Note:
This is a translation of the full version information paper entitled
“Freigabe radioaktiver Stoffe und Herausgabe nicht radioaktiver Stoffe aus dem Abbau von Kernkraftwerken”.
In case of discrepancies between the English translation and the German original, the original shall prevail.

Clearance of radioactive material and removal of non-radioactive material from the dismantling of nuclear power plants

INFORMATION PAPER – **Full version with detailed explanations**

Contents

1 Request for advice

With regard to the material flows resulting from the dismantling of nuclear power plants, the ESK suggested at its 61st meeting on 18 and 19 May 2017 that, among other things, as a source of information for the public, a document should be prepared in which the facts on clearance, removal and handling of the cleared substances from the dismantling of nuclear power plants are compiled and explained. The ESK commissioned the Committee on DECOMMISSIONING (ST) to prepare the consultations on this issue. At its 49th meeting on 21 and 22 June 2017, the ST Committee then set up the ad hoc working group CLEARANCE. The ad hoc working group first drafted a proposal for the purport and depth of such a document and an initial structure, which was agreed with the ST Committee and presented to the ESK at its 63rd meeting on 14 December 2017. The ad hoc working group then prepared the draft text for the information paper, which was presented to the ST Committee at its 54th meeting on 11 April 2018, at its 55th meeting on 23 May 2018 and at its 56th meeting on 20/21 June 2018 and discussed with the ESK at its 65th meeting on 19 April 2018 and finally discussed at the 67th ESK meeting on 5 July 2018. This information paper (full version) is to be regarded as a supplement to the information paper (summary) and contains more detailed information.

2 Basic information

Operation and dismantling of a nuclear power plant are subject to the provisions of the Atomic Energy Act and Radiation Protection Act. These provisions also apply to the operation of other installations and facilities as well as to the handling of radioactive material if specified activity values, so-called **exemption levels**, are exceeded. After abandoning the operation of an installation or facility subject to the provisions of the Atomic Energy Act and/or the Radiation Protection Act, the question arises under which conditions a so-called release of materials, components, buildings, sites, etc. from supervision under nuclear and radiation protection law is possible. This release is referred to as **clearance**. For this purpose, a procedure is required which determines the conditions of such a clearance. The material resulting from clearance does not require any further monitoring after release from regulatory control from a radiological point of view. The concept of clearance is based on the fundamental principle of law that minor matters are not regulated in a standard (“de minimis non curat lex” – the law does not concern itself with trifles).

According to the current state of knowledge, there is no threshold known for health effects from exposure to ionising radiation. Since the existence of such a threshold has not yet been proven or refuted, it is assumed for radiation protection purposes that any dose, however small – with a probability decreasing with the dose – can cause damage to health. It should be noted, however, that every human being is exposed to natural radiation which varies over a wide range, e.g. depending on the place of residence. In the following, the term dose is used as an abbreviation for the effective dose.

The average natural radiation exposure in Germany is approx. 2,100 µSv per year. Since the natural dose depends on the place of residence as well as on nutritional and lifestyle habits, it varies greatly from individual to individual and in Germany ranges from 1,000 to 10,000 µSv per year. A dose of 10 µSv per year (so-called de minimis dose), up to which clearance is permitted, is extremely low both in relation to the average natural dose and to its bandwidth.

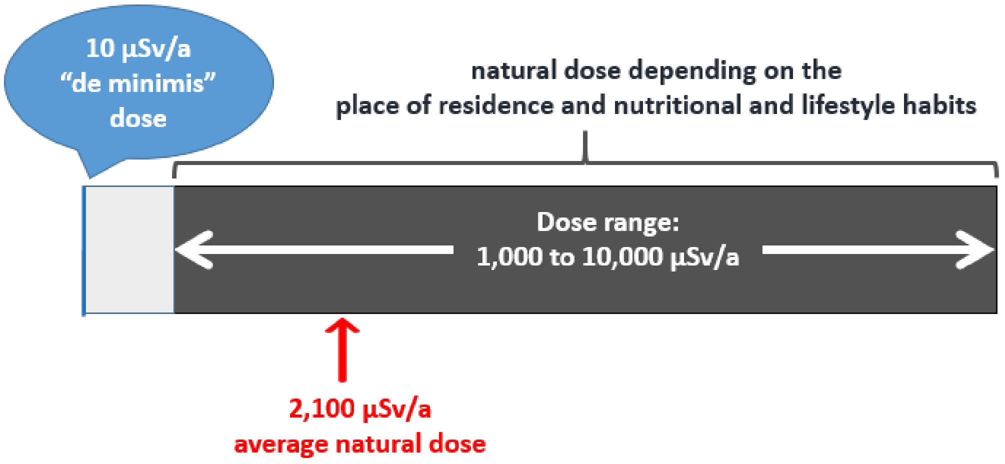


Figure 1: Dose range of the annual natural dose in Germany
(Data from: Federal Office for Radiation Protection (BfS), http://www.bfs.de/DE/themen/ion/umwelt/natuerliche-strahlenbelastung/natuerliche-strahlenbelastung_node.html)

Figure 2 illustrates the range of radiation exposure by comparing the average annual dose with the naturally occurring radioactive noble gas radon and its progenies in dwellings: A change of residence from the Hanover region to the districts of Passau or Fulda, can lead to an additional radiation dose of about 900 µSv per year.

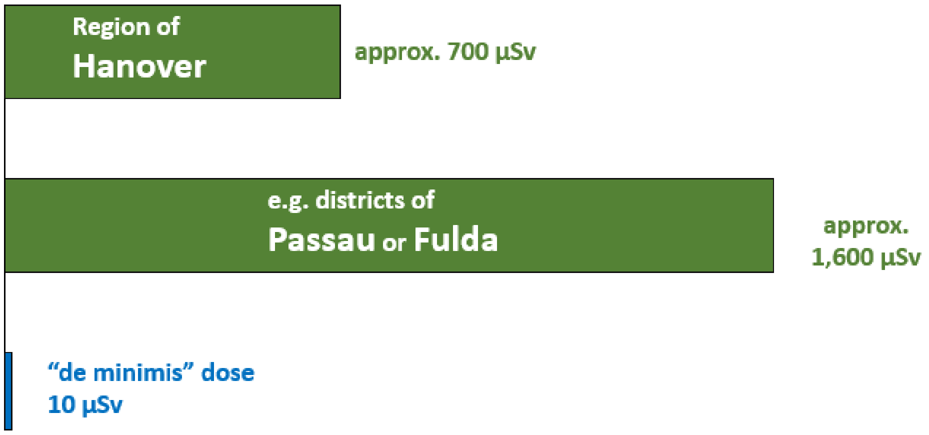


Figure 2: Estimation of the average contribution to the average annual natural dose by radon in dwellings (based on the values of the radon concentrations from Menzler S., Schaffrath R. A., Wichmann H. E., Kreienbrock L.: Abschätzung des attributablen Lungenkrebsrisikos in Deutschland durch Radon in Wohnungen. Landsberg/Lech: Ecomed Verlag 2006)

The so-called "de minimis concept" of clearance (alternatively: "10 µSv concept", see below) is based on a definition of which health risk and which degree of contamination derived therefrom can be regarded as negligible after clearance. This correlation was formulated by the International Atomic Energy Agency (IAEA) in 1988 in Safety Series No. 89 in its still internationally practised form. The acceptable health risk was derived from a consideration of the risks against which individuals would protect themselves by taking their own precautionary measures. The considerations at that time led to the proposal of a limitation to an annual dose of 10 to 100 µSv **(10 µSv concept)**. According to the current state of knowledge, a dose of 10 µSv per year is associated with a theoretical additional risk of health damage of the order of 1:1 million; the risk is therefore extremely low. Furthermore, the IAEA pointed out in its explanatory statement that such a potential dose is low compared to the real dose from natural sources.

It is not possible to monitor by direct dose measurements whether a dose of 10 µSv per year is maintained. On the one hand, it is much too low for it and indistinguishable from doses from other radiation sources, and on the other hand, the doses that may occur in the distant future should also be limited to 10 µSv per year. Therefore, calculation models have been developed on the basis of which the clearance levels were derived such that in case of compliance with them, a dose in the range of 10 µSv per year will not be exceeded.

The scenarios taken into account in the derivation of the clearance levels consider both persons dealing with cleared material in the context of their jobs as well as of the general public. For all persons, the same dose limitation applies, i.e. the limitation to 10 µSv per year. The general public also includes infants and their possible doses through the intake of breast milk. The dose level is based on the effective dose. This takes into account the effects of different types of radiation (α-, β- and γ-emitters, etc.) and the sensitivity of different body organs. The degree of harm used as a basis, the "detriment" introduced by the International Commission on Radiological Protection (ICRP), includes not only deaths from cancer but also genetic damage and other diseases that do not lead to death.

According to the current state of knowledge about the effects of ionising radiation, the Nuclear Waste Management Commission (ESK) is of the opinion that the dose limitation to 10 µSv per year is therefore entirely appropriate for clearance since possible additional health risks are negligible compared to the ubiquitous risks from natural radiation sources and their dose ranges.

3 History

The 1st Radiation Protection Ordinance of 24 June 1960 already regulated handling without requiring a licence. The licensing authorities were authorised to allow certain wastes not to be disposed of as radioactive waste. Here, a distinction was made between radionuclides with a half-life of up to 100 days and radionuclides with a half-life of more than 100 days. On this basis and with the aim of keeping the volume of radioactive waste as small as possible, regulations on the clearance of radioactive waste were, for example, included in the licence for the decommissioning and bringing about the state of safe enclosure of the Niederaichbach nuclear power plant (KKN) in 1975.

In 1976, the Atomic Energy Act of 1960 included requirements for non-detrimental utilisation or disposal of radioactive waste in a repository in a regulated manner. However, it was stipulated that these requirements did not apply to waste whose activity was so low that no special waste management was necessary to protect life, health and property from the hazards of nuclear energy and the harmful effects of ionising radiation.

With the amendment of the Radiation Protection Ordinance which entered into force on 1 April 1977, a nuclide-specific limitation of the activity for handling not requiring a licence was introduced for the first time. This led to a discussion among experts as to the extent to which this regulation could also be applied to waste from the nuclear sector. In 1979, the then competent Federal Ministry of the Interior issued a circular stating that the type, quantity and frequency of waste from nuclear applications had to be taken into account when applying the regulation. This regulation, combined with an additional limitation of the surface contamination of waste, was applied, for example, from 1980 to 1982 during the decommissioning of the nuclear-powered cargo ship “Otto Hahn” and its conversion into a conventional cargo ship and in 1985 for the decommissioning licence and for the safe enclosure of the Lingen nuclear power plant (KWL).

The “clearance levels” at that time referred to the nuclide-specific values of the so-called exemption levels. These exemption levels were derived for the handling of radionuclides within the framework of a professional activity. In order to take account of possible inhalation at the workplace when handling radionuclides, various values of the exemption limits were determined, depending on the half-lives of the radionuclides and their dose coefficient for inhalation.

Complex derivations of clearance levels based on exposure scenarios typical for clearance were made from the 1980s onwards, but mainly in the 1990s. The initial focus was on the clearance of metals (recommendations of the SSK of 1987 and 1992), then the clearance of buildings (SSK recommendation of 1995) and the clearance for disposal on a landfill or incineration (study by Poschner & Schaller 1995). In addition, EU publications on the clearance of scrap metal, buildings and excavated soil were issued from 1998 onwards. In a so-called overall recommendation, the SSK recommended clearance levels for unconditional clearance *(also referred to as unrestricted clearance)*, for disposal, for the recycling of scrap metal and for buildings in 1998.

The relevant recommendations of the SSK were implemented in the licence for decommissioning the entire Greifswald nuclear power plant, which is still the largest decommissioning project in Germany today (from 1995).

However, the practice of the clearance regulations was still very different at different competent authorities, also at the end of the 1990s. In this respect, it was an important step when, with the new Radiation Protection Ordinance in 2001, detailed regulations and clearance levels were included in this ordinance for the first time, from which also a legal claim for clearance was derived upon submission of the required demonstrations of the material's clearability.

With the first decision to phase out nuclear energy in 2000, large masses of cleared waste were to be expected in the future with the dismantling of several nuclear power plants at the same time. Against this background, the clearance levels for waste to be disposed of were reviewed by the SSK, also taking into account the changes in waste legislation that have taken place in the meantime, in particular changes in the Landfill Ordinance. In 2007, the SSK then recommended new levels for the clearance for disposal on a landfill or incineration, which were incorporated into the Radiation Protection Ordinance. These also included a limit on the mass of waste that can be disposed of annually via a landfill or waste incineration plant.

With EU Directive 2013/59/Euratom of 5 December 2013, which had to be transposed into national law by 6 February 2018, the EU set binding clearance levels for the unconditional clearance of waste. The clearance levels of the EU Directive differed in part from the previous German clearance levels. This is due in part to the different assumptions, parameters and rounding in the derivation. However, both the previous and the future set of values are based on the same dose criterion (10 µSv per year).

4 Why is clearance necessary in decommissioning?

Why not disposing of the entire mass of a nuclear power plant, or at least all parts of the controlled area (including building masses), in a repository?

In Germany, **all** radioactive waste is to be disposed of in deep geological formations in order to permanently keep it away from the human habitat There are no plans in Germany for surface disposal facilities for low- and intermediate-level radioactive waste, such as those built in other countries, e.g. in France.

The vast majority of the materials resulting from the dismantling of a nuclear power plant (e.g. most of the massive concrete structures) are neither contaminated nor activated. Another part of the materials, such as pipes from the controlled area, is only superficially contaminated and can be decontaminated by simple means. Thus, there is no need to treat these materials as radioactive waste.

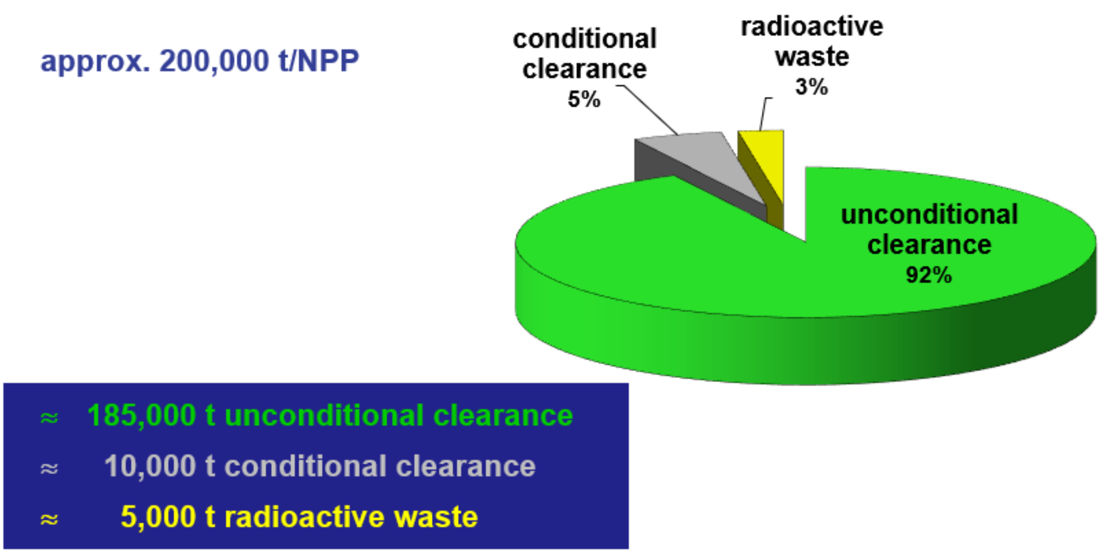


Figure 3: Approximate total mass from the controlled area of a German nuclear power plant (from the ESK presentation “Vergleich der Massenströme bei der Stilllegung von Kernkraftwerken in Deutschland und Frankreich” (Comparison of the mass flows from decommissioning of nuclear facilities in Germany and France) of 4 December 2014)

Emplacement of uncontaminated masses, which in Germany is essentially several million tonnes of building rubble, in a repository would require additional construction of such facilities, which, in view of the negligible hazard potential, from the point of view of the ESK is clearly to be rejected both economically and, in particular, ecologically.

Incidentally, the large masses from dismantling of the plants, e.g. the massive concrete structures, are **not** disposed of in the repository even in countries with surface disposal facilities for low- and intermediate-level radioactive waste (such as France) but assigned to the so-called “inactive zone” of the nuclear power plant and disposed of conventionally.

All components and building structures in a decommissioned nuclear power plant that are to be disposed of as radioactive waste are to be disposed of underground. This should not be delayed unnecessarily long, since the safety level is increased by disposal and conditioning of this waste to comply with the waste acceptance requirements for disposal (e.g. conditioning prevents digestion and fermentation processes and prevents the personnel involved from coming into contact with open radioactive substances).

A closer look at the handling of dismantled components, contaminated building rubble and operational waste shows that substances with a relevant contamination level are identified in a complex process by so-called **radiological characterisation**, separated from the substances that are contamination-free and assigned to the waste management routes. Substances with a relevant contamination level (above a few Bq/g Co-60 or Cs 137) are conditioned to comply with the waste acceptance requirements for disposal and, subsequent to storage, are delivered to the Konrad repository for disposal.

If substances are free of relevant activation and only superficially contaminated and if it is technically feasible to separate the contamination from the base material with reasonable effort, clearance of the contamination-free base material is aimed at. This is possible, for example, by mechanical methods (wiping, medium blasting (colloquially “sand blasting”) etc.), by chemical decontamination methods or by melting down metals in companies with a handling permit under radiation protection law. Using the latter method, many long-lived radionuclides, such as Cs-137 and alpha emitters, pass from the melt into the slag or filter dusts. These are usually disposed of as radioactive waste, while the metal is decontaminated in the melting process and – depending on the remaining contamination – can be processed, for example, into containers for radioactive waste or cleared based on measurements.

This process of **separation** is conducted for several reasons. On the one hand, the radioactive material is separated from the base material, thereby minimising the number of packages containing radioactive waste. On the other hand, recyclable material that is returned to the materials cycle by separating clearable material from non-clearable material. This contributes to the sustainable use of resources.

However, it is prohibited to mix or dilute contaminated waste exceeding the clearance levels with low-contaminated or contamination-free substances in order to achieve clearance in a targeted manner (**mixing ban** of the Radiation Protection Ordinance).

After removal of the entire inventory of a nuclear power plant, the **decontaminated buildings** remain. Alternative ways are increasingly discussed in public, such as the "abandonment of buildings", i.e. refraining from demolition of the controlled area buildings of nuclear power plants. In Germany, however, the abandonment of building structures is not regarded as a waste management route. Either the buildings still have a value for further use, then they can continue to be used conventionally if they fall below the specified clearance levels, or they are demolished after clearance measurement and the building rubble generated in the process is recycled conventionally. From the ESK's point of view, abandonment of the building structures would not produce any safety benefits. On the contrary, the expenditure for the maintenance of buildings increases considerably with increasing age of the buildings. It would require considerable effort to maintain then useless buildings in a safe structural condition for long periods of time. Otherwise, the risks would increase significantly during inspections and a (much later) demolition since the stability of some concrete structures decreases sharply as the age of the building increases. In addition, access of groundwater could not be ruled out for many decades of simply leaving it standing. Furthermore, conventional pollutants such as oils and PCB could be present in a decommissioned nuclear power plant, which require proper conventional waste management and cannot simply remain in place.
Another proposal discussed in public, the landfilling or the long-term storage of cleared material at the site, does not offer any safety-related advantages either in the view of the ESK.

The creation of additional contaminated sites cannot be desirable in a modern industrial society. In addition, burdens from the use of nuclear energy, which today can be eliminated without endangering operating staff or the population, should not be passed on to future generations.

If, after completion of all dismantling work, the building has been decontaminated such that the clearance levels for buildings are complied with, further use of the building rubble resulting from demolition is harmless from a radiological point of view.

For these reasons, Germany has deliberately decided to use clearance as an essential measure in the dismantling of nuclear power plants.

5 How does clearance work in practice and who controls it?

As defined in the Radiation Protection Ordinance (StrlSchV), clearance is an administrative act for the release of potentially radioactive substances from the scope of application of the Atomic Energy Act and the legal ordinances based thereon.

According to the basic radiation protection standards of the EU, clearance must take place without detrimental effects. This is specified in the EU basic standards in the form of the de minimis concept. The de minimis concept means that the radiological risks of the substances cleared in accordance with § 29 of the Radiation Protection Ordinance (StrlSchV) for a person are so low that there is no further need for regulation of the cleared material (see Chapter 2).

The basic process of clearance is presented below.

Figure 4: Simplified representation of the process of clearance

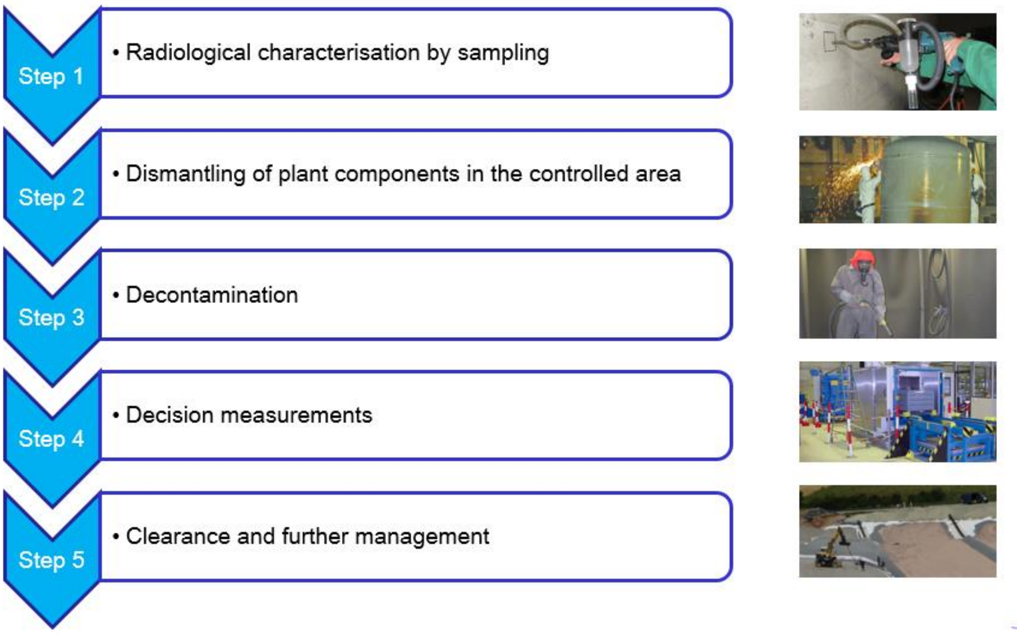
As a matter of principle, all materials from the controlled area are measured within the framework of the decision measurements. The prerequisites for release from regulatory control (clearance according to § 29 StrlSchV) must not be brought about, caused or facilitated in a targeted manner by mixing or diluting.

The individual clearance procedures, e.g. for systems and components, building rubble, buildings or the plant site, differ greatly. The concrete activity measurement methods are described, for example, in DIN 25457.

In the following, the basic process of clearance will be described in technical detail for a better understanding. It comprises five steps (see Figure 5).

Figure 5: Basic process of clearance

The radiological characterisation is carried out by preliminary examinations in the form of sampling (step 1). For this purpose, samples are taken at representative locations for the plant or the plant section or the system



– taking into account the operating history – to determine the radionuclide mixture, the so-called nuclide vector, and the spatial distribution of the activity. Here, it is usually necessary to carry out so-called “full analyses”[1] in order to be able to determine the percentages in the nuclide vector for all relevant radionuclides (including α-, β- and γ-emitters). This is done by correlating all nuclides determined in full analyses with the directly measurable nuclides. This is followed by an initial classification of the material according to waste management routes (unconditional clearance, various forms of conditional clearance *(also referred to as specific clearance)*, or disposal as radioactive waste) and classification according to batches that are as homogeneous as possible with regard to type of material, waste management route and origin.

In the course of dismantling (step 2), accompanying radiation protection measurements are carried out and specifications are made as to whether, for example, material can be cleared directly. It may be necessary to treat the material beforehand in the form of final disassembly and decontamination (step 3). Radiation protection measurements after decontamination are used to verify the decontamination success (ensuring sufficiently low residual contamination, exclusion of local activity accumulations) and to define the final clearance objective (unconditional clearance or conditional clearance).

In step 4, decision measurements are carried out by the operator to determine whether the material can be cleared. For this purpose, the parameters for the selected decision measurement method must be defined in

1 Full analysis of existing radionuclides

advance and checked by the authorised expert consulted. This includes checking whether all nuclides are covered by the applied nuclide vector. The decision measurement may only be carried out according to the specifications of the officially approved operating regulations and the official clearance notice with appropriate measurement methods.

All decision measurements must be documented in detail. The documentation includes all data and information to prove compliance with the clearance levels.

The authorised expert carries out control measurements on materials to be cleared using his own measuring equipment. The clearance documentation is also subject to control by the authorised expert. All controls by the authorised expert are also documented in writing.

In step 5– after clearance notice by the competent authority – the material is recovered or disposed of according to the chosen clearance pathways.

The entire clearance process takes place under the control of the competent authority, i.e. independent expert authorised by it. For the release of material from nuclear regulatory control, procedures reviewed and approved by the competent authority must be available. The procedures regulate all steps from the dismantling of material to the removal of a cleared material from the licensee's premises into the general national territory and are laid down in operational instructions which are subject to regulatory control. In addition to this, in some *Länder*, clearance schedules are used, which contain all the inspections performed by the operator and the controls carried out by the authorised experts consulted and are signed by the person conducting the inspection. On the one hand, these clearance schedules ensure the complete execution of all work and inspection steps and, on the other hand, they simplify the preparation of the clearance documentation. The controls already begin with the radiological characterisation to determine a provisional waste management objective and the allocation of a nuclide vector and also take place during the dismantling, disassembly and decontamination of material in the controlled area. The authorised expert is also involved in the commissioning and operation of the technical equipment, in particular that used for radiation protection measurements such as the corresponding equipment for the decision measurements. The authorised expert regularly participates in in-service inspections of the measuring equipment used. The scope of control for all steps is defined by the competent authority. This basic procedure applies to all *Länder* but may differ in individual steps.

If, in the course of the procedure, reasons should arise which result in a change of the process of clearance, then all changes to the basic operational regulations laid down in writing in the clearance decision must be carried out within the framework of the supervisory procedure with the approval of the authority before further material can be cleared.

Experience has shown that, on average, the specific activities determined in the practice of clearance with qualified measuring equipment do not fully exhaust the clearance levels, which leads to a lower effective dose for members of the public below 10 µSv in a calendar year. In addition, conservative assumptions regarding the calibration of the measuring instruments and the nuclide vectors on which they are based are generally made with the authorised expert within the framework of qualification of the measuring equipment used.

According to the Radiation Protection Ordinance, there are extensive requirements for the documentation of the entire clearance process. This **documentation must be retained for at least 30 years** and thus enables complete traceability over this period.

6 What clearance pathways are there?

6.1 General

Based on the clearance process described in Chapter 5, depending on their nature, origin and previous use, the materials may be submitted to unconditional clearance or conditional clearance (e.g. disposal on landfills, recycling of scrap metal or clearance of buildings and soil areas). Materials may be cleared if the clearance procedure laid down by the competent authority has been complied with and the results of the activity measurements can be demonstrated to be below the clearance levels of the Radiation Protection Ordinance. Cleared material will then be subject to waste law. In this chapter, the various clearance pathways are described in more detail.

The radiological characterisation described in Chapters 4 and 5 is the basis for decisions on which measurement methods to use. The parameters to be set during the measurement, the so-called calibration of the measuring instruments, are based on the data determined in the preliminary examination. The calibration determines how the display of the measuring instrument is to be converted into the actual activities. Here, also those nuclides are considered which are part of the nuclide vector but which do not contribute directly to the measuring effect due to their decay properties.

An appropriate measurement method is agreed with the authorised expert depending on the material to be subjected to clearance measurements. This may also include the performance of additional measurements to ensure the homogeneity of the activity distribution in the measured materials. Measurements with in-situ gamma spectrometers are suitable for the measurement of bulk material with a homogeneous activity distribution. This method enables the nuclide-specific measurement of gamma-emitting nuclides, also allowing to make a distinction between artificial and natural activity.

Metal scrap in packages with a size of up to 1 m^3 is preferably measured in clearance measurement facilities, where the total activity of the packages is determined and the homogeneity of the activity distribution of the packages is ensured again. With this procedure, a statement on the individual activities of all radionuclides contained can only be made via correlation factors or via supplementary sample evaluation in the laboratory (control samples).

Direct and indirect contamination measurements of surfaces are often used for preliminary examinations or in combination with other measurement methods because responsivity decreases strongly with penetrated contamination.

6.2 Unconditional clearance

All materials that go through the process of unconditional clearance can be handled without further restrictions in all areas of daily life. Unconditional clearance can be applied to solids as well as oils, oily liquids and organic solvents and coolants. Compliance with the mass-specific clearance levels are to be demonstrated for all these substances. The averaging mass for determining the mass-specific activity, i.e. the activity in relation to the weight, must not significantly exceed 300 kg.

If material has a solid surface on which contamination can be measured, compliance with the surface contamination values is also to be demonstrated on the basis of measurements. Here, the averaging area may be up to 1000 cm².

6.3 Conditional clearance

6.3.1 Clearance for disposal on a landfill or incineration

If the option of clearance for disposal is used, the cleared material must be disposed of on an appropriate landfill or in an incineration plant. The competent authority is to be informed of where the materials are to be transferred to for disposal before clearance is granted and a so-called declaration of acceptance from the operator of the recovery and disposal facility must be submitted. Recovery or reuse outside the landfill or incineration plant and return of materials to the economic cycle must be excluded.

For a clearance for disposal on a landfill or incineration, clearance levels are used that are usually higher than the levels for unconditional clearance. The reason for this is that certain exposure pathways can be excluded in the case of this **conditional clearance**, e.g. the continued use of contaminated objects as tools or commodities.

Material cleared for disposal on a landfill may be emplaced in the landfill body provided that a landfill has declared readiness for acceptance and issued a so-called Entsorgungsnachweis (proof of waste disposal). As in the case of disposal in incineration facilities, the cleared material accounts for only a small part of the total waste disposed of there.

The levels of conditional clearance for landfilling and incineration are based on calculations made on the basis of assumptions regarding typical technical equipment (e.g. of the landfill class and landfill water management), typical processes related to reception and, if applicable, the emplacement of the waste (landfill) by the personnel, and representative mass throughputs of the respective facility. Should these parameters not be complied with for the specific waste disposal facility, it has to be proven in each individual case that there is no violation of the 10 µSv concept. This can be done by a so-called Einzelfallnachweis (case-by-case demonstration) in which it is calculated, using the concrete characteristics of the landfill or the incineration facility, whether the 10-µSv concept is complied with when using the clearance levels to be used according to the Radiation Protection Ordinance. It may be required to define additional restrictions, such as the reduction of the quantities of cleared material that can be disposed of there.

The authority competent for radiation protection at the site of the landfill or incineration facility must be able to monitor the quantities of cleared substances delivered there. For this purpose, the Radiation Protection Ordinance stipulates that in the case of deliveries from other *Länder* exceeding a mass of 10 Mg, information shall be exchanged between the authorities involved.

In contrast to unconditional clearance, control steps of the competent authorities are carried out here after clearance has been granted. The entire process is not completed until the cleared material has demonstrably been emplaced in the landfill or incinerated in the incineration facility.

6.3.2 Recycling of metals

Metal scrap is produced when components are replaced, retrofitted and in large quantities when nuclear power plants are dismantled. Methods were developed at an early stage to decontaminate such scrap as far as possible and to return it to the reusable materials cycle.

The Radiation Protection Ordinance places certain requirements on the clearance of metal scrap for recycling: The competent authority must have no concerns as to the admissibility of the intended recycling path under waste law and its implementation. Therefore, a declaration of the applicant regarding the whereabouts of the future scrap metal and an acceptance declaration of the operator of the melting facility have to be submitted to the competent authority. Clearance requires that the scrap metal be melted down. According to the Radiation Protection Ordinance, only those melting facilities are suitable and admissible for this purpose for which a mixing ratio of 1:10 of cleared scrap metal to other metals can be ensured or which have a throughput of at least 40,000 tonnes per calendar year.

In the scrap trade and in melting facilities, monitoring for self-protection is carried out to prevent scrap with a considerable activity content or improperly disposed of radiation sources from being accepted at the scrap yard or melted down in a melting facility. This monitoring repeatedly leads to the discovery of radioactive material. In general, these are sources with radionuclides as they are common in medicine, technology and research which were disposed of with the scrap. In many cases, the radioactive substances have not got into the scrap metal in Germany. In a regular clearance procedure, such scrap cannot be cleared, so that these events do not call into question the clearance regulations.

If the contamination is too high to allow clearance pursuant to § 29 StrlSchV, melting down in a facility that is licensed to melt down radioactive material may be possible. Depending on the radionuclides contained, decontamination of the metal is also possible, i.e. if the radionuclides are transferred into the slag or filter dust during melting. Slag or filter dusts must then be disposed of as radioactive waste in case of contamination above clearance levels. If the product, the casting, cannot be cleared because radionuclides, e.g. cobalt-60, remain in the casting in too high a concentration, this metal can still be recycled in the nuclear sector. One possible recycling option is the manufacture of containers for disposal in a repository. This option does not represent a clearance but is mentioned here for the sake of completeness.

6.3.3 Buildings or building structures

The term "building" comprises individual buildings, rooms, room parts and parts of a building. Here, clearance measurement should principally take place at the standing structure since, in general, the activity is mainly at the surface and the probability of detecting and separating activity there is greater than in the rubble. In addition, inadmissible mixing with uncontaminated material is prevented in this way. For surface measurements, the averaging area to be taken as a basis may be up to 1 m². When clearing buildings for demolition, the competent authority may also permit larger averaging areas in justified cases. Within the framework of a preliminary examination, it is checked whether (and if so, how deep) contamination has penetrated the building structure. This has, as well as further parameters (e.g. the nuclide composition of the contamination) an impact on the applicability and the calibration of the different measuring instruments used.

There are two different scenarios for the clearance of buildings: When buildings are **cleared for demolition**, the building must be demolished, as the term suggests. The rubble produced does not require clearance again and can be disposed of or recycled conventionally. When buildings are **cleared for reuse and further use**, the building can be put to any subsequent use after clearance. For the clearance for reuse and further use of a building, the clearance levels to be complied with are more restrictive than for the clearance for demolition due to the various possible types of use.

Irrespective of which clearance pathway is aimed at for a building, the proceeding in the clearance process is the same for all of them. As a first step in the clearance process for buildings, the radiological characterisation is carried out to determine the nuclide vector, the depth profile or penetration depth, the homogeneity and the necessary extent of decontamination. It can consist of a combination of dose rate measurements, measurements with contamination monitors, gamma spectrometric measurements of samples from different depths of the building structures (e.g. drill cores or surface samples taken by chisel) as well as in-situ gamma-spectrometric measurements. Since the entire surface cannot be sampled with this method, the sample must be taken using a suitable raster method (see e.g. DIN 25457 Part 6). Based on the results of the preliminary examination, the extent of decontamination, i.e. how much material has to be removed from the wall, floor or ceiling, is determined. The decontamination of building surfaces is carried out by surface removal. Standard methods such as grinding, needle gunning, milling off or chiselling out screed are mainly used here. After decontamination, the decontamination success is checked, i.e. whether the desired clearance levels for buildings for demolition or for reuse and further use are reliably complied with. This can be done using the above methods. After successful decontamination, the decision measurements to determine compliance with the clearance levels are carried out. In most cases, direct surface measurements using contamination monitors and in-situ gamma-spectrometric measurements are used for the measurements to take a decision on clearance.

6.3.4 Soil areas

When a nuclear power plant is decommissioned, not only the buildings are subject to the provisions of the Atomic Energy Act but the premises must also be released from being subject to the Atomic Energy Act prior to further conventional use. This is done by clearance of soil areas at the site as contamination from plant operation may exist here. Such contamination of plant areas can be removed by excavating the affected soil or removing the sealed, superficially contaminated roads, floor spaces or paths. For this purpose, the Radiation Protection Ordinance contains relevant mass-specific clearance levels (averaging mass up to one tonne), which can be converted into surface-specific clearance levels if an average penetration depth is assumed.

Decision measurements for the clearance of soil areas are usually carried out using in-situ gamma spectrometry. Permissible averaging areas can be up to 100 m².

When clearing soil surfaces, it should be noted that there are also structures or components (e.g. pipes) below the surface. If they are contaminated, the same requirements for clearance measurement apply to these as to components from buildings in the controlled area. In the case of a clearance measurement of the plant site, only the contaminations caused by the plant or equipment on the premises are to be taken into account. This means that contaminations caused by the nuclear weapons fallout or the Chernobyl fallout may remain unconsidered in clearance. In contamination-free areas of the plant site where unsealed radioactive substances have not been handled in operating history, clearance can be waived under certain boundary conditions (see also Chapter 7 “What is removal of material?”).

For the clearance of large quantities of excavated soil or entire soil areas, the relevant clearance levels are to be referred to since scenarios e.g. of plant cultivation or drinking water production from wells have also been considered. The levels for unconditional clearance of e.g. rubble may not cover this.

6.4 Case-by-case demonstration of compliance

For material to be cleared that is not covered by the standard assumptions of the Radiation Protection Ordinance, proof of compliance with the 10-µSv concept can be provided on a case-by-case basis. As already mentioned in Section 6.3.1, this applies, for example, to disposal facilities that do not meet the standard basic requirements of the Radiation Protection Ordinance (e.g. minimum sizes). In addition, many liquids, such as aqueous solutions, are not covered by the clearance levels specified in the Radiation Protection Ordinance. If clearance of aqueous solutions is intended, it is required to demonstrate compliance with the 10-µSv concept in the individual case, taking into account the possible exposure pathways.

7 What is meant by removal of material?

According to § 29 StrlSchV, any material on the site of a nuclear power plant that is activated or contaminated must be measured and cleared as part of a clearance procedure before it can be reused or disposed of conventionally. In practice, this is interpreted such that already a reasonable suspicion of contamination, e.g. from operating history, requires subjecting this material to a clearance procedure, regardless of whether radioactivity can be detected on it at all. For example, as defined in the Guide to the decommissioning, the safe enclosure and the dismantling of facilities or parts thereof as defined in § 7 of the Atomic Energy Act (Decommissioning Guide), a clearance procedure has to be performed for any material from the controlled area of a nuclear power plant, even if it is from parts of the controlled area where contamination or activation is not assumed. However, it is generally possible to plausibly exclude contamination for some materials outside the controlled area and apply the so-called removal. Examples include the security fence or the staff canteen of a nuclear power plant. For these and other facilities outside the controlled area, looking at the operating history may show that there is no plausible reason to suspect contamination from plant operation.

In addition to plausibility considerations, taking into account the history of the facility, the absence of contamination of material intended for removal is also to be demonstrated by random evidence preservation measurements. According to the requirements of the ESK Guidelines for the decommissioning of nuclear facilities, the detection limits or decision thresholds of the evidence preservation measurements are approximately 10 times below the clearance levels for unconditional clearance.

In the selection of the evidence preservation measurements, so-called accumulation points are included at which activity that may be present there would most likely to be found, such as sediment in gullies for drainage from asphalt surfaces.

If there is no indication of contamination both from operating history and from the results of evidence preservation measurements, the material can be conventionally disposed of or reused without clearance.

If these evidence preservation measurements reveal findings as to radioactive substances which originate from the operation of the plant, it is checked whether the original assumption of absence of contamination is to be corrected. In general, this results in subjecting all the materials originating from this area to a clearance procedure.

In practice, material to be cleared often contains radionuclides that do not originate from the operation of the nuclear power plant. Examples include naturally occurring radionuclides such as potassium-40, which is contained in all substances without exception that contain the chemical element potassium (soil, stones, rubble, etc.). These substances, which surround people everywhere on our planet, are not subject to regulatory control due to their natural origin. On the other hand, the atmospheric nuclear tests of the 1950s and 1960s and the Chernobyl reactor accident in recent decades have led to widespread contamination. Even now, decades later, these contaminations are still detectable in Germany, especially in the soil. In particular, the radionuclide strontium-90 from nuclear weapons fallout and the radionuclide caesium-137, which in most regions of Germany originates predominantly from the Chernobyl fallout, can be found here. However, these contaminations are also not subject to the regulatory scope of § 29 StrlSchV and to supervision under nuclear and radiation protection law by the competent authority of the nuclear power plant, unless they result from handling in the plant subject to licensing.

In order to clarify the origin of any radioactivity detected, it may therefore be necessary to examine more closely the level and composition of the contamination in order to draw conclusions as to its origin. For example, the presence of the radionuclide cobalt-60 is a clear indication that the contamination originates from the operation of the nuclear power plant and is thus a radioactive substance within the meaning of § 29 StrlSchV. If, however, only the radionuclide caesium-137 is found, which is an essential component of the nuclear weapons and Chernobyl fallout, it must be clarified in each individual case whether its origin can plausibly be assigned to a specific source, taking into account the history of the plant (e.g. releases during plant operation) and the level of caesium-137 activity measured. From a safety point of view, the “normal” discharges of a plant with exhaust air do not stand in the way of a removal procedure.

A method for determining background subtraction for the contribution of the nuclear weapons or Chernobyl fallout may be established in consultation with the competent nuclear regulatory authority. Practice has shown that it is not possible to define a standard method for it since the level of this radioactivity strongly depends on the region of Germany concerned and on the type of material involved. For example, the levels of Chernobyl caesium are higher in southern Germany than in northern Germany. Likewise, the levels in soil are higher than on sealed surfaces, such as asphalt surfaces or building structures because contamination has penetrated into the soil and has meanwhile been removed from the sealed surfaces. Furthermore, there are also nuclear power plants with very different plant-specific nuclide compositions. For example, a method for background extraction developed for the site of a light water reactor can in general not be applied to the site of a high-temperature reactor since here, other nuclides may originate from plant operation.

Removal is by no means at the discretion of the plant operator. Instead, the key points of the removal procedure are a necessary integral part of the application documents in the licensing procedure for the decommissioning of nuclear power plants. The concrete proceeding in detail is then specified in written procedural instructions which are subject to control by the authority. Furthermore, the supervisory authority can carry out control measurements and review the associated documentation.

8 Conclusions

The concept of clearance is based on the fundamental principle of law according to which minor matters are not regulated in a standard (“de minimis non curat lex” – the law does not concern itself with trifles). The concept is therefore based on a definition of which health risk and which degree of contamination derived therefrom can be regarded as negligible. Annual radiation exposures in the range of a dose of 10 µSv are regarded as negligible.

According to the current state of knowledge on the effects of ionising radiation, the 10-µSv concept represents, in the opinion of ESK, an appropriate basis for risk reduction in the context of clearance. These provisions are applied in the same way in many countries worldwide that practise clearance. The provisions of the Radiation Protection Ordinance give rise to a legal claim to clearance, provided all the proofs required for clearance have been furnished.

In the German decommissioning practice, most of the material resulting from dismantling in the controlled area is cleared, and all radioactive waste is disposed of in deep geological formations. Alternative waste management concepts (disposal in near-surface facilities, abandonment of buildings of the controlled area) offer no advantages in the view of the ESK. Emplacement of these masses –several million tonnes of building rubble from the demolition of the nuclear power plants – in a repository would require the construction of near-surface facilities, which, in view of the negligible hazard potential, is to be rejected both economically and ecologically.

Likewise, there are no relevant advantages from the “abandonment” of buildings. Here, negative effects from the ageing of buildings clearly outweigh possible radiological advantages.

The clearance pathways contained in the Radiation Protection Ordinance have proven themselves in practice. For the waste management practice in Germany, further specific clearance for solids exist in addition to levels for unconditional clearance, e.g. for disposal on landfills or the clearance of soil areas. This enables legally compliant and controlled management for all materials from dismantling and release of the site from regulation under nuclear and radiation protection law.

In Germany, clearance procedures are subject to comprehensive control by the supervisory authorities and experts consulted.

For material not originating from controlled areas, removal is also possible if there are no indications of possible contamination or activation from the operating history and this is confirmed by evidence preservation measurements.

The ESK therefore advocates safety-oriented handling of all material from the dismantling of nuclear power plants that aligns the use of resources with the hazard potential. It considers clearance and removal as appropriate and necessary instruments in the process of dismantling of nuclear power plants to be able to return non-hazardous material to the material cycle or to dispose it of conventionally.