening of the collecting vial. In addition, and considering the analyses carried out, it is essential that the analyses are carried out as soon as possible after the preparation of the aliquot.

A summary description of the preparation of the aliquots for the French fleet is given as an example below.



Note: ¹⁴C and ⁶³Ni analyses are carried out by external laboratories

These arrangements in place in French nuclear power stations are similar to those described for the composition of composite samples in the Technical Guidance Notes M12 [3] and M18 [4].

1.2 CONDITIONING AND STORAGE OF THE LIQUID SAMPLES

Along with ensuring that the sample is representative, it is essential that adequate conditioning and storing of the sample are provided. Storing arrangements for liquid effluents are described in [2]. In particular, it is generally recommended that:

- the container is clean or preferably new;
- the container guarantees and preserves the nature and composition of the sample, avoiding any loss or pollution;
- the full containers after sampling are packaged and transported to the laboratory according to site arrangements;
- in most cases, the sampling containers are different from those used for the analyses;
- samples must be clearly identified (such as date, sampling time, person in charge of the sampling, origin...);
- during the period between sampling and analysis of the sample:
 - leaktighness of the sample should be checked to avoid pollution by capillary return feed;
 - the samples should be stored away from light;
 - the samples to be used for chemical and radiochemical analyses should be stored in the fridge.

These arrangements in place in French nuclear power stations are similar to those described for the sample containers and storage in the Technical Guidance Notes M12 [3] and M18 [4].

1.3 MEASUREMENT TECHNIQUES CURRENTLY IN USE FOR RADIOACTIVE LIQUID EFFLUENTS

1.3.1 Gross alpha and beta measurement

The main points of the procedure for the measurement of gross alpha and gross beta activities in liquid sample from existing stations [5] are described below.

Two simultaneous preparations are made up in the same conditions for each sample of the OKER [LRMDS], OTER [ExLWDS] and OSEK [SiteLWDS] tanks. For each preparation, a small volume (usually 10 mL) of the sample collected according to the procedure described in [1] is evaporated on a hot plate. The volume of sample to be evaporated may be adjusted so that the weight of the dry sample does not exceed 2 mg/cm². In addition, it is essential that the temperature of the hotplate is kept around 65°C in order to avoid loss of volatile substances, in particular iodine compounds that are volatile at higher temperatures.

Once prepared according the above procedure, the samples are placed in the counter (proportional counter for gross alpha and gross beta activities), pre-set on 10,000 impulsions in order to minimise counting time. Counting time is 50 min, and only one measurement is carried out on each sample. The results are subsequently automatically analysed by a software designed for the purpose and measurement recorded (manual verification of the calculations is carried out at least once for each new version of the software). Details of the calculations, uncertainties and detection thresholds are given in [5].

1.3.2 Measurement of gamma activity by spectrometry

The detail of the procedure for the measurement of gamma activity by spectrometry in liquid sample from existing stations is given in [6]. The main points of the procedure for the measurement of gamma activity by spectrometry in liquid sample are described below.

The sample (sampling method for liquid effluent as described above) is conditioned in a vial designed for the purpose (SG500 vial) and acidified with nitric acid to the target pH of 2. It is subsequently placed and counted in a gamma spectrometer equipped with a GeHP detector, while preventing any likely contamination. Alternatively, gross gamma activity of the sample can be analysed in a NaI spectrometer under a different procedure.

Counting time is determined depending on the sample considered. In particular, the requirement for a detection limit of 2 Bq/L for ^{60}Co for the analysis of the 0SEK [SiteLWDS] tanks (5 Bq/L for the 0KER [LRMDS] and 0TER [ExLWDS] tanks) implies that the counting times are generally long, between 2 and 10 hours depending on the material used. Daily standardisation of the spectrometer is carried out using a ^{152}Eu source standard, prior to any measurement. This is to ensure that the energies recorded and the resolutions of the spectrometer are adequate. Weekly checks of the resolution of the equipment and measure of the background noise, and monthly check of the efficiency are also carried out using a ^{152}Eu source according to [6] and [7].

The spectrum once obtained is analysed according to a library referencing all the radionuclides that have been detected at least once per site. This analysis is usually carried out automatically by the analyser; however, this is completed with a manual check in order to ensure that the adequate peaks have been considered. This analysis enables the determination of the activity concentration, the decision threshold and the detection limit. The details of these calculations are described in [6]. In all cases, the results are recorded and filed to ensure traceability.

1.3.3 Measurement of tritium beta activity by liquid scintillation

The measurement of the tritium activity (beta emission) in liquid effluents is currently carried out by liquid scintillation. The procedure is described in detail in [8]. The main points of the procedure are summarised below.

Liquid samples providing from the 0KER [LRMDS], 0TER [ExLWDS] and 0SEK [SiteLWDS] tanks are all analysed by liquid scintillation counting. 0SEK [SiteLWDS] samples can generally be analysed without any pre-treatment as the activity providing from radionuclides other than tritium is usually very low. In the case of 0KER [LRMDS] and 0TER [ExLWDS] samples (or contaminated 0SEK [SiteLWDS] samples), pre-treatment by cold distillation (i.e. at 30 to 35°C, which avoids loss of material in drops contained in vapour) is required in order to avoid quenching. The details of the distillation operations are given in [8].

In order to ensure reproducibility, two preparations are made up for each sample of effluent. Once the distillation operations have been carried out, an aliquot of each preparation is mixed with a set volume of scintillation cocktail before shaking (homogenisation of the sample), setting of the sample and counting in the liquid scintillation counter. Standardisation of the counter is carried out on a regular basis [9]. In order to ensure that it is reproducible and representative, each sample is counted several times for an appropriate duration.

The results are then analysed according to the latest French norm and the activity concentration of each sample of effluent determined from the average of the three measurements of each vial, along with the uncertainty of the measure and the decision threshold and LOD. Details of these calculations are given in [8]. All results are recorded and archived, as is the case for all analyses.

1.3.4 Measurement of ^{14}C beta activity by liquid scintillation

Monitoring of ^{14}C activity in liquid effluents is currently carried out by an external laboratory, and the main points of the procedure are summarised below [10].

A sample of the released tank is chemically conditioned to a high pH with NaOH to avoid release of the carbon dioxide form. A 1 mL aliquot of this effluent sample to analyse is then oxidised in a combustion system (typically type Oxidizer 307 Packard or equivalent) according to the manufacturer's specifications or the procedure in place [10]. Details of these operations are given in Figure 1. The role of the Oxidiser[®] is:

- to burn all chemical forms of carbon-14 in carbon dioxide;
- to trap it in a specific absorbent (Carbosorb E[®]).

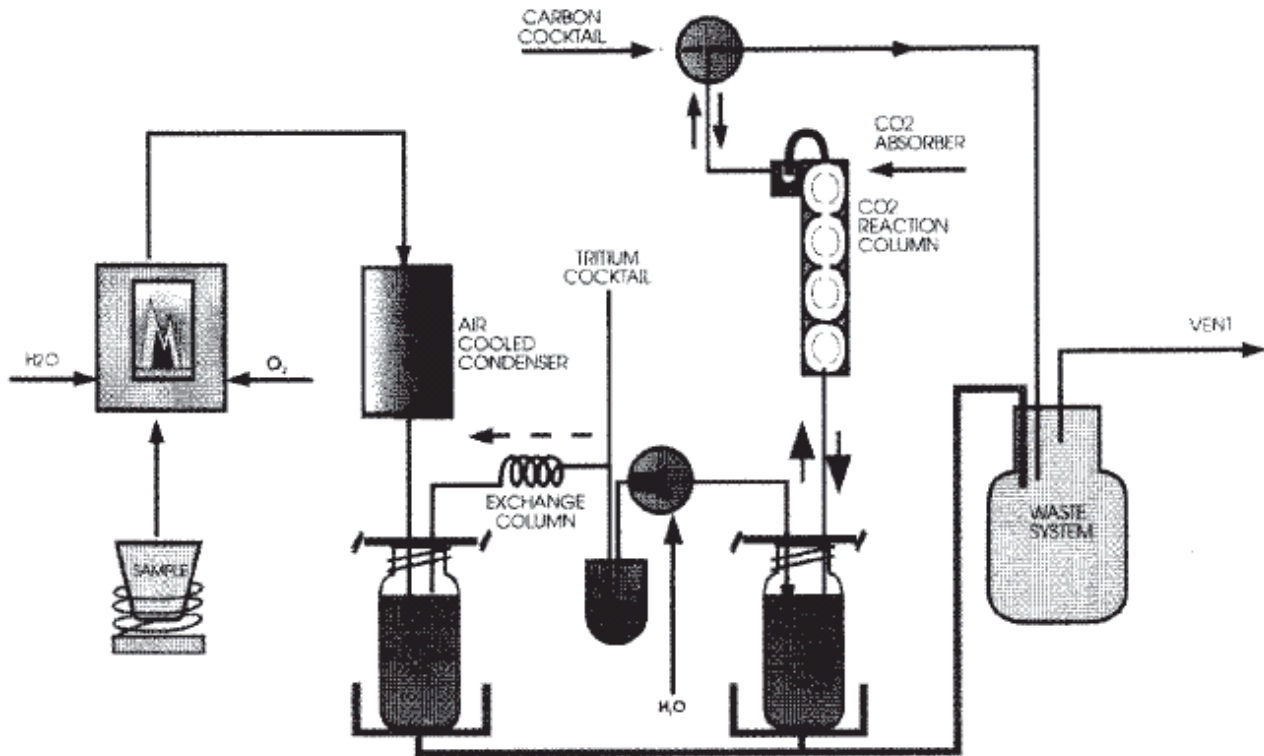


Figure 1: The Oxidizer system

Following combustion, carbon dioxide is trapped in the absorption column which is subsequently rinsed with scintillant cocktail before being collected in a counting vial. Depending on the determination method used (internal or external standard), one or two vials need to be prepared and counted twice for each sample of effluent (counting time: 100 min each time on the 7 – 50 keV energy window). In addition, reference and “memory” samples are also prepared and counted in the liquid scintillation counter (LSC counter type Tri Carb 3100 TR Packard or equivalent). Weekly check with standards, auto-normalisation and calibration of the LSC are carried out in order to ensure continuity of the measurements. The detection limit of the method is 100 Bq/L for a counting time of 30 minutes. The accuracy of the method is estimated to 15%.

The results are then analysed according to the norms in place (AFNOR/BNEN NFM 60 802.2) and the activity of the discharge tanks determined, along with uncertainties of the measure, decision threshold and detection limits. All the calculations carried out are described in detail in procedure [10]. All results and spectra are saved on the LSC computer. In addition, paper copies are recorded and archived, as is the case for all analyses.

1.4 MONITORING OF THE PRIMARY LIQUID EFFLUENTS CURRENTLY IN PLACE

The nature of the radioactive primary and spent liquid effluents is given in PCER Sub-chapter 6.2. Treatment and storage systems for these effluents are described in Sub-chapters 6.2 and 6.4.

The primary liquid effluents include:

- liquid leaked or drained from the primary coolant water. This contains only chemicals from the primary circuit (see PCSR Sub-chapter 5.5, notably boric acid and lithium) and is not otherwise contaminated by other chemicals or oils;
- water from circuits containing the primary coolant and discharged to downstream treatment systems in response to requirements to dilute boron through the fuel cycle.

In existing stations, these effluents are directed to the Primary Effluent Treatment System TEP [CSTS] where they are degassed and decontaminated: treatment on evaporator enables to separate water in the distillates and boric acid in the concentrates. The distillates that cannot be further recycled in the primary circuit are sent to the OKER [LRMDS] for storage before discharge; the non-recyclable concentrates are sent to Spent Effluent Treatment System 8TEU [LWPS] for treatment by demineralisation.

Radiological monitoring of these effluents (TEP [CSTS], TES [SWTS], TEU [LWPS]) is continuous and carried out via radioprotection lines specific to a station design.

Once they have been decontaminated, the primary effluents are stored in interim storage tanks. All tanks are fitted with a pumping system which function is to:

- enable mixing and homogenisation of the interim storage tanks prior to sampling;
- allow for potential transfer of the content of one tank into another;
- allow for transfer of the content of the interim storage tanks to the spent effluent treatment system (if the evaporators of the primary effluent treatment system are not available for a period of time); and
- enable the discharge of the content of the interim storage tanks into the OKER [LRMDS] tanks prior to final discharge if the effluents are not recyclable.

The primary effluent treatment system interim storage tanks in existing stations are currently monitored for the following substances detailed in Table 1. It is however expected that this practice will be different in the EPR.

Substance	Sampling type	Monitoring frequency	Measurement method
Total gamma	One-off sampling	Prior to treatment on evaporator	Nal detector
Tritium			Liquid Scintillation
Boric acid			Titrimetry
Lithium			Atomic Absorption Spectrometry (AA Spec)
Sodium			Inductive Coupled Plasma (ICP) or AA Spec
Chloride			Liquid Phase Ionic Chromatography (LPIC) or Specific Electrode
Fluoride			Liquid Phase Ionic Chromatography (LPIC) Specific electrode
Sulphates			Liquid Phase Ionic Chromatography (LPIC)
Total silica			Inductive Coupled Plasma (ICP)

Table 1: Monitoring of the interim holdup tanks of the primary effluent treatment system (TEP [CSTS])

In case of high value of Na, other measurements of Mg, Al and Ca could be implemented.

Tritium and lithium monitoring is carried out. Total gamma monitoring is carried out in order to ensure efficiency of the treatment systems.

Boron monitoring is carried out in order to estimate the concentration factor prior to treatment on the evaporator. Monitoring of sodium, chloride, fluoride, sulphates, and ionised silica enables to predict if the limit concentration in the concentrates may be reached, depending on the concentration factor. All the procedures currently in use in existing stations for the monitoring techniques of the above substances have been written and are readily available to all stations (on a database). The procedures for total gamma and tritium analyses are given as example in [6] and [8].

1.4.1 Distillates

The distillates come from the TEP [CSTS] evaporators. Their chemical characteristics are usually similar to that of the primary circuit water, and they are usually monitored for the following substances (see Table 2).

Substance	Sampling type	Monitoring frequency	Measurement method
Tritium	One-off sampling	Depending on total conductivity, prior to transfer to REA [RBWMS]	Liquid scintillation
Boric acid			Titrimetry
Lithium			ICP/ AA Spec
Sodium			ICP/ AA Spec
Chloride			Specific electrode/ LPIC
Fluoride			
Sulphates			
Ionised silica			Colorimetry

Table 2: Monitoring of the distillates from the Primary Effluent Treatment System (TEP [CSTS])

1.4.2 Concentrates

The concentrates also come from the TEP [CSTS] evaporators. They are recycled in the REA [RBWMS] system. When they cannot be recycled, they are redirected to the Spent Effluent Treatment System (Process Drains). The monitoring regime currently in place for the concentrates from the Primary Effluents Treatment System is as follows (see Table 3):

Substance	Sampling type	Monitoring frequency	Measurement method
Boric acid	One-off sampling	Prior transfer to REA [RBWMS]. Monitoring carried out during treatment of the TEP [CSTS] interim tank previously monitored	Titrimetry
Lithium		If the TEP [CSTS] cation resin is saturated in Li. Monitoring carried out during treatment of the TEP [CSTS] interim tank previously monitored	AA Spec
Sodium		Monitoring carried out during treatment of the TEP [CSTS] interim tank previously monitored	AA Spec
Chloride			LPIC/ Specific electrode
Fluoride			
Sulphates			
Ionised silica		Colorimetry	

Table 3: Monitoring of the concentrates from the Primary Effluent Treatment System (TEP [CSTS])

In particular, the results of the monitoring determine whether the effluents can be sent to the REA [RBWMS] system or not. In addition, for sulphates, chloride, fluoride, sodium and ionised silica, monitoring is carried out to ensure compliance to the chemical specifications of the primary circuit.

1.5 MONITORING OF SPENT LIQUID EFFLUENTS CURRENTLY IN PLACE

The treatment system of spent liquid effluents in the EPR is described in PCER Sub-chapters 6.2 and 6.4. It was established that the spent liquid effluents are divided in three groups: Process Drains, Chemical Drains and Floor Drains, and are all treated in the 8TEU [LWPS] system. Each category of effluent is selectively collected in designated tanks depending on the category they belong to. The aim of the 8TEU [LWPS] circuit is to limit the activities of the spent effluents prior to transfer to the storage tanks before final discharge (0KER [LRMDS] or 0TER [ExLWDS] tanks).

1.5.1 Process Drains

Process Drains contain polluted primary coolant from flushing of systems which are not recycled because they have a low boron content and may potentially have the wrong chemical properties or too much suspended material. They are directed to the demineralisation unit. Depending on their composition, they can also be treated by evaporation, or, after filtration of the content, be directly sent to the storage tanks (0KER [LRMDS] or 0TER [ExLWDS] tanks) before final discharge.

In addition to activity monitoring, the following chemical monitoring (see Table 4) of the Process Drains is carried out to determine the appropriate treatment:

Substance	Sampling type	Monitoring frequency	Measurement method
Boron	One-off sampling	Monitoring of the tank before treatment on demineraliser	Titrimetry
Sodium			AA Spec
Calcium			

Table 4: Monitoring of 8TEU [LWPS] Process Drain head storage tanks K ratio could also be calculated knowing that $K=Na/B$.

In existing stations, radiochemical monitoring (total gamma measurement) of these effluents is also undertaken after treatment, in order to ensure good efficiency of the treatment systems. Additional gamma spectrometry measurement can also be used to determine which radionuclide is not (or not well) retained on the demineralisers.

1.5.2 Chemical Drains

Chemical Drains are active effluents chemically polluted. They are monitored before being treated by evaporation. In existing stations, the concentrates collected in the 8TEU [LWPS] are chemically monitored for the following substances before being sent to the 8TES [SWTS] (see Table 5).

Substance	Sampling type	Monitoring frequency	Measurement method
Total boron	One-off sampling	Prior to treatment, as soon as the estimated B concentration ≥ 10 g/kg	Titrimetry/ AA Spec
Total sodium		Monitoring after treatment as soon as B concentration ≥ 10 g/kg	AA Spec
Dry extract		Monitoring as soon as B concentration ≥ 30 g/kg	Weighting
Calcium			AA Spec
Phosphates		Monitoring as soon as B concentration ≥ 30 g/kg if PO4 ≥ 5 g/kg	ICP/ colorimetry
Chloride		Monitoring once a month if B ≥ 30 g/kg	LPIC

Table 5: Monitoring of the 8TEU [LWPS] concentrates and chemical drains

The activity of the distillates is also monitored before transfer to OKER [LRMDS] (or OTER [ExLWDS]).

The aim of this monitoring regime is to:

- comply to the operating chemical specifications in order to ensure good use of the material (evaporator);
- comply to the criteria of waste treatment systems;
- ensure compliance to regulatory criteria for transportation of the waste.

1.5.3 Floor Drains

These effluents are only slightly contaminated and thus their management is based on activity criteria. They are usually treated by filtration (sometimes evaporation) before being sent to the OKER [LRMDS] (or OTER [ExLWDS]) tanks.

They are monitored prior to treatment to determine the appropriate treatment and after treatment.

1.6 MONITORING CURRENTLY IN PLACE PRIOR TO DISCHARGE

1.6.1 Monitoring of the OKER [LRMDS] storage tanks

The systems implemented prior to OKER [LRMDS] discharge are in place in order to monitor the effluents stored and define their discharge conditions. **In the existing plants**, the effluents in the OKER circuit come mainly from:

- the distillates from the evaporation activities from the treatment of the primary effluents;
- the purge of the interim storage tanks from the TEP [CSTS] and REA [RBWMS] systems;
- the Spent Effluents Treatment System;
- the laundry;
- the blowdown from the steam generators non recycled at the condenser.

All effluents collected in the OKER [LRMDS] tanks undergo a 5 µm filtration, except those from the steam generator blowdown system, filtrated at 25 µm. However, in the EPR, both filtrations will be at 5 µm.

Prior to any discharge of a OKER [LRMDS] tank, the content of the tank is homogenised and sampled. The mixing and sampling techniques in place to ensure that a representative sample is taken are summarised in section 1.1.1. [1] and [2].

Part of the sample is used for the chemical analyses, and part for the radiochemical analyses. The procedures for the storage of the samples are described in section 1.2.

The radiochemical analyses currently carried out in existing stations on the OKER [LRMDS] samples are as follows (see Table 6 and PCER Sub-chapter 7.3). The detail of the analyses currently carried out is given in [5], [6], [8], [9] (standardisation), [10].

Radionuclide	Sampling type	Measurement method	LOD
Check of the absence of gross alpha activity and measure of the gross beta activities	OKER [LRMDS] tanks	Proportional counter	(α) 2 Bq/L
			(β) 3.7 Bq/L
		Total gamma	10 Bq/L ¹³⁷ Cs eq
Tritium		Liquid Scintillation	100 Bq/L
FP/AP		Gamma Spectrometry*	5 Bq/L in Co60
C14 (carried out after discharge)		Liquid Scintillation	100 Bq/L
Check of the absence of total alpha activity	Monthly aliquot of the OKER [LRMDS] tanks	Proportional counter	0.74 Bq/L
Ni-63 (carried out after discharge)		Extraction and liquid scintillation	5 Bq/L

Table 6: Radiological monitoring of the OKER [LRMDS] tanks

* This measurement includes monitoring of the following radionuclides: ⁵⁴Mn, ⁵⁸Co, ⁶⁰Co, ^{110m}Ag, ^{123m}Te, ¹²⁴Sb, ¹²⁵Sb, ¹³⁴Cs, and ¹³⁷Cs. Other significant radionuclides potentially identified must also be reported.

The alpha measurement is carried out on a quarterly basis on an aliquot sample. If the gross alpha activity is over 1 Bq/L, an isotopic measurement is carried out. In the existing stations, gross alpha measurement is to be carried out on all discharge tanks prior to discharge, with an LOD of 2 Bq/L. This analysis is also carried out on the monthly aliquot sample. Tritium analyses are carried out on all tanks prior to discharge, whereas ⁶³Ni analyses are carried out after discharge. Overall, all the analyses carried out before discharge are also used to define the discharge conditions to comply with some limits in the receiving environment.

For chemical analyses, the samples used are firstly filtrated in order to carry out analyses for suspended solids. Part of the filtrate is then stored as such for boron analysis, while the rest of the filtrate is acidified with hydrochloric or sulphuric acid before further chemical analyses.

The chemical analyses currently carried out on the OKER [LRMDS] samples are given for indication and are as follows (see Table 7 and PCER Sub-chapter 7.4). The detail of the analyses currently carried out in existing stations is available in written procedures (not listed here).

Substance	Sampling type	Monitoring frequency	Measurement method	LOD
Boron (boric acid)	One-off sampling	Prior to every tank discharge	Concentration in the tank 2 hour flow 24 hour flow Annual flow Concentration added to the discharge Titrimetry ICP	> 50 mg/kg in boron
Lithine	Aliquot	Monthly	Concentration in the aliquot AA Spec ICP	> 0.0003 mg/kg in Lithium
Hydrazine	One-off sampling	Prior to every tank discharge	Concentration in the tank 2 hour flow 24 hour flow Annual flow Concentration added to the discharge Molecular Absorption Spectrometry	> 0.01 /0.15 mg/kg

Substance	Sampling type	Monitoring frequency	Measurement method	LOD
Morpholine	One-off sampling for tanks containing steam generator blowdown waters. If not, by aliquot	Either prior to every tank discharge or monthly, depending on the effluent present in the tank	Concentration in the tank/ aliquot 24 hour flow Annual flow Concentration added to the discharge / Capillary electrophoresis	> 0.15 / 0.5 mg/kg
Ethanolamine	One-off sampling for tanks containing steam generator blowdown waters. If not, by aliquot	Either prior to every tank discharge or monthly, depending on the effluent present in the tank	Concentration in the tank/ aliquot 24 hour flow Annual flow Concentration added to the discharge Capillary electrophoresis	> 0.15 mg/kg
Phosphates	One-off sampling	Prior to every tank discharge	Concentration in the tank 2 hour flow 24 hour flow Annual flow Concentration added to the discharge LPIC Molecular Absorption Spectrometry	> 0.01 mg/kg in phosphates
Detergents	One-off sampling for tanks receiving laundry effluents	Prior to every discharge of tank containing laundry effluent	Concentration in the tank 2 hour flow 24 hour flow Annual flow Concentration added to the discharge Molecular Absorption Spectrometry/deconvolution	> 0.5 mg/kg
Total metals (Cu, Zn, Mn, Ni, Cr, Fe, Al)	Aliquot	Monthly	Concentration in the tank 24 hour flow Annual flow Concentration added to the discharge ICP/ AA Spect	Varying depending on metal

Substance	Sampling type	Monitoring frequency	Measurement method	LOD
Suspended solids	Aliquot	Monthly	Concentration in the tank 24 hour flow Annual flow Concentration added to the discharge Weighting	> 2 mg/kg
COD	Aliquot	Monthly	Concentration in the tank 24 hour flow Annual flow Concentration added to the discharge Molecular Absorption Spectrometry	> 15 mg/kg
Ammonium*	One-off sampling	Each tank	Concentration in the tank 24 hour flow Annual flow Capillary electrophoresis/ colorimetry	> 0.15 / 0.01 mg/kg in ammonium
Nitrites*	One-off sampling	Each tank	Concentration in the tank 24 hour flow Annual flow Molecular Absorption Spectrometry/LPIC	> 0.01 mg/kg in N
Nitrates*	One-off sampling	Each tank	Concentration in the tank 24 hour flow Annual flow Molecular Absorption Spectrometry/LPIC	> 0.01 mg/kg in N

Table 7: Chemical monitoring of the OKER [LRMDS] tanks

*Depending on discharge authorisation

Figure 2 presents an overview of the preparation of the OKER [LRMDS] samples for radiological and chemical analyses.

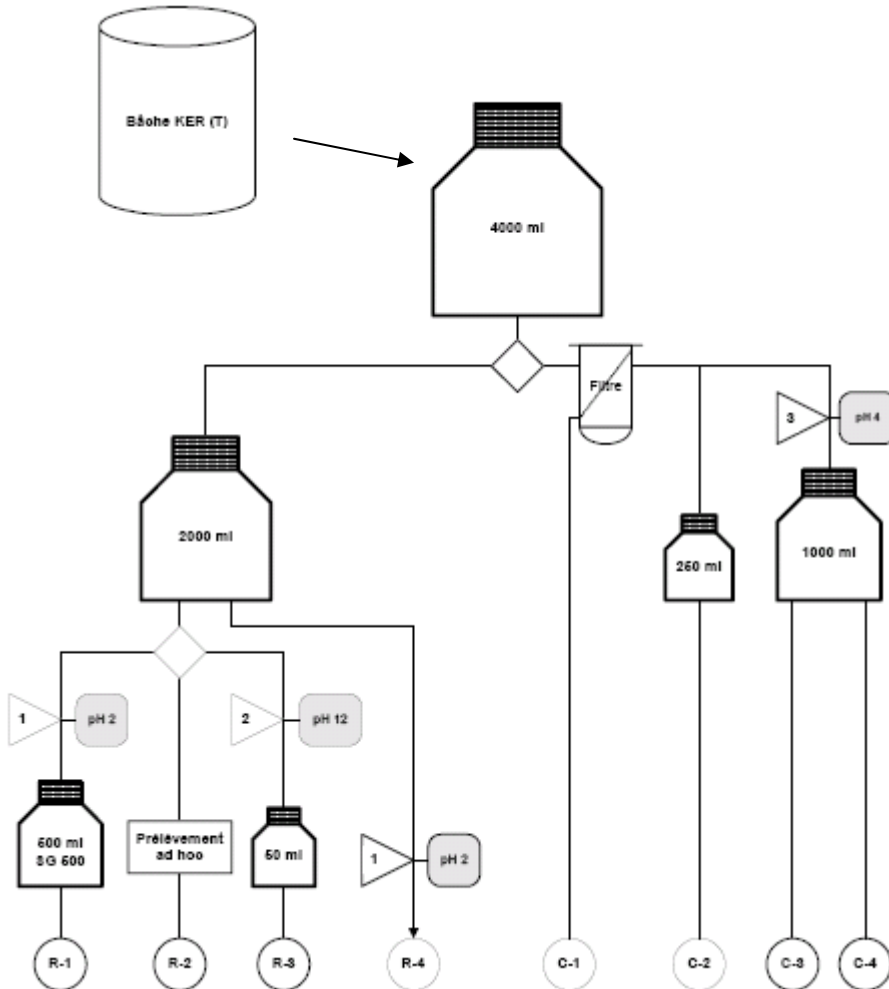


Figure 2: Representation of the preparation of the 0KER [LRMDS] samples for radiological and chemical analyses.

Caption:

◇ represents the division of the initial volume sampled into several small fractions. The volume given here is only indicative and shall be recalculated depending on the analyses to carry out.

△ represents the chemical conditioning of the sample. The volumes to add need to be adjusted in order to reach the target pH

1. add nitric acid
2. add sodium hydroxide
3. add hydrochloric or sulphuric acid 1N

○ represents the samples to be sent for analyses. (R for radiochemical analyses and C for chemical analyses)

R-1: analysis by gamma spectrometry and gross gamma. Sample to be kept for 4 months after analysis

R-2: Tritium, gross alpha and gross beta analysis

R-3: ¹⁴C analysis (according to each discharge authorisation) and making up of the average monthly aliquot (alkaline)

R-4: monthly aliquot (acidic) after R-1, R-2 and R-3

C-1: Total suspended solids analysis

C-2: boric acid analysis (sample filtered and not acidified)

C-3: Analysis for detergents, amines, hydrazine, ammonia, phosphorus or total phosphate and COD (sample filtered and acidified)

C-4: Storage of a 1000 mL sample for making up of the average acidic aliquot after C-3.

1.6.2 Monitoring of the 0SEK [SiteLWDS] storage tanks

The systems implemented prior to 0SEK [SiteLWDS] discharge are in place in order to monitor the effluents stored and to define the discharge conditions. The effluents in the 0SEK [SiteLWDS] circuit provide mainly from leaks or purges from the secondary circuit, except for the steam generator blowdown, directed to the 0KER [LRMDS] tanks.

As explained in PCER Chapter 7, some substances are monitored in each tank prior to discharge. This is because it has been reported that the concentrations of some chemicals can be very variable and reach high values. In particular, this is the case for hydrazine, tritium, and fission or activation products beta emitters. Other substances are also monitored in each tank, but the measurements are carried out after discharge. This is in particular the case of phosphates, and ammonia, nitrites and nitrates. Finally, some compounds are only monitored monthly by aliquot, such as boron, morpholine, ethanolamine, metals, suspended matter and COD (see PCER Sub-chapter 7.4). In addition, the aliquot is checked for absence of alpha emitters (see PCER Sub-chapter 7.3). The procedure for the preparation of the average monthly aliquot is given in 1.1.2 [2].

The radiochemical analyses currently carried out on the 0SEK [SiteLWDS] samples are as follows (see Table 8 and PCER Sub-chapter 7.3). The detail of the analyses currently carried out in existing stations is given in [5], [6], [8], [9] (standardisation), [10].

Radionuclide	Sampling type	Measurement method	LOD
Gross beta activity	0SEK [SiteLWDS] tanks	Proportionnal counter	3.7 Bq/L
Tritium		Extraction and Liquid Scintillation	100 Bq/L
FP/AP	Monthly aliquot of the 0SEK [SiteLWDS] tanks	Gamma spectrometry	2 Bq/L in ⁶⁰ Co
Check of the absence of gross alpha activity		Proportionnal counter	0.74 Bq/L

Table 8: Radiological monitoring of the 0SEK [SiteLWDS] tanks

The chemical analyses currently carried out on the OSEK [SiteLWDS] samples are as follows (see table 9 and PCER Sub-chapter 7.4). The detail of the analyses currently carried out in existing stations is available in written procedures (not listed here).

Chemical	Sampling type	Monitoring frequency	Measurement method and calculations	LOD
Boron	Aliquot	Monthly, only if boric acid was added in the secondary circuit	Concentration in the tank 2 hour flow 24 hour flow Annual flow Concentration added to the discharge Titrimetry ICP	> 50 mg/kg in boron
Hydrazine	One-off sample prior to discharge of the tank	Before each tank discharge	Concentration in the tank 2 hour flow 24 hour flow Annual flow Concentration added to the discharge Molecular Absorption Spectrometry	> 0.01 / 0.15 mg/kg
Morpholine	Aliquot	Monthly	Concentration in the tank/ aliquot 24 hour flow Annual flow Concentration added to the discharge Capillary electrophoresis	> 0.15 / 0.5 mg/kg
Ethanolamine	Aliquot	Monthly	Concentration in the tank/ aliquot 24 hour flow Annual flow Concentration added to the discharge Capillary electrophoresis	> 0.15 mg/kg
Phosphates	One-off sampling	Before each tank discharge	Concentration in the tank 2 hour flow 24 hour flow Annual flow Concentration added to the discharge LPIC Molecular Absorption Spectrometry	> 0.01 mg/kg in P

Chemical	Sampling type	Monitoring frequency	Measurement method and calculations	LOD
Total metals (Cu, Zn, Mn, Ni, Cr, Fe, Al)	Aliquot	Monthly	Concentration in the tank 24 hour flow Annual flow Concentration added to the discharge ICP/ AA Spect	Varying depending on metal
Suspended solids	Aliquot	Monthly	Concentration in the tank 24 hour flow Annual flow Concentration added to the discharge Weighting	> 2 mg/kg
COD	Aliquot	Monthly	Concentration in the tank 24 hour flow Annual flow Molecular Absorption Spectrometry	> 15 mg/kg
Ammonium*	One-off sampling	Each tank	Concentration in the tank 24 hour flow Annual flow Capillary electrophoresis/ colorimetry	> 0.15 / 0.01 mg/kg in ammonium
Nitrites*	One-off sampling	Each tank	Concentration in the tank 24 hour flow Annual flow Molecular Absorption Spectrometry CIPL	> 0.01 mg/kg in N
Nitrates*	One-off sampling	Each tank	Concentration in the tank 24 hour flow Annual flow Molecular Absorption Spectrometry CIPL	> 0.01 mg/kg in N

Table 9: Chemical monitoring of the 0SEK [SiteLWDS] tanks

* Depending on discharge authorisation

Figure 3 presents an overview of the preparation of the 0SEK [SiteLWDS] samples for radiological and chemical analyses.

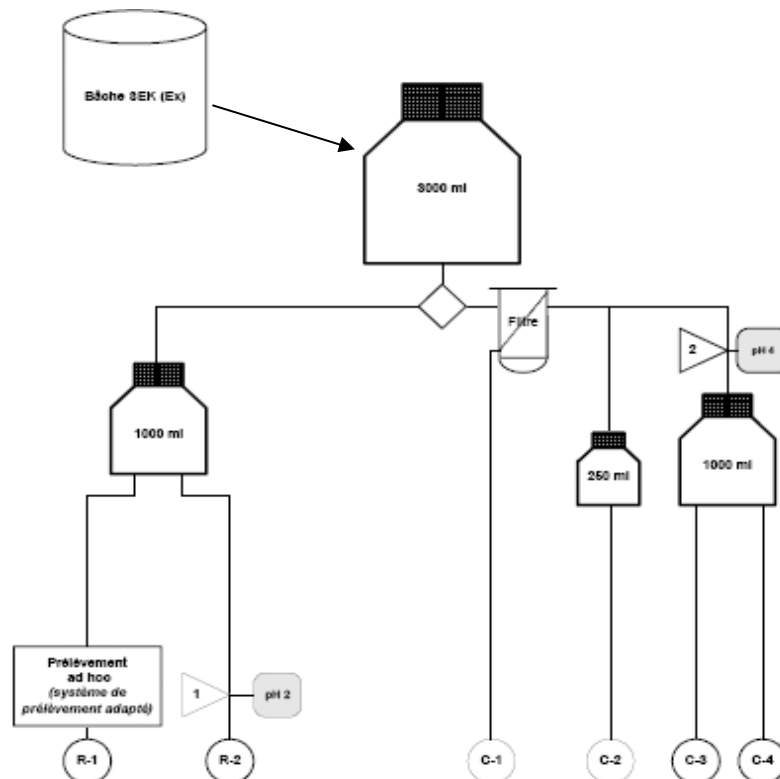


Figure 3: Representation of the preparation of the 0SEK [SiteLWDS] samples for radiological and chemical analyses.

Caption:

◇ represents the division of the initial volume sampled into several small fractions. The volume given here is only indicative and shall be recalculated depending on the analyses to carry out.

△ represents the chemical conditioning of the sample. The volumes to add need to be adjusted in order to reach the target pH

1. add nitric acid 65%
2. add hydrochloric or sulphuric acid 1N

○ represents the samples to be sent for analyses. (R for radiochemical analyses and C for chemical analyses)

R-1: Tritium, gross beta analysis

R-2: Storage of a 1000 mL sample for making up of the average acidic aliquot after R-1 for once month. Sample is stored for 4 months.

C-1: Total suspended solids analysis

C-2: boric acid analysis (sample filtered and not acidified)

C-3: Analysis for amines, hydrazine, ammonia, phosphorus or total phosphate and COD (sample filtered and acidified)

C-4: Storage of a 1000 mL sample for making up of the average acidic aliquot after C-3.

1.6.3 Monitoring of the effluents before general discharge

Monitoring of effluents contained in the 0KER [LRMDS], 0TER [ExLWDS] and 0SEK [SiteLWDS] tanks is carried out in order to ensure compliance to the annual, 2 hour and 24 hour flow limit values when required. When possible, these flows are estimated based on calculations rather than measurements, as this enables to discard the uncertainties associated with experimental measures and is considered to be more reliable. However, for some substances, in addition to the determination of the flows, periodical measure (in general, monthly) can also be carried out. In this case, volume flowmeters are used for their determination.

Calculation-based estimate is always used for substances originating from a single origin. This is because the existing methods to dose the various chemical parameters in the outfall structure do not provide adequate accuracy and sensitivity. For chemical substances with several sources, the sum of the activities from each individual source provides the basis to ensure compliance to the added concentration criteria. However, a measurement is also carried out in order to guarantee adequacy of the effluents discharged. If it is identified that the parameters are not stable between the discharge source and the outfall, the location of the measurements is determined on a case-by-case basis.

The substances measured in the outfall structure are as follows (see Table 10):

Substance	Sampling type	Monitoring frequency	Measurement method	LOD
Ammonia	24 hour sampling	Weekly	Capillary Electrophoresis	> 0.15 / 0.01 mg/kg in ammonia
Nitrites			Molecular absorption spectrometry/CIPL	> 0.01 mg/kg in N
Nitrates				> 0.01 mg/kg in N
COD			Molecular absorption spectrometry	> 15 mg/kg

Table 10: Monitoring carried out in the outfall structure

For all other chemicals (boric acid, hydrazine, morpholine, ethanalamine, phosphates, detergents, total metals and suspended solids) the concentrations added in the main outfall structure are calculated based on the concentrations measured in the 0KER [LRMDS], 0TER [ExLWDS] and 0SEK [SiteLWDS] tanks.

2 MONITORING OF GASEOUS EFFLUENTS

The purpose of this section is to present the monitoring activities related to gaseous effluents, in terms of both radiochemical and chemical composition, from their production through to collection, storage and discharge. Some information concerning the operations related to the monitoring of gaseous effluents have been provided in PCER Sub-chapter 7.3 (radioactive effluents) and Sub-chapter 7.4 (chemical associated with radioactive effluents). In addition, the processes taking part in the management of the gaseous effluents are described in PCER Sub-chapter 6.2. The aim of the current section is to provide additional details on the monitoring arrangements in place **in existing stations** and that could be implemented in the UK EPR.

2.1 SAMPLING AND STORAGE ARRANGEMENTS

Sampling procedures of gaseous effluents are very dependent on the type of sample required for further analyses. Elements are given in each individual section below for the description of the radiochemical analyses carried out.

Generally speaking, isokinetic sampling is essential in order to obtain a representative sample. Indeed, the air and the particles to sample must enter the sampling device (pipe) at the same speed as the discharge. Sampling arrangements have been normalised and are implemented on site according to the international standard ISO 2889: 1975. This enables to determine the dimensioning of sampling installations (flow rate, pipe size), and subsequently the operating conditions (such as sampling duration).

2.2 MEASUREMENT TECHNIQUES CURRENTLY IN USE FOR RADIOACTIVE GASEOUS EFFLUENTS

Unlike liquid effluents, the EPR Gaseous Effluent Treatment System (TEG [GWPS]) presents some major differences to that currently in place in existing stations (typically 1300 MW(e) fleet). As such, it is expected that some of the monitoring activities may be different in the EPR. However, the techniques employed to carry out the analyses should be similar for both designs. This section describes the activities currently in use **in the existing French fleet**.

2.2.1 Gamma spectrometry of gaseous effluents

The current section deals with the regulatory analyses currently carried out in existing 1300 MW(e) stations on:

- The continuous gaseous discharges at the stack
- The “planned” discharges from the TEG [GWPS] and the air of the reactor building
- The ventilation circuits during the efficiency tests of the iodine traps.

2.2.2 Gaseous halogens

In existing stations, the continuous discharges and the air of the reactor building are currently monitored by the radioprotection devices and sampling is carried out by the KRT [PRMS] lines at the stack of the Nuclear Auxiliary Building: sampling of the radio halogens is carried out on activated carbon cartridges (DAFF 10 from MERLIN GERIN or equivalent). A similar portable device is used for monitoring of the effluents from the TEG [GWPS], but a device to trap water is added at the channel entry. The detailed procedure for the monitoring of gaseous halogens is given in [11].

Two cartridges in series are used for each sampling, in order to ensure maximum retention of the iodine in the gaseous effluents. In particular, studies have shown that, although the absorption yields of the cartridges are very dependent on a number of factors (such as the sampling flow rate, the relative humidity of the sample, the chemical form of the iodine present in the sample and the sampling duration), the use of two cartridges ensured retention of over 95% of the iodine (for a maximum sampling flow rate of 9 m³/h). In addition, a filter paper is fitted on the line upstream of the cartridges to retain any particulate halogens or aerosols, and the direction of the gaseous flow is recorded on the cartridges, as retention will be higher on the first cartridge than on the second one. The device used in French PWRs is therefore similar to that described in the M11 guidance [12] for monitoring of gaseous effluents.

In order to ensure maximum retention, it is recommended that the sampling flow rate for the continuous discharges is $3 \text{ m}^3/\text{h} \pm 20\%$. This flow rate should be below $3.6 \text{ m}^3/\text{h}$ for the sampling of the TEG [GWPS] tanks and for monitoring of the air of the reactor building. Sampling duration should not exceed an administrative period¹ (7 to 10 days), and the volume of effluent filtered depends on the type of effluent: around 500 m^3 for continuous discharges, $> 0.5 \text{ m}^3$ for planned discharges from the reactor building and $> 0.2 \text{ m}^3$ for planned discharges from the TEG [GWPS]. The volumes are usually measured by GALLUS type volume flowmeters.

Once the gaseous radio-halogens to monitor have been trapped, air is blown through the activated carbon cartridge (pressure $< 0.5 \text{ bar}$ air flow rate = $3 \text{ m}^3/\text{h}$ and duration $> 1\text{h}$) to remove potential noble gases also trapped. The first cartridge on the sampling line is then counted by gamma spectrometry (gamma counter equipped with GeHP detector preliminary calibrated (see procedures [11], [7] and [13] for standardisation operations). In order to determine the activity of the radioisotopes present in the gaseous sample. The second cartridge is only counted if an activity over 10 Bq is detected in the first cartridge, in which case the results are summed up.

The sample should be analysed as soon as possible after the end of sampling, and no later than 24 hours after. Counting duration depends on the sample activity and the accuracy of the measurement required, but is usually taken as 4000 sec. Once obtained, the peaks of the spectrum are compared to a reference table (see [13]), and the decision threshold, limit of detection and activity of the sample are determined according to calculations given in [13]. The activity of the discharge can then be worked out from the above calculations, however, manual verification should also be undertaken. More details on the calculations can be found in [11].

2.2.2.1 Aerosols

The procedure [14] for the monitoring of aerosols from continuous gaseous discharges and planned discharges in existing stations is essentially similar to the procedure described in the M11 guidance [12] and is summarised below.

Particulate iodine present in the gaseous effluents is retained on filter papers placed upstream of the carbon cartridges used to trap gaseous iodine (see Section 2.2.2). The locations of the sampling points are therefore relatively close to each other, and deposition of aerosols on the filter paper is carried out in the same conditions as described above for the deposition of halogens on the carbon cartridges (sampling flow rate for the continuous discharges $3 \text{ m}^3/\text{h} \pm 20\%$; flow rate below $3.6 \text{ m}^3/\text{h}$ for the sampling of the TEG [GWPS] tanks, and volumes of effluent filtered of around 500 m^3 for continuous discharges, $> 0.5 \text{ m}^3$ for planned discharges from the reactor building and $> 0.2 \text{ m}^3$ for planned discharges from the TEG [GWPS]).

The filter paper is then placed in a plastic bag (in order to avoid contamination of the detector) and counted by gamma spectrometry (gamma counter equipped with GeHP detector preliminary checked (see procedures [11], [7] and [15] for standardisation operations) to determine the activity of the radioisotopes present in the gaseous sample. The analysis of the results and the interpretation of the spectrum obtained are similar to that described for the gaseous halogens.

2.2.2.2 Noble gases

In existing stations, monitoring of noble gases is carried out by the KRT [PRMS] line. Details of the procedure for the sampling of noble gases are given in [16].

¹ The administrative periods are defined as follows for each month: 1st to 7th, 8th to 14th, 15th to 21st and 22nd to the end of the month. As such, an administrative period can last between 7 and 10 days.

Designated sampling points are located on the KRT [PRMS] line according to technical specifications, and a representative sample is taken prior to analyses. Sampling locations are situated in the same area as those used for the sampling of the other gaseous radionuclides.

Sampling is carried out in a normalised bottle designated for the purpose of these activities (container type “capacity” SG3000G in aluminium for the sampling of continuous discharges and planned discharges from the reactor building; container type SG500G for the planned discharges from the TEG [GWPS] and exceptional discharges. However, for low-activity measurements, a SG3000G container can be used). It is essential to accurately know the volume of each container (provided by the manufacturer along with the uncertainty on the determination of the volume) for further determination of the sample activity and it is recommended to dedicate a sampling container to one sampling point and sampling type.

Purging of the container is carried out prior to sampling of the gas. The duration of the purge depends on the sampling method, but it is advised that it should be equivalent to 5 times the container’s volume. In some cases, a one-off measurement of the gas flow rate is carried out in order to determine this duration. In all cases, an indicator of flow rate is fitted on the sampling line. In addition, it is essential that the gases sampled are dried in order to avoid any wet contamination of the container. The purging time for sampling the radioactive decay storage tanks of the TEG [GWPS] should be adjusted to take into account additional purging time of the line, equivalent to 2 sec for each meter of pipe (specifications determined for a length of sampling line of 72 m and diameter of 6 mm).

Once sampled, the “capacity” is counted in the laboratory by gamma spectrometry. Counting time varies depending on the sample activity, but the requirement for a detection limit of 200 Bq/m³ in ¹³³Xe for the continuous discharges implies that counting times are generally long. Gamma spectrometers should be preliminarily calibrated daily with a ¹⁵²Eu source, and additional checks of the background counts, resolution and efficiency of the counters carried out weekly/monthly according to procedure [7]. Once obtained, the spectrum is analysed by comparison to a reference library as given in [16]. In particular, the following radionuclides must be reported:

- ¹³³Xe and ¹³⁵Xe for continuous discharges;
- ⁸⁵Kr, ^{131m}Xe and ¹³³Xe for TEG [CSTS] discharges; and
- ⁴¹Ar, ¹³³Xe and ¹³⁵Xe for reactor building discharges.

The analysis of the spectrum is carried out automatically by a purpose-designed software, and the sample activity, decision threshold and detection limit are determined. More details on the calculations carried out are given in [16].

The EPR presents a major improvement for the monitoring of noble gases compared to those in place in currently existing stations: on-line gamma monitoring is also used on the discharge stack of the Nuclear Auxiliary Building (detector: high purity Germanium), in addition to the periodical monitoring as described above. This enables continuous monitoring of noble gases activity by providing a sample that is representative of the composition and concentration of the discharge, and enables to detect any unplanned rise of the activity or excess of the regulatory threshold.

2.2.3 Alpha/ beta activity measurement of aerosols

The procedure for the monitoring of gross alpha and gross beta activity of aerosols in existing stations is described in detail in [17]. The filter paper used for the detection of gamma activity (see section 2.2.2.1) is reused for the alpha/beta measurement and therefore the sampling method is the same as that described above.

Prior to alpha/beta counting, the sample is placed in a stainless steel planchet, and the aerosols collected are fixed on the filter paper by addition of several drops of fixing solution (Collodion 5% CODEX ERBA or equivalent). Once dry, the filter paper and the planchet are placed in the alpha/beta counter (counter type: proportional counter) and counted twice (preset counts: 10,000 impulsions - preset time 50 min). Calibration of the counter is carried out periodically according to [18]. Once obtained, the counting is analysed automatically with a purpose-designed application 'Effluents'. Manual checks are also carried out at least once. The gross alpha and beta activity of the sample, detection limit, decision threshold and uncertainty of the measurement are then determined according to the calculations detailed in [17], and the results recorded and archived as is the case for all laboratory measurements.

This procedure is similar to that described in M11 guidance [12] for the monitoring of gaseous effluents.

2.2.4 Measurement of beta activity from tritium by liquid scintillation counting

The procedure for monitoring of tritium beta activity by liquid scintillation counting [19] is summarised below.

Sampling is carried out either at the stack (sampling via the KRT [PRMS] line) or locally for the TEG [GWPS] tanks. However, work is currently undergoing to study potential improvements in the sampling of tritium in order to increase assurance that the collected samples are representative.

In existing 1300 MW(e) stations, most of the tritium discharged provides from the evaporation of the storing pools and therefore is mainly found as vapour. As such, sampling is carried out by bubbling in a preliminarily determined volume of high purity water of a known volume of the discharged gas (at constant flow rate), in order to trap the tritium. This is similar to the procedure described in M11 guidance [12] for the monitoring of gaseous effluents.

Two bubblers are fitted in line on the monitoring channel. A filter is also fitted upstream to refrain any aerosols from being trapped in the water. In addition, it is recommended to refrigerate the sampling bottles in order to avoid loss of tritium by evaporation. Sampling points are located on the KRT [PRMS] line. The volume of gas to pass through the trap solution (and thus bubbling time) is determined depending on the equipment used and the type of effluent sampled. Details are given in [19]. At the end of the sampling period, the exact total volume of gas sampled is recorded.

Once sampled, a known volume of the trap solution is counted by liquid scintillation counting, as it the case for liquid effluents. Samples originating from the stack or reactor building discharges (likely to contain low activity providing from radionuclides other than tritium) can usually be analysed without any pre-treatment. However, for samples from TEG [GWPS] discharges, pre-treatment by cold distillation (i.e. at 30 to 35°C, which avoids loss of material in drops contained in vapour) is required. The details of the distillation operations are given in [8].

All subsequent steps for the preparation of the sample or the analysis of the spectra are identical to those described in 1.3.3.

2.2.5 Measurement of beta activity from ^{14}C by liquid scintillation counting

The principle of beta activity from ^{14}C measurements in gaseous effluents [20] is summarised below.

Sampling is carried out at the stack, via the KRT [PRMS] line. However, work is currently undergoing to study potential improvements in the sampling of C14 in order to increase assurance that the samples collected are representative.

Sampling of ^{14}C is carried out automatically on a molecular sieve left in place for 3 months. Two samples are collected per stack over 3 months, on two different molecular sieves. It is French practice to send one sample to the Regulator at the end of the sampling period. The other is sent to the external laboratory carrying out the measurement on behalf of EDF.

Around 1.5 m^3 of air is sampled and the inorganic forms of carbon (mainly CH_4 and C_2H_6) are oxidised in a catalytic furnace (see Figure 4). The gas then passes through 300 g of molecular sieve (preliminarily activated), which entirely fixes CO_2 and water vapour. At the end of the 3-month sampling period, the cartridge containing the molecular sieve is sent to the laboratory along with a record of the number of cycles carried out by the sampling device (essential for the calculation of the volume of effluent sampled and thus the accurate determination of the volumic activity).

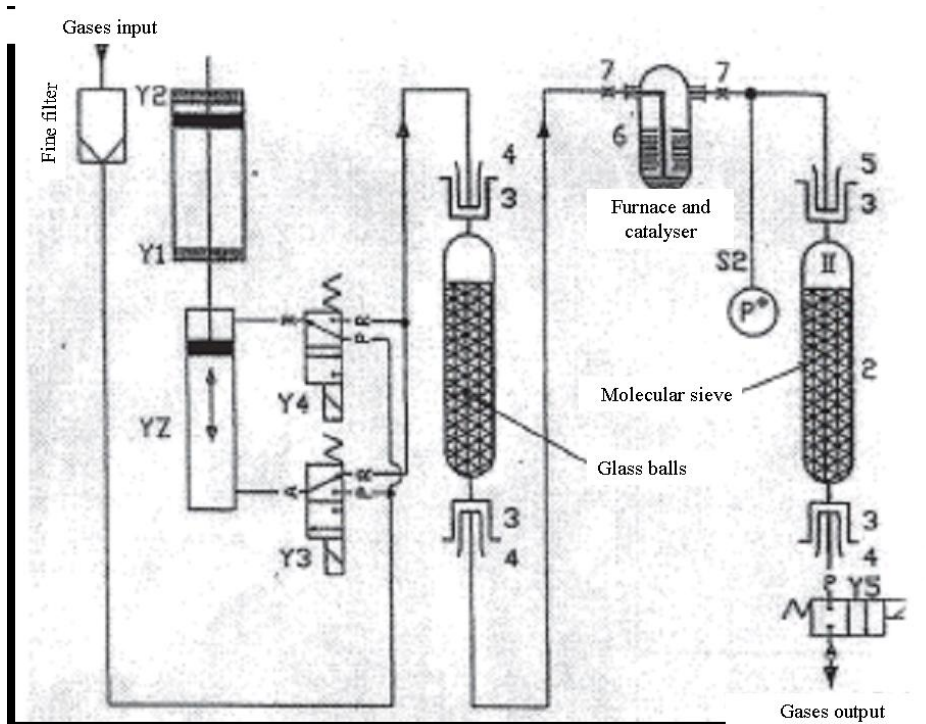


Figure 4: Gaseous C-14 sampling system description

At high temperature (450°C) and under nitrogen flow (150 mL/min), the water and CO₂ trapped on the molecular sieve desorb (4 hours at 450°C). These gases are then sent to a bubbler where CO₂ is trapped in sodium hydroxide. Addition of barium chloride to the solution precipitates barium carbonate, which can in turn be dried, grounded and added to 10 mL of scintillant cocktail before being counted by liquid scintillation (counter Perkin Elmer Tri Carb 3100 TR or equivalent). Each vial is counted twice for 30 min in the energy window 4-30 keV. In addition to the sample, a Ba¹⁴CO₃ reference and a sample made of commercial BaCO₃ are also counted twice. Studies have shown that the yield of these preparatory steps (absorption, desorption and bubbling) is close to 100%. The results obtained are subsequently analysed according to [20] and the activity, uncertainty, decision threshold and detection limit determined.

This procedure is similar to that described in M11 guidance [12] for the monitoring of gaseous effluents.

2.3 MONITORING THE GASEOUS EFFLUENTS CURRENTLY IN PLACE

The nature of the EPR radioactive gaseous effluents is given in PCER Sub-chapter 6.2. Treatment and storage systems for these effluents are also described in that Sub-chapter. Because the EPR gaseous effluent treatment system is different to that in place in existing 1300 MW(e) stations, and more similar to that in place in KONVOI reactors, a comparison of both monitoring systems (1300 MW(e) and KONVOI) has been carried out in the following sections.

2.3.1 Existing 1300 MW(e) fleet – France

The gaseous radioactive effluents in the existing 1300 MW(e) stations in France can be split into 4 groups:

- the hydrogenated gaseous effluents: they originate from the degassing activities of the primary water in the TEP [CSTS] and in the primary water holding tanks (under controlled atmosphere). They are essentially made up of hydrogen, nitrogen and gaseous fission and activation products and are therefore radioactive. They are treated in the TEG [GWPS], where they are stored for radioactive decay before being discharged to the stack (following treatment on filters and iodine traps) by the ventilation system of the Nuclear Auxiliary Building;
- The aerated gaseous effluents: they originate from the storing tanks containing radioactive effluents under air atmosphere. As such, they are mainly made up of air contaminated with radioactive gases. They are also treated in the TEG [GWPS] (treatment on iodine traps) before being discharged by the ventilation system of the Nuclear Auxiliary Building;
- The gaseous effluents from the ventilation systems: these effluents originate from the ventilation of the Nuclear Auxiliary Building, the Fuel Building, or the Reactor Building. They are made up of air potentially contaminated with radioactive gases. They are treated in the ventilation systems of the various buildings from the nuclear island, filtered on absolute filters and potentially on iodine traps before being discharged to the stack;
- The effluents from the secondary circuit: they are mainly made up of air contaminated with radioactive gases, tritium in particular, in case of leaks between the primary and the secondary circuits located at the steam generator tubes. They are collected by the condenser vacuum system before being filtered on absolute filters in the Nuclear Auxiliary Building ventilation system and being discharged.

Monitoring of the discharges from the Nuclear Auxiliary Building ventilation system is carried out on-line by site-specific radioprotection channels.

2.3.1.1 Planned discharges

One specificity of the 1300 MW(e) fleet is the existence of two types of gaseous discharges:

- planned discharges;
- continuous discharges.

The planned discharges occur for discharges of:

- hydrogenated gaseous effluents (drainage of TEG [GWPS] tanks or of the hydrogenated gaseous effluent storage tanks, following a minimum of 30 days decay period);
- gaseous effluents from the depressurisation of the reactor building;
- gaseous effluents from testing of the iodine traps of the ventilation circuits;
- gaseous effluents from the calibration tests of the gaseous beta monitoring channel at the stack.

In the EPR, the planned discharges concern scheduled batch gaseous discharges carried out via the stack. They correspond to the gaseous waste from the ventilation linked to the scavenging for staff access in the reactor building (unit in operation), to the iodine trap tests of the various ventilation systems and to the calibration tests of the activity measuring channels. The monitoring activities and discharge conditions for such discharges from the EPR are described in PCER Sub-chapter 7.3.

Prior to any planned discharges from existing units, the effluents from the hydrogenated gaseous effluent and the reactor building storing tanks are monitored as follows (see Table 11):

Radionuclide	Sampling type	Monitoring frequency	Measurement technique	LOD
Gross beta activity	One-off sampling	On each storing tank or via the KRT [PRMS] channel in the reactor building, prior to discharge	Proportional Counting	N/A
Tritium			Liquid scintillation counting	100 Bq/m ³ for effluents from the reactor building 1,000 Bq/m ³ for effluents from the hydrogenated gaseous effluent storing tanks
Iodine			Gamma spectrometry (Ge or LiGe detector)	0.8 to 1 Bq/m ³
Noble gases				200 Bq/m ³ in ¹³³ Xe (reactor building) 2,000 Bq/m ³ (effluents from the hydrogenated gaseous effluent storing tanks)
Other fission and activation products				50 mBq/m ³

Table 11: Monitoring carried out prior to planned discharge of the hydrogenated gaseous effluent and the reactor building storing tanks

These monitoring activities enable to determine the composition of the effluents to discharge, define whether the discharge is possible (compliance to the annual activities in the discharge authorisation), and, if so, determine the discharge flow rate in order to comply with the maximum activity flow rates at the stack as defined in the discharge authorisation.

2.3.1.2 Continuous discharges

Continuous discharges occur at the stack for the following:

- aerated gaseous effluents;
- gaseous effluents from the reactor building outside of degassing activities;
- gaseous effluents from the secondary circuit.

In the EPR, continuous discharges concern gaseous discharges permanently discharged via the stack, i.e. gaseous waste discharges extracted via the ventilation excluding drainage of air from the reactor building and gaseous waste discharges from the secondary cooling system.

In existing 1300 MW(e) stations, monitoring of the following substances is carried out at the stack of each Nuclear Auxiliary Building (both for continuous and planned discharges, see Table 12):

Radionuclide	Sampling type	Monitoring frequency	Measurement technique	LOD
Gross beta	Continuous	Continuous (stack of the Nuclear Auxiliary Building and condenser vacuum system)	Proportional counting	0.37 Bq/m ³
Beta (Gas)			Ionisation chamber	-
C14	Continuous	Quarterly monitoring (stack of the Nuclear Auxiliary Building)	Liquid scintillation counting	20 Bq/m ³
Tritium	Continuous	Determination over the administrative periods (stack of the Nuclear Auxiliary Building)	Liquid scintillation counting	40 Bq/m ³
Iodine	Continuous		Gamma spectrometry (Ge or LiGe detector)	3.7 Bq/m ³ ¹³⁷ Cs eq 2 mBq/m ³ in ¹³¹ I
Noble gases	One-off sampling			200 Bq/m ³ in ¹³³ Xe
Other fission and activation products	Continuous			2 mBq/m ³ in ⁶⁰ Co

Table 12: Monitoring carried out at the stack of each Nuclear Auxiliary Building

These monitoring analyses enable to determine all the activities discharged and the activity flow rates at the stack, in order to ensure compliance with the annual activity limits and activity flow rates as determined in the discharge authorisation.

2.3.2 KONVOI reactors – example of Germany Neckarwestheim

The sampling and treatment systems of gaseous effluents in a KONVOI reactor [21] comprise:

- circuits for sampling and treating gaseous effluents originating from the degassing of radioactive fluids or sweeping of the atmosphere of storage tanks (Off gas systems, equivalent to the TEG [GWPS] in French 1300 MW(e) reactors);
- circuits holding the ventilation systems of the potentially contaminated buildings. All these circuits are fitted with absolute filters and iodine traps.

The KONVOI off gas system is quite different from the French 1300 MW(e) system for the management of hydrogenated gaseous effluents, as there are no planned discharges. In normal operating conditions, all of the gaseous flow is recycled and therefore the gaseous discharges are almost inexistent.

In case of an increase of activity in the primary circuit, the flow can be directed to a delay beds device instead of being recycled: two sets of five carbon delay beds each ensure that ^{133}Xe is retained for over 52.9 days and $^{85\text{m}}\text{Kr}$ for over 43.9 hours. Overall, this corresponds to retention of over 60 days for ^{133}Xe and over 110 hours for $^{85\text{m}}\text{Kr}$, and enables noble gases to be retained for over 10 half lives, reducing the activity to be discharged to 0.1% of the initial activity. This is similar to French regulatory requirements for noble gases (minimum of 30 days storing time).

As such, recycling is only used during normal operation. The delay beds are then only used in anticipation of shutdown or in case of an increase of gaseous activity.

The designs of ventilation systems of the 1300 MW(e) and KONVOI also present major differences, such as:

- no depressurisation of the reactor building and no planned discharges from the reactor building (no use of pneumatic valves in KONVOI);
- the totality of the air originating from the buildings (apart from part of the Nuclear Auxiliary Building) that can be treated is systematically filtered on filters and iodine traps before being discharged at the stack.

Monitoring carried out at the ventilation systems:

As mentioned above, one of the main differences between the French 1300 MW(e) and German KONVOI designs concerning gaseous discharges lies in the inexistence of planned discharges in the latter. Indeed, there are no systems to store and analyse gaseous effluent in any of the circuits prior to discharge. Instead, on-line systems are in place to monitor the activity discharged. These are also required to determine the composition of the discharges, as they depend on a number of operational factors.

Measurements are thus carried out at the outputs of the ventilation systems of some of the buildings. In particular, total beta measurement is carried out on the ventilation systems of the reactor building, the annular building (i.e. building holding the reactor building, the 4-loop cooling system, and some high pressure pumps and material related to the ventilation systems) and the Nuclear Auxiliary Building in order to monitor the discharges of noble gases. Aerosols are also sampled and analysed three times a week from these buildings. Finally, samples and analyses for iodine are carried out on the ventilation systems of the Nuclear Auxiliary Building and the Annular Building. These analyses are also carried out 3 times a week, and enable to differentiate between the three chemical forms of iodine: aerosol iodine are trapped on a filter, molecular iodine (I₂) is fixed on a specific absorbent (DSM11), and organic iodine is trapped on activated carbon.

Monitoring of gaseous effluents at the stack

The discharge stack of the KONVOI reactor considered is fitted with three sampling lines:

- a “low flow” sampling line only used in incidental or accidental situations and fitted with specific devices for sampling of iodine and aerosols;
- an “A” line fitted with:
 - specific devices for the sampling of iodine and aerosols;
 - equipment for on-line monitoring of beta activity;
 - gamma spectrometry equipment for on-line monitoring of noble gases;
 - equipment fitted with an NaI detector for the continuous monitoring of iodine;
- a “B” line fitted with:
 - specific devices for the sampling of iodine, aerosols, tritium and C14;
 - a compressor for the collection of gaseous samples;
 - equipment for on-line monitoring of beta activity;
 - a “high activity” device for the continuous monitoring of noble gases;
 - equipment fitted with a NaI detector for the continuous monitoring of iodine and aerosols.

The monitoring of total beta activity and sampling of iodine and aerosols are redundant on both the “A” and “B” lines.

A summary of all the monitoring activities carried out at the stack of a KONVOI reactor is given in the table below:

Radionuclide	Type of analysis	Monitoring frequency	Measurement recorded	Detector type	LOD* (Bq/m ³)	Regulatory LOD
Noble gases	Total beta activity	Continuous	No	Plastic detector	2000	Pre alarm 4.10 ¹⁰ Bq/h Alarm 4.10 ⁶ Bq/m ³
	Gamma Spectrometry	Continuous	Yes	High purity Ge detector	60 in ¹³³ Xe	500 Bq/m ³ in ¹³³ Xe 10,000 Bq/m ³ in ⁸⁵ Kr
	Gamma spec (200 bars pressure bottle)	Weekly	No	High purity Ge detector	50 in ¹³³ Xe	
Aerosols	Gamma spectrometry	Weekly	Yes	High purity Ge detector	0.8 mBq/m ³ in ⁶⁰ Co	20 mBq/m ³ in ⁶⁰ Co
	Total beta	Continuous	No	Nal detector	1	Alarm 4.10 ⁶ Bq/h
Iodine	Gamma spectrometry	Weekly	Yes	High purity Ge detector	0.9 mBq/m ³ in ¹³¹ I	20 mBq/m ³ in ¹³¹ I
	Gamma spect (320-410 keV window)	Continuous	No	Nal detector	0.4	Alarm 2.10 ⁶ Bq/h
Sr89/90		Quarterly	Yes	Analysis on aerosol filters	0.05 mBq/m ³	1 mBq/m ³
Alpha emitters	Alpha spectrometry	Quarterly	Yes	Analysis on aerosol filters	0.01 mBq/m ³	5 mBq/m ³ in ²⁴¹ Am
Tritium		Quarterly	Yes	Sampling on molecular sieve	0.6	1 – 100 Bq/m ³
C14		Quarterly	Yes	Sampling on molecular sieve	0.3	Detection of 5 GBq/y

Table 13: Monitoring carried out at the stack – KONVOI reactor

*: The German LOD is equivalent to the French decision threshold with a slightly different statistical calculation (α risk of 5% instead of 2.5%). As such, the German LOD is equal to half of the French LOD for noble gases and LOD/1.5 for all other radionuclides.

Overall, the accountancy of the activity discharged from a KONVOI reactor is based on similar samples and measurements to those of 1300 MW(e) reactors, except for noble gases. Indeed, on-line gamma spectrometry is in place in the KONVOI reactor studied, rather than one-off sampling for each administrative period followed by gamma measurement in the laboratory as carried out in France. On-line monitoring represents a major improvement to the monitoring of the gaseous discharges, and will be implemented in the UK EPR.

3 QUALITY ASSURANCE

Monitoring of liquid and gaseous effluents is part of the Quality Assurance system. In particular, all sampling arrangements and detection limits in use have been validated by the French Safety Authority, and written procedures are in place describing all stages of sample collection, transport, analysis and equipment calibration. In addition, calibration of all sampling and measurement instruments is carried out on a regular basis using adequate reference standards (see adequate procedures for detail). Staff carrying out the sampling and analyses is competent and trained for these operations. All laboratories carrying out analyses are also ISO 9001 and ISO 14001 certified.

Proficiency tests have recently been run for both chemical and radiochemical analyses, along with evaluation of the equipment used. In particular, the aim of these studies was to:

- determine the performance of the laboratories and check their continuous performance (ability tests);
- estimate the efficiency and comparability of potential new methods;
- validate the chosen methods (including accuracy, reproducibility).

Finally, all monitoring results are recorded and regular audits are carried out.

These elements of quality assurance are in agreement with the M11 [12], M12 [3] and M18 [4] guidance notes.

4 CONCLUSIONS

This document presents the arrangements in place for the monitoring of both liquid and gaseous effluents from existing 1300 MW(e) reactors, along with examples of the arrangements in place for the monitoring of gaseous effluents from a KONVOI reactor that could be implemented in the EPR.

In addition, improvements have been added to the EPR monitoring regime compared to that currently existing in operating units, in order to reflect the implementation of Best Available Techniques. As such, on-line gamma monitoring of noble gases at the stack, as in place in the KONVOI reactors, represents a significant improvement to the current monitoring regime.

These arrangements, along with the Quality Assurance associated with the analyses, provide evidence that the monitoring regime involves the Best Available Techniques for both batch and on-line monitoring, and is adequate and in line with the requirements from guidance M11 [12] and M12 [3] for the monitoring of liquid and gaseous effluents from Nuclear Facilities.

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