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## 1. INTRODUCTION

This document has been written to collate information that has been provided to the HSE/EA to support the Generic Design Assessment of the UKEPR, on the issue of "decontamination during operation, maintenance and decommissioning". This information is supplementary to information provided on operational and decontamination waste within the GDA PCSR (sub-chapter 11.3) /PCER (sub-chapter 6.3) [1] and the supporting document on decommissioning [2].

This information is provided as three appendices that address the following issues:

- Decontamination during operation and maintenance
- Minimisation of decontamination waste arising from EPR
- Decontamination during POCO and decommissioning

## 2. REFERENCES

- [1] PCSR Sub-chapter 11.3 - Outputs for the operating installation", UKEPR-0002-113 Issue 04
- [2] "GDA UK EPR – Decommissioning", UKEPR-0016-001 Issue 01

**ANNEXE 1- DECONTAMINATION DURING OPERATION AND  
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## **1. PREDICTED DECONTAMINATION REQUIREMENTS IN OPERATION AND MAINTENANCE**

This section provides information regarding the need for decontamination for key plant areas, systems structures, components in operation and maintenance.

Contamination during normal operation (including outages) is related to equipment and structures having been in contact with primary fluid. Contamination results either from normal circulation of the primary fluid through the system and its associated equipment (pipes, valves, pumps), filling and draining of pools, or leaks to the floors either during operation or during maintenance.

Decontamination may be needed to return to an acceptable level of activity for the area according to the plant cleanliness zoning. This is necessary so that maintenance of the installation can be performed once more in clean conditions, i.e. with no / limited dose intake by the persons in charge of the maintenance. Decontamination can also be used to enable a lower waste classification of used equipment, thereby optimising the radioactive waste volume.

During operation and maintenance of the EPR the primary coolant, which flows in the reactor coolant system (RCP) [RCS] and auxiliary systems, need continuous decontamination, to limit the activity in the circuit. This ensures reduced dose intake by workers who undertake maintenance in the rooms where equipment associated with the primary coolant, are installed.

After completion of refuelling activities, the reactor pool and equipment used in and around the pool, needs to be decontaminated. Also the fuel handling tools used in the fuel building need to be de-contaminated after completion of any fuel handling activities.

Outside the Nuclear Island, rooms in the waste treatment building (ETB) into which the operators need to enter, must be maintained clean and decontaminated. Also after completion of maintenance activities, the local worksite is required to be returned to the initial status of cleanliness so as to allow further access and prevent any spread of contamination.

## **2. BASELINE DECONTAMINATION STRATEGY / PHILOSOPHY IN-SITU DECONTAMINATION OR AT DESIGNATED LOCATION(S)**

In-situ decontamination of equipment would normally be considered as the best option in terms of limiting the numbers of tasks to be performed and avoiding transfer of contaminated items. However decontamination worksites have to be defined considering several aspects:

- the ambient dose rate of the room,
- the space remaining available around the worksite,
- the equipment to decontaminate.

As the majority of equipment decontamination tasks takes place during outages, which are extremely busy periods where access to equipment needs to be optimised, feedback experience shows that it is not always easy to install decontamination facilities directly in the room or in the corridors nearby. Therefore, the baseline philosophy adopted during the reference EPR design is to provide dedicated spaces in the Nuclear Island where equipment can be brought in for decontamination. These are described with more detail below.

### **3. DESIGN FEATURES TO SUPPORT DECONTAMINATION: E.G. MINIMISATION OF MATERIAL HOLD-UP, MATERIAL SELECTION, SPACE / LAYOUT, CONNECTION POINTS**

#### **3.1 NUCLEAR AUXILIARY BUILDING "WORKSHOPS AREA"**

A large space called "workshops area" is implemented in the Nuclear Auxiliary Building (NAB) and can be used for decontamination activities.

{ CCI Removed }<sup>a</sup>

The large decontamination space available is beneficial since it provides a single area where these decontamination activities would normally be expected to be performed, and limits, by its location, the amount of handling of materials that are to be decontaminated.

During reactor shutdown periods the workshops area is connected with the surrounding areas

{ CCI Removed }<sup>a</sup>.

This provides a single large zone. The cleanliness/waste design zoning classification of the overall area is "N1", i.e. it is considered as a potentially contaminated area (maximum surface contamination between 0.4 B/cm<sup>2</sup> and 4 Bq/cm<sup>2</sup>). This facilitates the personnel movements between the buildings as there are no constraints linked to changing of zones.

{ CCI Removed }<sup>a</sup>

The workshops area is connected to two tool stores that can be supplied with the equipment that is required to install temporary decontamination workshops and the tools that are required to facilitate the decontamination. The cleanliness/waste arrangement of this area allows a separation between a "hot tools" store and a "cold tools" store.

{ CCI Removed }<sup>a</sup>

The workshops that will be temporarily installed in this area will be provided with ventilation and tenting to contain the contamination by difference of pressure between rooms. More details on the types of decontamination equipment that could be installed in the Workshops area is provided Annexe 3 of the present report which also provides discussion of choice of materials to minimise the requirements for decontamination.

### **3.2 CONNECTION OF BUILDINGS IN THE NUCLEAR ISLAND**

{ CCI Removed }<sup>b</sup>

## **4. DECONTAMINATION SYSTEMS IN THE GDA DESIGN FOR DEPLOYMENT IN OPERATION AND MAINTENANCE**

### **4.1 DECONTAMINATION OF SYSTEMS**

During normal operation decontamination of systems in contact with primary coolant is ensured through the continuous primary coolant treatment.

Maintaining the primary fluid contamination at an acceptable level and prevention of corrosion of the primary circuit materials by appropriate control of primary circuit chemistry, is performed through the Chemical Volume and Control System (RCV [CVCS]). Continuous letdown flow is taken from the primary circuit, from where the fluid is sent for purification in the coolant purification system (TEP [CSTS]), before being re-injected into the primary circuit; these systems are described in PCSR sub-chapters 9.3.2 and 9.3.3 [2].

The contamination is retained on (cartridge) filters and mixed-bed filter resins which become solid waste conditioned in the waste treatment building (as described in PCSR Chapter 9.4); Contamination present in dissolved gases which are released from the primary coolant, are cooled and treated by the Gaseous Waste Processing System (TEG [GWPS]), described in PCSR sub-chapter 11.4.3 [3].

Primary reactor coolant that is not able to be recycled back to the primary circuit, is treated by the evaporator in the effluent treatment building (ETB).

### **4.2 DECONTAMINATION OF LARGE ITEMS**

During outage, large items need decontamination such as:

- The multistud tensioning machine (MSDG) which is decontaminated in the Fuel Building SDA whilst on it's dedicated stand,
- The refuelling machine which is decontaminated in the refuelling hall in the Fuel Building.

Decontamination of these items is normally achieved by manual swabbing.

### **4.3 SMALL ITEMS AND ITEMS THAT HAVE BEEN REDUCED IN SIZE**

Decontamination of small items such as handling tools and items that have been reduced in size (e.g. by dismantling) will typically be achieved in facilities installed into the Workshop area that is described in section 1.3 above.

### **4.4 PLANT AREAS**

All the EPR rooms located in the controlled zone are equipped with decontaminable surfaces, allowing decontamination measures.

#### **4.5 PONDS AND FUEL PITS**

The ponds/pits required to be decontaminable on the EPR are:

- in the Fuel Building (FB): the fuel transfer pit and the fuel loading/unloading pit
- in the Reactor Building (RB): the reactor pool, the internals storage pit and the fuel transfer pit.

The surface finish of the metallic parts of these ponds/pits (liner, gates) is a requirement for the supplier and is to be defined with the future licensee.

{ CCI Removed }<sup>b</sup>

In addition, doors are provided to allow access directly to the bottom of these ponds/pits: in addition to the access, they facilitate the use of the robots the operator could decide to use for decontamination.

A special requirement is specified for the gate between the reactor pool and the internals storage pit. This gate is stored on the service floor which is an area with frequent access at power and during an outage.

{ CCI Removed }<sup>b</sup>

Finally, the UK EPR will include a radiation protection monitoring control room equipped with video/sound devices and linked to the dose rate information collected by the personnel dosimeters. This will allow information to be gathered on the decontamination efficiency, on the volume of exposed work and on the dose uptake.

#### **4.6 DECONTAMINATION IN THE EVENT OF INCIDENTS OR ABNORMAL OPERATIONS**

In addition to the general provisions mentioned above that equip the EPR, the decontamination of the rooms containing equipment required to be accessible in the post-accident (PCC4 LB-LOCA and Severe Accident) long term phase has been ensured. The systems contained in these rooms can be drained and rinsed with clean water as mobile facilities (pumps in particular) can be connected between the contaminated circuit and the clean water tank located nearby. In addition, the contaminated water that would have been released on the floor is collected into sumps also equipped with pumps that reinject the contaminated water inside the reactor building.

#### **4.7 DECONTAMINATION OF PERSONNEL**

The facility to allow decontamination of personnel is located at the access tower, level -6.40 m where showers are located in the controlled zone, near the radiation protection team offices. In the event of an employee being significantly contaminated, he/she is taken care of by the medical centre.

## **5. DECONTAMINATION SYSTEMS AND TECHNIQUES THAT COULD BE USED BY THE SITE OPERATOR IN THOSE AREAS WHERE DECONTAMINATION SYSTEMS ARE NOT INCLUDED IN THE GDA DESIGN**

Some decontamination systems and techniques which could be used during operation and maintenance are presented in Annexe 3 of the present report related to decontamination during POCO and decommissioning. The decontamination systems and techniques that are used by the licensee will be selected dependent on the specific requirements of the decontamination task.

## **6. LEVEL OF AUTOMATION: E.G. DETAILS ON ANY AUTOMATED / REMOTE CLEANING OF THE REACTOR POOL**

No specific tool for decontamination is provided with the design of the EPR reactor pool. Manual decontamination (swabbing) is a current practice to decontaminate surfaces. However, as explained above, doors are provided to facilitate the introduction of robots, should the future operator decide to use robots for decontamination of the reactor pool.

## **7. REFERENCES**

- [1] { CCI Removed }<sup>a</sup>
- [2] "PCSR – Sub-chapter 9.3 – Primary System Auxiliaries", UKEPR-0002-093 Issue 03
- [3] "PCSR - Sub-chapter 11.4 - Effluent and waste treatment systems design architecture", UKEPR-0002-114 Issue 04

**ANNEXE 2– MINIMISING OF DECONTAMINATION WASTE  
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## **1. OPERATIONAL AND MAINTENANCE DECONTAMINATION WASTE FROM OPERATION**

Reduction of contamination waste arisings has been a continuous process and not a specific development for the EPR. Improvements developed in N4 and Konvoi NPP have been transferred for use in the EPR, (e.g. optimised operational water chemistry, cleanliness/waste zoning, design of material and equipment to reduce contamination thereby reducing the need for decontamination and subsequent direct and secondary wastes, design of equipment to ease decontamination, utilisation of decontaminable surfaces).

A quantitative analysis of the reduction in contamination levels and waste streams waste arisings from operation is not yet possible since operational feedback on the performance of EPR is not yet available.

## **2. DECONTAMINATION WASTE FROM DECOMMISSIONING**

Benefits of the above mentioned design and operational methods fully apply to decommissioning since they will lead to reduction in levels of contamination within the plant at the commencement of decommissioning.

It is not yet possible to provide quantitative information regarding expected reductions in contamination levels nor reduction of waste stream since operational feedback on the EPR is not yet available.

Additional information regarding decontamination of the primary circuit is provided in Chapter 2 section 4.1 and Chapter 6 section 3.1 of Reference [1].

## **3. CONSISTENCY WITH THE EPR GDA ENVIRONMENTAL SUBMISSIONS**

Information related to the decontamination wastes produced during operation, maintenance, POCO and decommissioning of the UK EPR<sup>TM</sup> has been provided in:

- PCSR sub-chapter 11.3 (reference [2]) which gives type and quantities of wastes produced through operating process or maintenance activities; decontamination wastes produced during operation and maintenance of UK EPR are included.
- PCSR sub-chapter 20.2 (reference [3]) and supporting document (reference [4]) which give type and quantities of wastes produced during the decommissioning; decontamination wastes are accounted for by inclusion of the volume of the Ion Exchange Resins (IER) generated by the Full Decontamination of the primary circuit envisaged prior to the decommissioning of the reactor.
- Chapter 6 "Disposability Assessment" of document UKEPR-0016-001 (reference [1]) provides an estimate of quantities of consumables and other secondary wastes that can be anticipated for the decommissioning of the NI of the UK EPR<sup>TM</sup>, including decontamination wastes.

A GDA Disposability Assessment (reference [5]) has been undertaken by the RWMD of the NDA for the higher activity wastes and spent fuel expected to be generated from operation of an EPR. The disposability assessment has considered three types of waste and materials:

- ILW arising from reactor operations and maintenance activities (operational ILW);
- ILW arising from the decommissioning of the reactor and associated plant (decommissioning ILW including the IER produced by the preliminary full decontamination of the primary circuit);
- Spent fuel arising from reactor operation.

RWMD have concluded that ILW (including IER from the preliminary decontamination) and spent fuel from operation and decommissioning of an EPR should be compatible with plans for transport and geological disposal of higher-activity waste.

Wastes being dealt with through alternative routes, e.g. LLW and/or VLLW are not considered within the scope of this Disposability Assessment.

However, experience feedback on operation, maintenance, POCO and decommissioning, as well as methods for the segregation of waste will be taken into account while preparing these associated activities. As a consequence, it is reasonable to assume that LLW arising from decontamination activities will be acceptable to the LLWR (LLW Repository Ltd) even if full characterisation of decontamination LLW produced during decommissioning cannot be predicted at this time.

In addition, secondary waste arising from decontamination operations completed during decommissioning will be monitored and classified in the same manner as the wastes produced during the operational and maintenance phases. There is no evidence that decontamination waste will be different in their characteristics so as to prevent them meeting the disposability criteria for the LLWR.

In the same manner, VLLW produced during decontamination activities completed during decommissioning will be similar to those produced during operation. They will therefore be treated similarly.

It is reasonable to consider such decontamination ILW, LLW and VLLW wastes to be compliant with the corresponding acceptance criteria for the relevant disposal routes.

#### **4. REFERENCES**

- [1] "GDA UK EPR - Decommissioning", UKEPR-0016-001 Issue 01
- [2] PCSR Sub-chapter 11.3 - Outputs for the operating installation", UKEPR-0002-113 Issue 04
- [3] "PCSR Sub-chapter 20.2 - Decommissioning - Implementation for the EPR ", UKEPR-0002-202 Issue 01
- [4] "EPR UK – Decommissioning waste inventory", ELIDC0801302 revision A
- [5] "Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from Operation of the UK EPR", NDA. Radioactive Waste Management Directorate. Technical Note no. 11261814

(<https://www.nda.gov.uk/documents/upload/TN-17548-Generic-Design-Assessment-Summary-of-Disposability-Assessment-for-Wastes-and-Spent-Fuel-arising-from-Operation-of-the-EPWR.pdf>) October 2009. (E)

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## 1. INTRODUCTION

In the following sections, the baseline decontamination strategy for a UK EPR is outlined for POCO and decommissioning with respect to a variety of criteria.

In Section 2, after some introductory information, the requirements for decontamination of the EPR due to functional and radiological reasons are outlined.

Section 3 provides the Baseline POCO and decontamination strategy within which is defined more precisely which parts of the EPR require decontamination, and information is provided on the flow of activities.

In Section 4, the “toolbox” for decontamination methods is provided, supplying information on the methods that may be applied to perform the decontamination activities described previously in the POCO and De-contamination strategy.

## 2. PREDICTED DECONTAMINATION REQUIREMENTS DURING POCO AND DECOMMISSIONING

### 2.1 DECONTAMINATION

Radiological decontamination is performed in all NPP's (including the EPR) and nuclear installations. It is performed on (contaminated) systems and structures of any type with the following aims:

- Reduction / prevention of radiological dose:

Dose is reduced e.g. by removal of “hot” particles or accumulations of material of higher dose. This is required, when higher dose levels than expected are detected in an area or when dose levels are not considered acceptable. The requirement for decontamination is normally detected in situ of the respective component.

- Contamination removal:

Loose contamination is removed e.g. by wiping off a thin contamination layer from a surface. (“Contamination” is referred to, when increased surface activity is detected e.g. by a swipe test).

The reason for performing these sometimes expensive operations is that the ALARP / ALARA principle has to be maintained at nuclear installations to protect workers and environment appropriately from internal and external exposure to ionising radiation in all phases of the EPR's lifetime. It is the responsibility of the operator to determine the balance of the dose reduction that can be achieved by decontamination against the dose intake while performing the decontamination operations.

In normal (Power) Operation decontamination is performed, e.g.:

- to avoid accumulation of activity (“housekeeping”) or
- in case of an actual need, i.e. during maintenance and repair of equipment or in the event of abnormal leakage.

During POCO decontamination is performed e.g. to:

- prepare certain rooms for decommissioning operations
- reduce dose to a minimum, or
- reduce / remove residual contamination for upcoming decommissioning activities
- allow removal of items from the controlled area.

In decommissioning decontamination is performed, e.g. to:

- reduce dose to a minimum, (e.g. for dismantling access) or
- change waste classification (e.g. LLW -> VLLW) or
- reduce residual contamination (e.g. for handling purposes)
- remove contamination generated by ongoing decommissioning operations
- allow removal of items from the controlled area.

It is intended that the UK EPR follows the above described good (standard) practices.

Notes:

For all non-routine (non-preventive) decontamination operations it must be considered, that these are performed based on case to case decision and in co-operation with radioprotection specialists.

A generic “acceptable level” of dose or residual contamination after completion of decontamination work cannot be defined; it depends on the planned activity and must be agreed with the licensee’s responsible radiation protection department.

## **2.2 ORDER OF DECONTAMINATION STEPS IN POCO AND DECOMMISSIONING**

In POCO and decommissioning the EPR, the general decommissioning and decontamination rule from “high to low” will be applied:

Under consideration of accessibility, systems and components of the EPR will be decontaminated following the ALARA / ALARP principle for worker / environment protection. Systems and components with high level of activation / contamination are decontaminated first, and then systems of respective lower activation / contamination. This general rule is applied under consideration of functional requirements: (Contaminated) systems and

installations required for decommissioning, safety or operational purposes (e.g. radioactive waste water treatment system) can be decontaminated and deconstructed only late in the decommissioning process, since they are required in the process.

By this general principle, persons and machinery required for following and/or neighbouring activities are protected appropriately from undesired radiological effects. Hereby also the risk is reduced for the spread of contamination.

Note:

It is to be considered, that all described decontamination activities are following the flow of decommissioning / deconstruction activities described in other documents. Thus, a schedule or a detailed order for decontamination activities cannot be provided; it is expected, that the order of activities is considered together with technical scheduling information provided on decommissioning and deconstruction of the EPR.

### **2.3 DIFFERENCES BETWEEN DECONTAMINATION DURING OPERATION AND DURING DECOMMISSIONING**

Between the two plant situations “power operation” and “POCO / decommissioning”, there is a significant change in restrictions of decontamination methods:

In EPR “power operation”, decontamination is mostly performed on parts that are planned to be used again, thus the applied methods are restricted in their effects on the original part (e.g. decontamination should not alter the characteristics of the respective part in its properties so it can not be used again.)

In POCO and decommissioning, systems, components and parts that are decontaminated mostly are considered as scrap after dismantling and will not be used again; thus, decontamination methods are less restricted in their effects; to the contrary, the higher the decontamination factor, the higher is the probability that the respective component can be treated as conventional waste after appropriate release measurements; even though, decontamination methods are always applied under consideration of the generation of secondary wastes.

Generally the decontamination methods applied at an EPR in power operation and POCO / decommissioning will be similar, but they will vary in application, based on the detailed decontamination task being tackled.

## **3. BASELINE POCO AND DECONTAMINATION STRATEGY**

The baseline decontamination consists of two elements:

- Preventative decontamination of rooms and external equipment surfaces (“good housekeeping”).
- Decontamination due to ongoing or completed (decommissioning) activities.

The routines for “housekeeping” of the EPR will follow similar procedures and regulations as any PWR plant. Following a standard plan, floors, rooms and surfaces of relevant equipment

will be cleaned by appropriate cleaning agents to prevent agglomeration of dust, dirt and potential contamination. Depending on the classification and ongoing activities in relevant rooms, the frequency of cleaning activities will vary. Some flexibility in these procedures is considered as normal due to operator specific and national requirements. Still the responsibility for good performance of related housekeeping plans lies with the utility that will operate the plant.

Beside “good housekeeping”, decontamination of equipment that is, due to its function, in contact with radioactive material has to be performed (e.g. tanks, vessels, tools, pumps, etc.). Decontamination of this equipment can be performed either during outages as a “standard” outage operation, during programmed maintenance of equipment that is not part of the outage maintenance program, or depending on operational or radiological requirements. Again, the responsibility for this lies with the future operator. Some change in the organisation of this is considered as normal due to operational experience and continuous improvement of equipment utilisation.

Independent from the method of decontamination, most decontamination methods suggested today for the EPR, limit utilisation of chemical agents in order to prevent the potential for them to cause problems later in the waste treatment routes.

In the following sub-sections some standard decontamination equipment planned to be utilised in the EPR will be explained.

### **3.1 DECONTAMINATION REQUIREMENTS FOR POCO / DECOMMISSIONING**

After final shutdown of the plant systematic steps for decommissioning of the plant are taken [1]. Closely linked to this “mechanical” deconstruction and decommissioning are decontamination activities. These are required:

- to prepare successive decommissioning operation
- for “good housekeeping” during and after deconstruction works (see above)
- for waste volume reduction (concentration of activity / contamination)

Decommissioning is not possible without decontamination. Since the EPR is a nuclear installation with related controlled areas, its installations, systems and components have to be assumed as potentially contaminated. Appropriate radiological checks at the time of cessation of operation will determine / confirm which equipment requires decontamination and which does not. (Further information is provided in Chapter 5 of reference [1])

In the following section, information on the expected decontamination requirements of the EPR is provided. It should be noted that the order of sub-sections numbering is not intended to provide an order of decontamination activities. Detailed planning of the order of these activities depends on the related decommissioning activities and the related cooperation of the radioprotection specialists.

Independent of the order of decommissioning and decontamination activities, decontamination of clothing, masks, shoes etc will be required. Thus, a related hot laundry facility will be required, either on-site or off-site. It should be noted that at a certain point of time in the decommissioning, utilisation of a potentially internal hot laundry would have to be discontinued due to upcoming dismantling of the hot laundry. At this stage, external providers are required to take this over.

Decommissioning of the hot laundry (if an on-site hot laundry has been used): After decontamination and flushing of the system, potentially utilising chemical agents for better results, the machines are taken to a hot work shop for dismantling and further decontamination if needed. Piping, valves etc. are deconstructed / size reduced and additional decontamination is applied if necessary e.g. in the decontamination booth (see below).

## **3.2 DECONTAMINATION OF KEY PLANT AREAS**

When the EPR is shut down at the end of the power generation phase, it is not expected that contamination above levels found in normal operation will be found in any of the plant areas. Proper housekeeping is assumed as standard and is expected to be maintained at all times up to the last day of power generation. EPR “key” areas that require immediate decontamination during POCO / decommissioning cannot be identified during the design phase.

It may be the case that during the EPR’s lifetime, during an incident situation, a (local) contamination has been generated. Ideally this will have been removed during the operational period, but if not then it ideally would be one of the first activities in POCO or decommissioning. Such a decontamination activity then will be part of the scheduled decommissioning and decontamination activities.

Decontamination activities during POCO and decommissioning are performed in a similar way to decontamination activities in outages:

- either as described above in close link to deconstruction / decommissioning works in preparation or following decommissioning activities, or
- as a housekeeping activity.

The methods applied for decontamination of plant areas, surfaces etc. are similar to those mentioned in section 3.4 “Structures / Buildings”.

## **3.3 SYSTEM DECONTAMINATION**

### **3.3.1 Primary Circuit**

The primary circuit is the origin of nuclides generated by the EPR during power operation and thus is contaminated and partly activated; together with its components and including all pipework, it is the most significant system to be decontaminated.

Decontamination of the primary circuit concerns the following components:

- Reactor Pressure Vessel
- Steam Generators
- Reactor Coolant Pressurising System
- Reactor Coolant Pumps and pipes
- Piping related to the above

Since these components are connected by pipework, they can be decontaminated jointly in a “full system decontamination” of the primary circuit by utilising the CORD UV process or similar. The main reasons are the following positive effects:

- Full system decontamination is a major contribution to reduction of individual and total dose during all following decommissioning and deconstruction operations
- It reduces dose rates to allow contact (“hands-on”) dismantling of many of the primary circuit components.
- It minimises the volume of packed waste by removal and concentration of activity, taking account of the production of secondary waste (e.g. ion exchange resins).

Further details are provided in section 4.1.7 “CORD UV Process”.

It is foreseen to perform the primary decontamination of components of the primary circuit in situ. If needed, this can be performed as well in a workshop after removal of the respective component (with the exception of the RPV).

Following the CORD UV decontamination, large components of the primary circuit (e.g. SG’s, pumps) can be transferred to a workshop for size reduction; depending on the radiological situation, an additional decontamination step for individual components can be added, utilising e.g. CORD UV.

Smaller (and mid size) components are (if possible according to radiology) transferred to a hot workshop for (iterative) deconstruction and decontamination: These components are deconstructed into their subcomponents and prepared for decontamination e.g. in the decontamination booth (details are provided in section 3.4).

Waste generated both by decontamination and decommissioning of the primary circuit is considered in the NDA disposability assessment [3]. Information on the waste generated by decommissioning of the primary circuit is considered in table 21 and 29 of [3.]

By applying the CORD UV process, only resins remain as waste, UV light destroys the chemicals; only H<sub>2</sub>O and CO<sub>2</sub> remain as additional products.

Depending on the radiological needs, a secondary decontamination can be applied to the pipe segments after dismantling of the respective systems, e.g. by utilising the decontamination booth (see section 4.1.2).

### **3.3.2 Auxiliary Systems**

All systems in touch with the primary coolant are to be considered as contaminated. To follow ALARP / ALARA principle and to reduce material to be disposed of as radioactive waste, they have to be decontaminated before or during operations for their deconstruction / decommissioning.

These systems include:

- Reactor Safety Injection System (RIS), also used for residual heat removal,
- Reactor Water Treatment and Purification System (TEP) and
- Reactor Volume Control System (RCV)

Since these auxiliary systems are decontaminable by the CORD UV process, it is intended that this process is applied for the EPR (for details on the process, see below in chapter "CORD UV process".) Waste generated by decontamination of these systems is considered in the NDA disposability assessment.

Following the CORD decontamination, larger components of these auxiliary systems where an in-situ segmentation is not feasible can be transferred to a hot workshop for size reduction; depending on the radiological situation, an additional decontamination step for individual components can be added, utilising e.g. the decontamination booth (see below). Mid size (and smaller) components are (if possible according to radiology) transferred to a hot workshop for (iterative) deconstruction and decontamination.

### **3.4 STRUCTURES / BUILDINGS**

Concrete structures of the EPR are partly contaminated and to a very small part activated. Both for removal of contaminated and activate concrete surfaces, similar methods will be applied. Decontamination methods (removal of activated surface structure) are described in the sub-section "Clean-up of contaminated walls / floors".

Parts of building structures that were subject to a spill of radioactive liquid or a different type of release of radioactivity due to an incident are (potentially) contaminated. Contamination resulting from these events is either cleaned up immediately (and thus is not to be considered during POCO / decommissioning) or is immobilised and recorded in a contamination database for later decontamination.

Furthermore, depending on the functions of certain rooms, these may be contaminated. After due radiological inspection of these rooms of the EPR and identification of decontamination requirements, they can be decontaminated using methods that remove the contaminated part of the surface. For further details see section 4.1.6 "Physical Abrasive / Destructive Methods".

After successful decontamination and subsequent monitoring / surveys the building structures can be demolished and disposed of as conventional waste; should subsequent demolishing not be possible, they are isolated from other (contaminated) areas to prevent cross contamination by decommissioning works.

Beside the concrete structures, the EPR makes use of steel structures, e.g. cable trays, support for vessels, load bearing structures etc.) To ease decontamination by conventional methods (e.g. wiping), they are covered with decontaminable paint.

However, in decommissioning the largest part of these structures of the EPR are expected to be recycling waste after appropriate decontamination. Therefore, after size reduction, beams, bars and other metallic material can be decontaminated e.g. by surface removal utilising abrasive blasting. Details on this method are described below in section 4.1.6 "Physical Abrasive / Destructive Methods".

The selection of the method finally to be applied depends on the future radiological and technical situation.

### **3.5 COMPONENTS**

Originating from deconstruction of (larger) systems, a large number of components (valves, pumps, pipe segments, tools, support elements, tools, etc.) have to be decontaminated

before further processing is possible (e.g. release measurements or packaging for transfer to appropriate storage facility). Depending on the radiological properties, the system of which they are part, is decontaminated potentially in a primary step (e.g. by CORD UV process, see related chapter). A secondary decontamination may be performed to achieve additionally required effects, e.g. to allow classification as exempt waste. To achieve this, the component is deconstructed in a hot workshop into smaller parts and prepared e.g. for decontamination in the decontamination booth (see Section 4 below).

In the EPR, tools and smaller instruments are used like in any other power plant or industrial installation. These can get contaminated e.g. due to their operational function. Due to their size, for decontamination of these parts, an ultrasonic or immersion bath can be applied. For more complex parts, electropolishing is applied. Further details on these methods are described in Section 4 below.

### **3.6 CABLING**

It is anticipated that a significant amount of the EPR cables used for transfer of electricity, either for power transfer or for signals will be obsolete and not re-usable as cables. Therefore, if these are contaminated and can not be decontaminated by e.g. swiping, a cable stripper / shredder can be applied to separate the potentially contaminated coating from e.g. copper that is potentially suitable for recycling. Further information on this method is described in Section 4 below.

## **4. DECONTAMINATION SYSTEMS AND TECHNIQUES, DESIGN FEATURES**

### **4.1 DECONTAMINATION SYSTEMS AND TECHNIQUES**

#### **4.1.1 Decontamination of employees**

When contamination of an employee is detected e.g. by one of the monitors of the controlled area accesses, related decontamination activities are always performed in cooperation with radioprotection.

As a first step, the exact location of the contamination is identified. Next, the adequate decontamination method is defined and taken. Mostly standard decontamination equipment (i. e. showers), cleaning agents, etc. are sufficient. Further measures are possible and agreed with radiation protection specialists.

{ CCI Removed }<sup>a</sup>

In decommissioning of the controlled area of the EPR, one of the last pieces of equipment to be dismantled are the stationary decontamination facilities for operators. If needed, mobile equipment is used to replace these for the remaining decommissioning time.

Liquid waste generated by utilisation of these showers is treated (and subsequently conditioned) by the EPR's Liquid Radwaste Treatment system, or a mobile facility ultimately when the Liquid Radwaste Treatment system itself has been decommissioned.

#### **4.1.2 Decontamination Booth: High pressure water decontamination**

The decontamination booth is an installation located in the site specific hot workshop of the EPR. It can receive larger items to be decontaminated and has an internal cabinet, in which these items are placed e.g. on a support structure or on the grid floor. Depending on operator need, the decontamination booth for the EPR can be additionally equipped for automated processes (e.g. with a rotating table) thus allowing decontamination without personnel being present in the decontamination booth. Pressurised water is used to remove surface contamination from the item; the operator has the option to add cleaning agents to the water for certain applications. The contaminated water is collected and transferred to the treatment installations.

A decontamination booth is a standard equipment to decontaminate process related and non-process related equipment, e.g. pumps, valves, tools, containers, pipe pieces etc. It may be utilised in power operation, outages and during decommissioning of the EPR.

{ CCI Removed }<sup>a</sup>

Liquid waste generated by utilisation of the decontamination booth is treated (and subsequently conditioned) by the EPR's Liquid Radwaste Treatment system and ultimately by a mobile treatment unit.

#### **4.1.3 Ultrasonic Bath / Immersion Bath**

The ultrasonic / immersion bath is an installation that can be located in the site specific hot workshop of the EPR. It can receive smaller or size reduced metal parts of lower contamination level (e.g. instruments, tools, small valves). Items to be decontaminated are placed in the bath and the ultrasonic process is started. During the process contamination is removed from the surfaces due to cavitation effects of the ultrasonic waves and subsequent cleaning in the immersion bath.

The process may be used to decontaminate parts for:

- re-utilisation in the EPR (during the operational phase)
- declassification of parts to a lower waste group (LLW -> VLLW) (in operational and decommissioning phases)



**Figure 3: Ultrasonic & Immersion bath (Finnsonic)**

#### **4.1.4 High Pressure Nozzle Tank Cleanout**

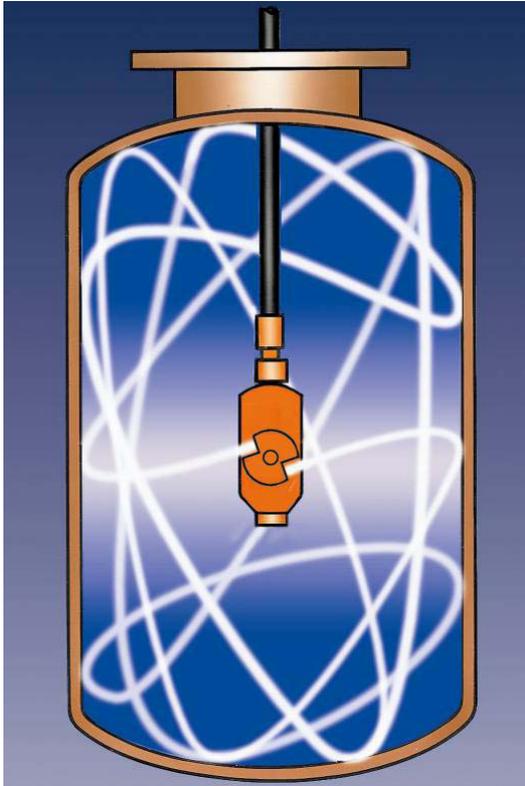
The High Pressure Nozzle is a mobile cleaning device that could be utilised by an operator in the EPR to decontaminate internals (e.g. of stationary tanks and vessels). To operate it, a related system providing the required pressurised water is needed.

In advance of the cleaning process, the spray head is inserted into the required tank; then the tank is appropriately covered to prevent water spraying out of the facility. After connecting to the pressurised water supply, the cleaning process is started. Contamination is washed off by the pressurised water and is released through the bottom opening to the treatment installations of the waste building. For certain applications, the operator has the option to add cleaning agents to the water.

The system may be used e.g. to decontaminate the following tanks:

- Volume Control Tank
- Boric Acid Storage Tanks

The spray nozzle may be used both in power operation and during decommissioning of the EPR.



**Figure 4: Spray Nozzle (Uraca)**

Liquid waste generated by utilisation of the high pressure nozzle is treated (and subsequently conditioned) by the EPR's liquid Radwaste Treatment system, and ultimately by a mobile treatment unit.

#### 4.1.5 Pressure Cleaning

Pressure Cleaning is a similar method like the above mentioned. High Pressure Nozzle Tank Cleanout; it is used for decontamination of system components, e.g. columns, filters and pumps. It can be operated utilising the same mobile system but it does not require a nozzle. In operation the system is designed as a loop containing the component to be decontaminated. Circulating water (potentially supported by cleaning agents) removes contamination.

The system may be used e.g. to decontaminate following components:

- Mixed Bed Filters
- Boric Acid Column
- Circulating Pumps

#### 4.1.6 Physical Abrasive / Destructive Methods

Abrasive / destructive methods are methods utilised when other less aggressive methods are not sufficient or inappropriate to achieve the required decontamination goal. They are also

applied during decommissioning of the plant for surfaces, that unavoidably are contaminated due to their function and are not accessible at an earlier time, e.g. during an outage. It is the target of these methods to only remove the contaminated material layer in order to keep the volume of contaminated waste low. Remaining structures can either be repaired for further utilisation or fully dismantled and prepared for radiological check to allow release as conventional waste.

The following methods are presently available on the market:

- **Abrasive grit blasting (airless)**

Abrasive grit blasting is a method to remove the contaminated surface off a wall, floor or metallic structure; for smaller parts, stationary systems are in use: Abrasive material (e.g. steel grit) is blasted onto a surface; the kinetic energy and the rough grit surface destroy and remove the material surface, together with the contamination. Blasting grit is recycled, removed particles are collected and treated as radioactive waste. When concrete surfaces are decontaminated by this method, measures are taken to prevent cross contamination, e.g. by covering cleaned surfaces.

Decontaminated metallic waste can be recycled after appropriate radiological measurement; concrete structures can be demolished conventionally.

A similar method utilises frozen CO<sub>2</sub> for surface removal; advantage of this method is the avoidance of secondary waste.

- **Milling (concrete)**

Concrete milling is used to remove the contaminated surface of a wall or floor.

- **Grinding (metal)**

Grinding is used to remove the contaminated surface of harder material, e.g. of casings or sheet metal.

- **Shaving (concrete)**

Shaving utilises a diamond armed steel wheel for surface removal. The wheel is turning at high revolutions and removes material off the machined surface.

- **Cable shredder / Cable stripper**

A cable shredder / stripper is used to separate the (contaminated) cable coating from its metallic interior. After radiological check, the metallic part can be recycled; the coating is treated as contaminated or non-contaminated waste.

- **Needler (concrete, plaster)**

A needler is used to remove contaminated surfaces of concrete floors and walls in small confined areas, e.g. for hot spots or corner machining.

The selection of the appropriate method is performed on a case-to-case basis; criteria such as accessibility, automation, contamination depth, material properties, generation of secondary waste and other process specific advantages and disadvantages are to be considered when selecting the method. These are too detailed choices and it is not possible to tell at current time which ones will be used for EPR decommissioning.

#### 4.1.7 CORD UV Process

The CORD UV process is a chemical decontamination method that can be applied if needed to single larger components of the EPR's primary circuit (e.g. steam generator) or as a Full System Decontamination (FSD) to the primary circuit as a whole.

Decontamination to single larger components is performed e.g. in case these need to be replaced to reduce dose to workers in subsequent dismantling operations. A decontamination of the primary circuit of the EPR is performed when it has reached the end of operational life. It is foreseen to be performed a short time after final shutdown as preparation for further decommissioning work.

By performing a FSD:

- dose rates at components/systems and working areas are minimised for individuals,
- total doses for decommissioning works are minimised,
- the volume of waste which can be declassified is increased,
- decommissioning concepts and health physics activities are facilitated.

In addition since the process is well proven worldwide, the authority approval process is expected to be much easier and faster, thus giving more planning safety. By performing decontamination of primary circuits and auxiliary systems (FSD) of the EPR directly after shutdown, it is ensured that all NPP systems are fully operational and, more importantly, NPP personnel with excellent system knowledge are still available.

##### Process description:

The NPP-System that needs to be decontaminated is filled with demineralised water and heated to approximately 95°C. After reaching the process temperature the chemicals are injected into the system without intermediate rinsing or exchange of water during the decontamination procedure. Crud as well as metal oxides including activity which are deposited on the internal system surface, are oxidised with permanganic acid. With the addition of oxalic acid into the system the decontamination step is initiated. All the corrosion products (Fe, Cr, Ni) including the activation products, are dissolved and are placed on ion exchange resin beds together with the manganese by bypass cleanup during the entire decontamination step. When the activity output ceases, the oxalic acid is decomposed by ultraviolet light to water and CO<sub>2</sub>.

The quality of the water after the decontamination cycle is comparable to the one before decontamination. Preoxidation – reduction – decontamination – decomposition steps (decontamination cycle) can be repeated as often as required until the activity is sufficiently removed and placed on IER. Usually three or four cycles are sufficient to remove the embedded activity to the required level.

{ CCI Removed }<sup>a</sup>

By performing the CORD UV process, very high Decontamination Factors (DF's) can be achieved. DF's achieved are typically: 30 for auxiliary systems, 75 to 750 for primary loops, 160 to 1400 for SG tubes.

Waste water and resins are treated by the equipment in the EPR's waste building, thus utilising fully operational equipment and the knowledge of the operating staff.

By performing a full decontamination of the primary circuit and related auxiliary systems of one EPR, as a first estimation about 35 m<sup>3</sup> of ILW resins are expected to be produced (the exact quantity depends on the actual contamination content and cannot be predicted at the design stage). Resins production during decommissioning is further considered in references [1] and [2].

#### **4.1.8 Electropolishing**

Electropolishing is a process for removal of contaminated metallic surfaces by an electro-chemical process. It is applicable for geometrically complex metal parts (e.g. complex machine casings). Contaminated sludge is separated and treated as radioactive waste.

#### **4.1.9 Washing machines - Decontamination of equipment**

Personnel entering controlled area of the EPR must wear appropriate clothing, shoes and, if needed, breathing equipment. After use, it has to be cleaned to allow it to be used again.

For this purpose, washing machines (with related drying and monitoring equipment) are used. Depending on the strategy of the utility operating the EPR, these may be either on- or offsite in a "hot" laundry facility.

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Waste generated by washing contaminated clothing is derived both from operational and decommissioning phases. It is treated (and subsequently conditioned) by the EPR's liquid Radwaste Treatment System and ultimately by a mobile treatment unit.

#### **4.1.10 Clean-up of contaminated walls / floors**

##### **4.1.10.1 Preventative measures**

Certain measures are foreseen at the design and construction phases to prevent contamination of concrete walls and floors, e.g. use of liners, decontaminable surface paint (coating) and peelable paint. These measures ease clean-up activities, since contamination can be:

- cleaned easier off the respective surface or
- removed together with the surface coating.

Both methods prevent contamination of the concrete below the protective layer. These measures are taken e.g. for certain building walls (liner) and building floors. During

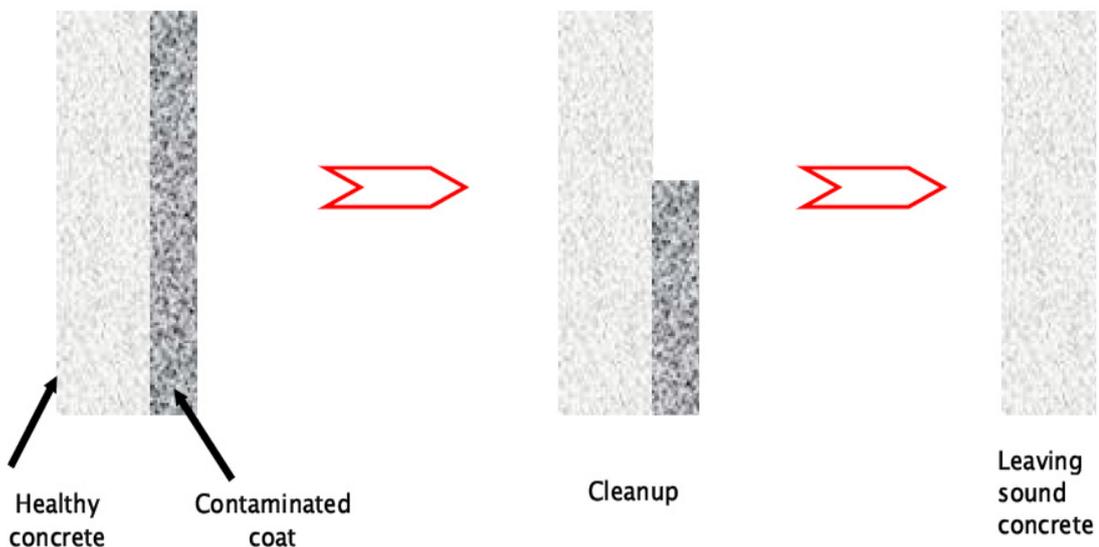
maintenance and decommissioning a mobile containment system may be utilised to prevent spreading of contamination in cases where work is being performed in a certain limited area.

**4.1.10.2 Corrective measures**

In case a concrete surface is contaminated (e.g. after a spill of contaminated liquid or as a result of a radiological inspection during decommissioning activities), the following steps are taken to allow the transition of the structure from “nuclear waste area” to “conventional waste area”:

- Review of operational historical data
- Sorting of surfaces
- Radiological measurement (survey/monitoring of the wall or floor)
- Cleaning work (for applicable techniques see section 4.1.6)
- Approval of the regulator
- Dismantling in conventional condition

The following sketch display the applied principle of the decontamination process of walls; where necessary, contaminated concrete will be removed physically, leaving a conventional structure.



**Figure 7: Principle of decontamination process**

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These measures will be applied only to surfaces which will have been identified as contaminated and other methods are not applicable. (Chapter 5 of reference [1]).

#### **4.1.11 Decontamination in the event of incidents or abnormal operations**

Decontamination activities in abnormal / fault situations are situations that may occur in the EPR as in other facilities dealing with radioactive material. Should such an event occur, it is in the responsibility of the utility to foresee the right procedures on how to deal with this. Nevertheless, the following general rules shall be followed in the EPR:

- Decontamination in case of incidents or abnormal situations are planned and performed always in cooperation with the specialist radioprotection department.
- Measures are always to be defined situation specific. An instruction on the appropriate measures for “all” situations would be wrong and thus cannot be provided. This has to be decided on the day; even though appropriate measures consist usually of one or more of the above mentioned decontamination methods.

Appropriate measures are never “heroic” activities; they must be always well coordinated and agreed with relevant departments, potentially involving authorities.

## **4.2 DETAILS ON ANY ENABLING DESIGN FEATURES**

The design features supporting decontamination activities during decommissioning, e.g. minimisation of material hold-up, material selection, space/layout, and connection points are

principally the same as those that support decontamination during operations and maintenance.

Details on these features are described in the following sub-sections.

#### **4.2.1 Hot Workshop**

Hot workshops are a very relevant part of preparation and execution of decommissioning and decontamination activities in a PWR in general and will be in the EPR in particular. They contain mixed (stationary) equipment for size reduction and decontamination of assembled equipment, thus allowing an iterative process of deconstruction and decontamination.

#### **4.2.2 Minimisation of material hold-up**

Minimisation of material hold up is realised by provision of sufficient decontamination equipment for a certain purpose in co-operation with proper planning; e.g. it will be avoided, that the same type of decontamination equipment is required to be used simultaneously for decontamination of multiple items.

#### **4.2.3 Material selection**

Materials used in the EPR are selected following the engineering requirements, environmental requirements and to facilitate decontamination. This is discussed in section 1 of reference [4].

#### **4.2.4 Space / layout**

In POCO and decommissioning it is foreseen to utilise already existing hot work shop(s), decontamination facilities and methods of the EPR. The future operator may expand these, if deemed necessary at the time of decommissioning, as after removal of inactive systems, respective empty rooms can be assigned, after proper preparation, to a new decommissioning / decontamination purpose. To provide an example, for the EPR it is foreseen to change the turbine hall after removal of the respective machinery into a decommissioning / decontamination workshop.

#### **4.2.5 Connection points**

In a primary decommissioning phase it is foreseen to utilise the existing operating decontamination equipment. These systems are connected to the fixed installed piping and waste treatment systems and thus no further "connection points" are required.

In a secondary phase, external (mobile) treatment and conditioning systems will be utilised, since the formerly operating equipment has to be decommissioned at a certain point of time. These systems will ultimately be either connected to a mobile treatment (and conditioning) system, or the generated wastes will be transported to a respective external treatment and conditioning facility.

#### **4.2.6 Decontamination of large components**

Generally, decontamination of large components (e.g. heat exchangers, pressuriser etc.) can be done either in situ, or after removal and transfer of the respective component, to a hot workshop.

With respect to decommissioning, decontamination of large items of the EPR shall be performed at an early stage after reactor final shutdown and in situ and before initiation of dismantling operations. At this time all systems and existing waste treatment equipment are fully available and functional, thus facilitating related activities.

When referring to “large components” mostly items are concerned that are subject to internal exposure to radioactive liquids; this makes the CORD UV process applicable for their decontamination (see related sub-section). In situations, where the CORD UV process is not applied (e.g. due to only a local decontamination demand, the High Pressure Nozzle Tank Cleanout method (see above) can be applied. Best choice is, to perform this decontamination activity in situ, since the vessel is connected to piping that can be used to supply all waste water to the fully operational waste water treatment system of the EPR. Depending on the needs, this method can also be applied after removal of the respective vessel to a hot workshop with connection to the waste water system.

Following this, the vessel can be dismantled either as preparation to further decontamination (e.g. by decontamination booth, see related chapter) or for packaging.

#### **4.2.7 Shielded Enclosures**

The EPR reference plant foresees a shielded enclosure, an encapsulation cell. Decontamination of this is performed:

- by removal of the related equipment to a hot workshop for further decontamination and size reduction, and subsequently
- by decontamination of the room by above mentioned. methods for decontamination of concrete surfaces (see section 4.1.10).

Note that depending on operator strategy, cementation of wastes may be realised also by mobile systems and / or external service providers; thus, a shielded enclosure may not be required.

#### **4.2.8 Pools and fuel pits**

The EPR is equipped with pools and pits required e.g. for fuel storage and transfer of fuel from the reactor to the fuel pool. The concrete structure of the pools and pits are covered with a stainless steel liner (or other coating), thus facilitating decontamination activities. Due to the surface conditions, contamination can be removed e.g. by high pressure water jet, potentially with added chemical agents if deemed necessary.

Subsequent to decontamination operation, the decontaminated part of the liner is radiologically checked; if the decontamination is not sufficient, the process can be repeated, potentially utilising brushes. To prevent cross – contamination, appropriate covers can be used to protect cleaned surfaces.

Due to the depth of a pool, the cleaning operations can be performed by operators working from a basket, used as working platform, which is lowered into the respective pool. Stepwise, the water level is lowered until the operators can work while standing on the bottom of the pool (or pit). After completion of the decontamination of the floor of the pool or pit, the activity is completed.

Resulting waste water is pumped to the waste building for treatment.

#### **4.2.9 Manipulation Systems**

Use of remote operated manipulation systems allows a large reduction of exposure of operators to ionising radiation both in power operation and decommissioning. This makes it a preferable solution for dismantling and handling operations (in water or air) of activated components that could otherwise not (or only with great difficulty) be dismantled.

For dismantling of the EPR's RPV it is presently foreseen to perform cutting operations under water utilising remote operated equipment. Due to normal wear and required maintenance of the manipulation systems, this equipment need to be decontaminated to allow required activities. Decontamination is started by rinsing the equipment with demineralised water, potentially using a spray nozzle to remove deposits. Further decontamination is performed, if needed, utilising the above mentioned equipment, e.g. decontamination booth or ultrasonic bath.

Should a manipulation tool be so highly contaminated that decontamination is not possible, it has to be treated as radioactive waste. The equipment has to be replaced.

## 5. ABBREVIATIONS

<b>Abbreviation</b>	<b>Full wording</b>
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
AMDA	Automatic Mobile Decontamination Appliance
CORD-UV	UV Chemical Oxidation Reduction Decontamination (Ultra Violet)
DF	Decontamination Factor
EPR	European Pressurised Reactor
FSD	Full System Decontamination
IER	Ion Exchange Resins
ISF	Interim Storage Facility
ILW	Intermediate Level Waste
NDA	Nuclear Decommissioning Authority
NI	Nuclear Island
NPP	Nuclear Power Plant
POCO	Post Operation Clean Out
PWR	Pressurised Water Reactor
RCP	Reactor Coolant Pump
RPV	Reactor Pressure Vessel
RWMD	Radioactive Waste Management Directorate (of NDA)
SG	Steam Generator
SF	Spent Fuel

## 6. REFERENCES

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