Strahlenschutzkommission

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Implementation of Article 65 (2) of the new European Basic Safety Standards on radiation protection for the protection of the environment

Recommendation by the German Commission on Radiological Protection

Adopted at the 267th meeting of the German Commission on Radiological Protection on 12 December 2013

The German original of this English translation was published in 2013 by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety under the title:

Umsetzung von Artikel 65 Abs. 2 der neuen europäischen Grundnormen des Strahlenschutzes zum Schutz der Umwelt

Empfehlung der Strahlenschutzkommission

Contents

1 Introduction and advisory mandate

Article 65 (2) of Council Directive 2013/59/EURATOM (Euratom Basic Safety Standards) laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom of 5 December 2013 (EC 2013) stipulates the following with regard to environmental protection:

"*In addition, these discharge authorisations shall take into account, where appropriate, the results of a generic screening assessment based on internationally recognised scientific guidance, where such an assessment has been required by the Member State, to demonstrate that environmental criteria for long-term human health protection are met.*"

In connection with implementing this stipulation, in a letter dated 12 July 2013, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) requested the German Commission on Radiological Protection (SSK) produce a statement on cases where a generic screening assessment should be carried out. In its statement "On the feasibility of the European Commission's proposals regarding Chapter IX of the new European Basic Safety Standards on radiation protection" adopted at the 257th meeting of the SSK on 5/6 July 2012 (SSK 2012), the SSK already concluded that there is no apparent need to extend the supervisory monitoring of nuclear power plants to include plants and animals. The SSK does however consider it necessary to establish whether, or under what conditions respectively, discharges from other nuclear or radiation protection-licensed facilities, and discharges from mining or NORM industries, could lead to situations that would require controlling. In a letter dated 12 July 2013, the BMU also asked for a statement on how "generic screening assessment based on internationally recognised scientific guidance" could be practically implemented. To this end, recommendations 108, 114 and 124 of the International Commission on Radiological Protection (ICRP) should be used as a basis for protecting the environment (ICRP 2008, 2009 and 2014) together with the results of the "Systematic investigation of exposure to flora and fauna when complying with the limits of the German Radiation Protection Ordinance (StrlSchV) for humans" study carried out by the Öko-Institut e.V. and the Helmholtz Zentrum Munich (HMGU) (Öko-Institut 2012). In particular, the SSK was requested to investigate the extent to which the stipulation of activity limits for radioactive discharges would be feasible for ensuring compliance with environmental criteria.

2 Recommendations

In Article 65 of the Euratom Basic Safety Standards of 5 December 2013, which lays down the need to demonstrate compliance with environmental criteria in terms of long-term health protection of humans, the SSK also sees a need to protect non-human species from the adverse effects of ionising radiation. In light of this, the SSK recommends using ICRP recommendation 108 (ICRP 2008) as a basis for practical implementation.

The SSK specifically recommends the following:

- Only the 12 reference animals and plants (RAPs) listed in ICRP 2008 as representatives of organism groups should be used as a reference for doses to the living environment.
- The weighted absorbed dose should be used as a measurand for doses to RAPs. For their calculations the SSK used radiation weighting factors of 1 for gamma radiation and high-

energy beta radiation (E >10 keV), 3 for low-energy beta radiation (E < 10 keV), and 10 for alpha radiation (Ulanovsky et al. 2008).

– Screening should only involve the 75 radionuclides listed in ICRP 2008, the dose conversion factors stipulated for these nuclides in ICRP 2008, and the concentration ratios for the accompanying chemical elements set out in ICRP 2009.
– The lower values of the bands of DCRL (derived consideration reference level) pursuant to ICRP 2008 should be used as a criterion for assessing dose rates to RAPs and interpreted as insignificance thresholds for the effect of ionising radiation on populations when carrying out screenings.

The SSK argues that such a method is suitable for screening pursuant to Article 65 (2) of the Euratom Basic Safety Standards of 5 December 2013.

If radionuclides are discharged with exhaust air or waste water as a result of practices[1], the SSK considers plants and animals to be protected if compliance with the dose limits for the reference person is demonstrated on the base of the administrative provisions relating to § 47 of the Radiation Protection Ordinance (StrlSchV). Individual screening is not necessary in such cases, and the SSK also sees no need for additional generic discharge limits or the specification of activity limits for radionuclides in environmental media in order to protect plants and animals.

Given an average level of natural background activity in Germany, the doses to most RAPs due to naturally occurring and discharge-related radioactivity are, upon application of the general administrative regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV), lower than the lower values of the bands of DCRL. The SSK therefore sees no need for action in these cases.

With certain RAPs (reference frog, reference flatfish, reference duck), however, further clarification of the exposure situations due to naturally occurring radionuclides is required as variability may lead to the lower values of the bands of DCRL being exceeded locally on account of increased activity concentrations.

The SSK believes that during the further development of calculation guidelines for NORM industries and mining, discharges in specific planned exposure situations should be identified for which a screening process is required according to the ICRP assessment approach and based on current knowledge in order to prove acceptable releases and discharges related to the protection of plants and animals. If doses due to natural and discharge-related radioactivity are lower than the lower values of the bands of DCRL, the SSK also sees no need for action in such cases.

The SSK predicts advancements in the state of the art in science and technology in terms of both developing models to protect plants and animals, and of determining relevant parameters. Based on current knowledge, the SSK considers the recommendations set out in ICRP 2008 to be a sufficient basis for implementation in practical radiation protection. The SSK will continue

[1] According to the definitions in § 3 (1) StrlSchV practices include:
a) the operation of installations for the generation of ionizing radiation,
b) the addition of radioactive substances to the manufacture of certain products or the activation of such products,
c) any other practices which may increase radiation exposure or contamination
aa) as they involve man-made radioactive substances or

bb) as they involve naturally occurred radioactive substances and if these practices are carried out due to the radioactivity of these substances or in order to use these substances as nuclear fuel or to produce nuclear fuel.

to monitor the progress made in this domain and, if necessary, provide revised recommendations based on future findings.

3 Scientific foundation

3.1 Scientific basis and assessment criteria for protecting plants and animals

During the course of the last decade, a number of scientific studies were carried out to develop various concepts aimed at estimating and assessing doses to plants and animals.

The European Union initiated the FASSET (Framework for Assessment of Environmental Impact) and ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management) research projects in order to come up with the scientific basis for estimating and assessing doses to plants and animals (Larsson 2004, 2008).

Within the scope of these research projects, a number of methods were developed to estimate and assess doses to plants and animals. All of these projects investigated a limited set of selected reference organisms.

A similar model was established in the US under the name of RESRAD-BIOTA (USDOE 2002, 2004), and a number of other projects in the same vein are also in use.

Dose estimates are performed using highly abstracting models which contain weighted absorbed dose estimates. In order to evaluate these doses, either uniform dose rates such as 10 µGy/h are proposed as the screening level (i.e. predicted no-effect concentration - PNEC), or specific dose rates for certain reference organisms are determined for this purpose (e.g. bands of DCRL defined by the ICRP).

A comparison of the various models available shows a number of significant differences in determining the reference organisms to be investigated and their accompanying model parameters. However, these models still allow the derivation of a bigger picture focusing on exposure levels and the differences between the various species. On the other hand, the specific differences make it difficult to directly use the results of these scientific investigations as a basis for a framework. For this reason and in analogy to using a reference person in connection with the radiation protection of man, ICRP recommendation 103 suggested using a limited set of reference animals and plants (RAPs) in order to provide a feasible framework for protecting the living environment in all exposure situations (ICRP 2007). This basic idea was elaborated on in ICRP recommendation 108 (2008).

The RAPs introduced by the ICRP are hypothetical entities which each cover specific basic taxonomical groups of the living environment. The following questions were used to determine these entities:

– Are they typical to key ecosystems?
– Is their habitat typical to certain environments (land, surface water, seas and oceans)?
– Which stages of their life cycle are relevant to doses?
– What radiobiological data/information is available?
– Are they available for future research projects?
– Are they relevant to other aspects of environmental protection?

The radiation exposure (dose) to these RAPs under typical exposure conditions is used to measure and assess the effect of ionising radiation and/or the effect of radioactive contamination of environmental media on the living environment. RAPs as defined by the ICRP are concrete species and include for the different habitats:

– Terrestrial habitats: reference deer, reference rat, reference duck, reference frog, reference earthworm, reference bee, reference grass, reference pine tree,

– Freshwater habitats: reference duck, reference frog, reference trout,

– Marine habitats: reference flatfish, reference crab and reference brown seaweed

According to the ICRP, the reference deer serves to represent all large terrestrial mammals, while the reference rat represents all small terrestrial mammals that spend time underground. Animals represented by these two reference animals for the purpose of radiation protection have a worldwide distribution. Their classification as reference animals should also take all other terrestrial species of mammal into account, including those covered by nature conservation laws. The SSK recommends using only the 12 reference animals and plants (RAPs) listed in ICRP 2008 as a reference for doses to the living environment and only using the terms set out in table 1 to describe them.

Tab.1: RAPs pursuant to ICRP 2008 and represented groups of organisms

Name pursuant to ICRP	**Designation of represented organism groups**
Reference deer	Large (herbivorous) land mammals
Reference rat	Small (omnivorous) land mammals, may also live underground
Reference duck	Land- and water-based waterfowl
Reference frog	Land- and water-based amphibians
Reference earthworm	Earthworms
Reference bee	Insects
Reference trout	Freshwater fish
Reference flatfish	Saltwater fish living on sediment
Reference crab	Larger crabs
Reference brown seaweed	Large seaweed
Reference pine tree	Trees
Reference wild grass	Grasses

The so-called weighted absorbed dose (rate) resulting from the absorbed dose multiplied by radiation weighting factors is used as the unit for doses to RAPs. In the course of discussions (Ulanovsky et al. 2008) on figures for radiation weighting factors, 10 is used for alpha radiation, 3 for low-energy beta radiation ($E < 10$ keV), and 1 for high-energy beta radiation ($E > 10$ keV) and gamma radiation. In (ICRP 2008), the ICRP did not recommend any specific radiation weighting factors. Instead it specified dose conversion factors and their distribution among the three radiation types stated above in order to calculate absorbed doses. This permits the use of dose conversion factors with a number of different radiation weighting factors. Based on current knowledge, the SSK recommends using radiation weighting factors of 1 for gamma radiation and high-energy beta radiation ($E > 10$ keV), 3 for low-energy beta radiation ($E < 10$ keV), and 10 for alpha radiation.

This weighted absorbed dose enables radioactivity to be modelled in terms of its effect on plants and animals as a pollutant with impact termini relevant to populations. This is intended to ensure that the protection of plants and animals does not serve individuals, but instead ensures the conservation of entire populations.

In (ICRP 2014), the ICRP defined bands of dose rate (derived consideration reference level, DCRL) for evaluating doses to RAPs. These bands each include an order of magnitude. Depending on the RAP at hand, the lower value of the bands of DCRL may be 0.1 mGy/d, 1 mGy/d or 10 mGy/d. The SSK recommends using these lower values of the band of DCRL pursuant to ICRP 2008 as insignificance thresholds for the effect of ionising radiation during screenings. If these values are not reached during a screening, it can be assumed that plants and animals are sufficiently protected against ionising radiation and that no further specific investigation is required.

The individual models investigate the various radionuclides involved. ICRP 2008 recommends the inclusion of 75 radionuclides, but this number may be increased or decreased depending on the model used. The available concentration ratios for converting radioactive substance concentrations in environmental media, i.e. air, soil and water, into absorbed dose rates for RAPs require equations that are unexpected when deriving very short-lived radionuclides. The SSK considers the 75-radionuclide spectrum recommended by the ICRP for screening to be sufficient in protecting plants and animals. By taking the results of the study (Öko-Institut 2012) into consideration, the SSK recommends using the 75 radionuclides stated in ICRP 2008, the dose conversion factors stipulated for these nuclides in ICRP 2008, and the concentration ratios for the accompanying chemical elements set out in ICRP 2009 as a basis for screening.

The SSK expects the state of the art in science and technology to advance further in terms of both developing models to protect plants and animals, and in terms of determining relevant parameters. As things stand, the SSK considers the ICRP recommendations (ICRP 2008, 2009 and 2014) to be a sufficient basis for implementing practical radiation protection. The SSK will continue to monitor the progress made in this domain and, if necessary, provide revised recommendations based on future findings.

3.2 Investigation and results of the "Systematic investigation of exposure to flora and fauna when complying with the limits of the German Radiation Protection Ordinance (StrlSchV) for humans" study

3.2.1 General study concept

In its advisory mandate, the SSK was requested to use the results of the "Systematic investigation of exposure to flora and fauna when complying with the limits of the German Radiation Protection Ordinance (StrlSchV) for humans" study (Öko-Institut 2012) for its assessment.

As the Radiation Protection Ordinance (StrlSchV) (BMU 2012a) stipulates limits for doses for individual members of the general public due to the discharge of radioactive substances into the air or water, but no specific protection standards for the environment, an investigation should be performed within the scope of the study (Öko-Institut 2012) to determine whether the application of the General Administrative Regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV) (BMU 2012b) as proof of compliance with dose limits for individual members of the general public is also sufficient for protecting plants and animals.

The following boundary conditions were obligatory for this investigation:

- To take all 750 radionuclides from Part D of Appendix VII of the Radiation Protection Ordinance (StrlSchV) into account
- To take reference organisms native to Germany that are covered by ICRP (2008) and the FASSET (Larsson 2004) and ERICA (Larsson 2008) research projects into account
- To use the value of 10 µGy/h derived in the ERICA project as a generic criterion for sufficient protection.

The "activity concentrations from radiation protection areas" in Part D of Appendix VII of the Radiation Protection Ordinance (StrlSchV) were stipulated for air and water. With plants or facilities that are neither subject to authorisation as stipulated in §§ 6, 7 or 9 of the Atomic Energy Act (AtG), nor to planning permission as stipulated in § 9b of the Atomic Energy Act (AtG), the competent authority may waive the need to stipulate activity quantities and activity quantities as set out in § 47 (4) of the Radiation Protection Ordinance (StrlSchV) and consider compliance with limits for members of the general public to have been proven if the annual average of these concentration values is not exceeded. The SSK (2002) has documented the derivation of these concentration values.

3.2.2 Reference organisms

The selection of relevant reference organisms in the Öko-Institut study (2012) led to the following result:

- Terrestrial reference organisms: deer, rat, duck, duck egg, earthworm, louse, snail, amphibian, reptile, bee, lichen/moss, wild grass, bush, tree
- Freshwater reference organisms: muskrat, waterfowl, amphibian, benthic fish, trout, snail, mollusc, crab, dragonfly larva, vascular plant, phytoplankton, zoo plankton
- Marine reference organisms: Porpoise, sea turtle, seabird, plaice, pelagic fish, crab, snail, sea anemone, lugworm, vascular plant, macroalgae, phytoplankton, zoo plankton.

This set of reference organisms is much larger than the one stipulated in ICRP 2008.

Figure 1 shows the basic approach used to estimate the extrapolated additional exposure to reference organisms due to discharges. To this end, dose conversion coefficients (DCCs) are determined for each reference organism which describe exposure as a function of contaminations in the air, soil and water. The parameters of the general administrative regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV) can be used to estimate which contaminations in the air, soil and water are possible if the dose limits for humans are complied with. Linking these two factors then provides the extrapolated additional exposure to reference organisms due to discharges.

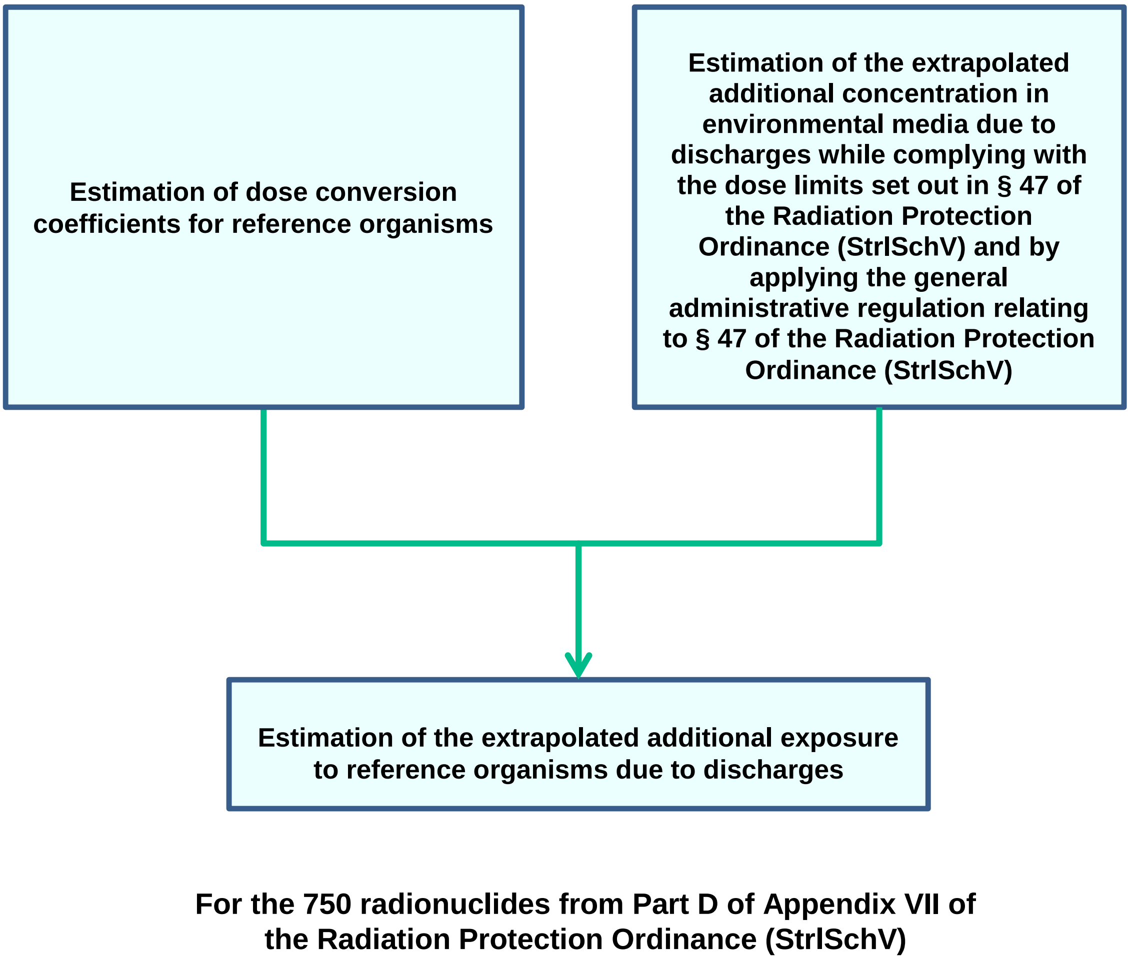

Fig. 1: Basic approach used to estimate the extrapolated additional exposure to reference organisms due to discharges (© SSK)

The Öko-Institut study (2012) derived standardised DCCs for the reference organisms. These standardised DCCs apply to the concentration of a radionuclide, including any arising daughter nuclides, which has been present in the environment (soil, water and air) for prolonged periods.

DCCs were derived to include external exposure including submersion and internal exposure (where data was available internationally for individual elements). A model was developed for the investigated terrestrial mammals which permitted an estimate of the dose by inhalation. The DCCs from the Öko-Institut study (2012) are deemed to be best estimators that were derived according to the state of science at that time.

A radiation weighting factor of 10 was used for alpha radiation, 3 for low-energy beta radiation, and 1 for high-energy beta radiation and gamma radiation.

3.2.3 Extrapolated additional concentrations in environmental media due to discharges

The extrapolated additional concentration in the soil, water and air due to discharges was determined for all 750 radionuclides from Part D of Appendix VII of the Radiation Protection Ordinance (StrlSchV) in the event of compliance with the dose limits for the most exposed reference person and the organ most exposed in relation to the limit.

The exposure situations regarding reference persons were selected such that they may be seen as scenarios typical to the derivation of generic values (e.g. maximum permissible activity concentration from radiation protection areas pursuant to Part D of Appendix VII of the Radiation Protection Ordinance (StrlSchV)). In terms of discharges with exhaust air, the less favourable outcome of two scenarios was used with differing release heights (20 metres and 200 metres). Plausible long-term dispersion factors, long-term fall-out factors and long-term wash-out factors were used for these scenarios. The transfer factors of individual chemical elements (Ti, Fr, Es, Fm, Md) missing from the General Administrative Regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV) were added on the basis of their chemical similarity to other elements.

Potential concentrations in the air (close to the ground and at release height) were estimated on the basis of the maximum radionuclide discharges with exhaust air permissible while ensuring human protection. An entry that has been valid for over 50 years was used as a basis for deposition onto the soil, and contamination in the 50th year was taken as a basis for estimating doses to reference organisms.

In terms of discharge into rivers, the maximum permissible concentrations of a radionuclide in such waters were determined if the dose limits for reference persons are to be complied with when applying the General Administrative Regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV). These maximum permissible concentrations are not related to a specific river. In the event of discharge into rivers, a distinction in terms of sedimentation is to be made between the immediate area (time of attachment to suspended particles ≤ 10 hours) and distant areas (time of attachment to suspended particles > 5 days). In line with the mandate to remain conservative, the scenario leading to lower exposure was used to estimate doses to humans. Concentration factors for fish meat, half-lives for attachment to suspended particles, and transition constants from water into sediment were added in order to cover all of the radionuclides set out in table 4 of Appendix VII of the Radiation Protection Ordinance (StrlSchV) and were assigned according to their chemical similarity. Additional data from specialist international literature was also used for freshwater fish.

As none of the nuclear plants in Germany discharge radioactive waste water directly into the sea, the general administrative regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV) does not contain any models fur such situations. Discharges into the sea via rivers may be deemed to have been covered by investigations into rivers. For this reason, a direct discharge into a marine habitat was examined. International literature was used to select parameter values and, where necessary, additions were made due to chemical similarity. The consumption rates of marine foodstuffs used for the reference persons pursuant to the Radiation Protection Ordinance (StrlSchV) were fixed at such a level that they correspond with the philosophy of the General Administrative Regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV). Here, the consumption of marine foodstuffs (fish, crustaceans, molluscs and algae) were taken into consideration along with the time spent on beaches.

3.2.4 Extrapolated additional exposure of the reference organisms due to discharges

The results for discharges of radioactive substances with exhaust air showed that a dose rate of 10 µGy/h is not exceeded for every radionuclide and reference organism if human protection is ensured as per the requirements of the Radiation Protection Ordinance (StrlSchV) in conjunction with the general administrative regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV).

Assuming the potential concentration of radioactive substances in a body of water for which human protection is still guaranteed, discharges into rivers and marine waters lead to many radionuclides exceeding the reference dose rate of 10 µGy/h. These are largely very short-lived radionuclides with half-lives of minutes or hours. Furthermore, all of these radionuclides are of no practical importance in terms of nuclear technology, isotope applications, and research. With short-lived radionuclides, the current state of science and technology requires retention by decay as opposed to discharge into waters.

Therefore, the Öko-Institut study (2012) introduced additional conditions that describe more realistic scenarios for discharges into waters. When protecting plants and animals, the focus is not on the protection of individuals, meaning that a certain volume of water has to be contaminated to constitute potential damage. This in turn gives rise to a total activity which must be constantly present in this body of water. In order to maintain a constant concentration of a radionuclide in a specific body of water, the radioactive decay due to continual discharges must be compensated. This, in turn, allows the required annual discharge value to be estimated. Radioactive decay is also accompanied by a loss of radionuclides due to the exchange of water in the body of water to be investigated. This loss also has to be compensated by constant discharges. All of these points result in the required annual discharge into a body of water that can be limited to the maximum total typical activity that occurs in practice.

The habitat to be investigated was defined as a body of running water with a volume of 5,000 m^3 (e.g. 1 m deep, 10 m wide, 500 m long). A flow rate of 0.1 m/s was used, which is a conservative value for rivers. In terms of seas, a body of water with a volume of 10^{+7} m^3 (e.g. 10 m deep, 1 million m^2 surface area) was used as a habitat, where 1% of the water is exchanged every day. With rivers, these additional assumptions no longer led to the dose criterion of 10 µGy/h being exceeded if the annual derived activity level of a radionuclide is lower than the maximum annual discharges from German nuclear power plants into rivers.

In terms of discharges into marine waters, similar considerations led to the result that – the dose criterion of 10 µGy/h is not expected to be exceeded by adhering to the current applicable regulations, particularly with regard to the retention of very short-lived radionuclides by decay storage.

The Öko-Institut study (2012), however, noted the following restriction: This consideration does not cover populations of living beings such as snails or mussels that only inhabit a small volume of water and tend not to move very far. In such cases, damage cannot be entirely excluded due to the need to protect humans. The question of whether sufficient protection is present can only be assessed in each individual case by drawing upon a specific activity entry, a specific dispersion situation, and a specific species. To this end, it should be noted that the reference dose rate of 10 µGy/h is highly conservative for most reference organisms.

3.3 Consequences of adapting the boundary conditions of the Öko-Institut study to ICRP

The SSK investigated the consequences that arise in connection with the results of the Öko-Institut study (2012) if the radionuclides, reference organisms, dose criterion, dose conversion factors and concentration ratios chosen were adapted to ICRP recommendations 108, 114 and 124 (ICRP 2008, 2009, 2014).

3.3.1 Limitation to 12 RAPs pursuant to ICRP

The Öko-Institut study (2012) investigated a wider spectrum of reference organisms than the RAPs defined by the IRCP. The study included, for example, reference organisms with far higher exposure levels than those of RAPs in freshwater habitats such as the muskrat, snail or phytoplankton. In terms of aquatic habitats, when complying with the requirements to protect humans from ionising radiation, it is possible that the lower value of the band of DRCL may not be exceeded for every potential reference organism not covered by ICRP 2008. However, the level of exposure to such reference organisms (and, if applicable, any other organisms in aquatic habitats) is also limited if it falls below the lower value of the band of DCRL for RAPs defined by the ICRP. This therefore represents an improvement in the protection of organisms from ionising radiation when compared to the previous concept, which only involved a limit on doses to humans. In view of the uncertainties in assessing ionising radiation as a relevant stressor in ecosystems that extend into the upper values of the bands of DCRL, the SSK considers this to be a sufficient improvement over the current state of knowledge.

There is currently only a limited amount of knowledge available about the potential level of radiation exposure of certain species, particularly with regard to internal doses and concentration ratios of (modelled) tissue of RAPs which include water, soil and air as environmental media. As things stand, the SSK does not see any need to recommend additional generic requirements to protect plants and animals beyond the scope of the reference organisms covered by ICRP 2008. The SSK will continue to monitor such developments and make any recommendations should the need to do so arise.

3.3.2 Limitation to 75 radionuclides pursuant to ICRP

As K-40 is one of the radionuclides included in ICRP recommendation 2008 but not in Part D of Appendix VII of the Radiation Protection Ordinance (StrlSchV), no extrapolated additional concentrations in environmental media were extrapolated for this radionuclide in the Öko-Institut 2012 study. The SSK therefore also extrapolated the corresponding values in the same way. It should be noted that the ICRP dose conversion factors only contain external exposure to K-40, as a saturation state of the living being due to naturally occurring potassium can generally be assumed.

Stipulations were made for living beings that live in both terrestrial and freshwater habitats. The reference duck is deemed to spend 70% of its time on land and 30% in freshwater, while the reference frog spends 80% of its time on land and 20% in freshwater. The reference rat was conservatively estimated to spend all of its time underground.

In terms of the RAPs in terrestrial and marine habitats, the lower values of the band of DCRL are not exceeded for the 75 radionuclides covered by ICRP 2008. This applies largely to RAPs in freshwater habitats, while RAPs in marine habitats always fall below the lower values of the bands of DCRL. The nuclide P-33 for the reference trout and nuclides Th-227 and Th-231 for the reference duck lie between the lower values and upper values of the bands of DCRL. This means that insignificance has not been definitively proven in these cases. The SSK does, however, consider this to be sufficient for a screening, and sees no need for additional generic requirements in terms of radiation protection for plants and animals.

3.3.3 Conclusions from the results of the study

The SSK does not see any need to take action for typical exposure situations involving increased radionuclide concentrations in environmental media that only occur on a very small scale. The SSK believes that it may only be useful to estimate exposure on the basis of the ICRP concept in individual cases, e.g. if a population only settles in a small habitat contaminated by discharges from practices[1], mining or NORM industries.

3.4 Maximum activity limits in discharges to ensure protection of plants and animals

The Öko-Institut study (2012) determined the extrapolated additional exposure to reference organisms based on the extrapolated additional contaminations of water, soil and air by observing the dose limits for reference persons and applying the General Administrative Regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV). The definition of habitats and flow rates/water exchange rates can be used to calculate an acceptable annual discharge of radionuclides, i.e. falling below the lower values of the bands of DCRL, with a view to protecting plants and animals.

The SSK also performed such a calculation which only involved the radionuclides and RAPs from ICRP 2008, and only applied the dose conversion factors from ICRP 2008 and concentration ratios from ICRP 2009. The dose was then assessed using the bands of DCRL defined by the ICRP. This led to the annual discharges set out in table 2 for exhaust air, rivers, and into the sea which are deemed acceptable for the protection of plants and animals. In terms of the air pathway, these derivations are based on the dispersion model in the General Administrative Regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV) in conjunction with the model approach used in the Öko-Institut study (2012) which, in turn, uses the annual discharge to determine the concentration in the environmental media water and air. Alongside the model used in the Öko-Institut study (2012), an investigation was performed to determine the annual discharge required to maintain a radionuclide concentration in a certain volume of water that would lead to the lower values of the bands of DCRL being reached. However, the model approach used in the Öko-Institut study (2012) leads to discharges already limiting such values when applying the general administrative regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV) or a similarly conservative approach for direct discharge into the sea.

In terms of the individual nuclides, there are vast differences between the acceptable discharges. In cases where the limit on discharges is in compliance with the dose limits for humans by applying the General Administrative Regulation relating to § 47 of the Radiation Protection Ordinance (StrlSchV), the limits on discharges are safely met, i.e. not reached. The SSK also sees no current need to introduce additional discharge limits in order to protect plants and animals (maximum activity limits).

[1] Practices in the sense of Footnote 1.

Table 2: Annual discharges from nuclear facilities and installations where the lower values of the bands of DCRL for RAPs defined by the IRCP are not reached

Nuclide	With exhaust air in Bq	Into rivers in Bq	Into the sea in Bq	Nuclide	With exhaust air in Bq	Into rivers in Bq	Into the sea in Bq
H-3	1.5E+16	5.3E+16	1.9E+17	Cs-134	4.0E+12	3.8E+12	3.1E+14
C-14	5.0E+14	1.1E+12	4.4E+12	Cs-135	4.4E+12	2.0E+13	1.5E+15
P-32	3.6E+13	2.3E+11	1.7E+15	Cs-136	1.7E+14	3.4E+12	1.6E+15
P-33	3.1E+14	4.0E+10	2.0E+12	Cs-137	7.6E+11	4.2E+12	3.2E+14
S-35	4.2E+15	1.9E+13	3.9E+16	Ba-140	2.0E+14	1.5E+12	1.2E+13
Cl-36	2.5E+11	3.4E+13	1.3E+16	La-140	3.2E+15	4.1E+12	4.0E+13
K-40	3.6E+12	9.7E+16	8.8E+16	Ce-141	4.2E+15	6.6E+12	5.1E+13
Ca-45	9.1E+13	2.4E+13	1.2E+16	Ce-144	5.5E+14	9.8E+11	4.0E+12
Cr-51	8.6E+15	8.8E+14	1.9E+15	Eu-152	1.4E+12	5.0E+13	4.2E+12
Mn-54	2.6E+13	6.5E+12	8.4E+12	Eu-154	1.9E+12	3.1E+13	2.6E+12
Co-57	2.9E+14	2.3E+13	9.3E+13	Eu-155	1.3E+14	1.9E+14	1.4E+13
Co-58	9.6E+13	8.5E+12	7.0E+13	Ir-192	1.2E+14	1.0E+14	2.2E+13
Co-60	1.4E+12	3.7E+12	1.6E+13	Pb-210	3.9E+13	5.6E+13	1.8E+12
Ni-59	1.4E+14	5.0E+13	8.3E+13	Po-210	2.1E+13	9.6E+10	6.3E+09
Ni-63	6.4E+13	3.7E+13	6.1E+13	Ra-226	4.0E+10	8.5E+09	1.7E+11
Zn-65	4.9E+13	6.6E+11	1.4E+12	Ra-228	3.5E+12	3.1E+12	7.1E+13
Se-75	1.2E+14	4.5E+12	6.3E+12	Th-227	2.8E+15	4.6E+09	8.8E+10
Se-79	7.6E+12	6.8E+12	4.6E+12	Th-228	2.8E+12	8.4E+08	3.8E+09
Sr-89	9.7E+13	3.3E+11	3.2E+14	Th-229	1.0E+12	5.6E+09	2.2E+10
Sr-90	3.4E+11	1.7E+11	7.7E+13	Th-230	1.1E+12	5.8E+09	2.3E+10
Zr-95	1.5E+14	2.8E+12	6.6E+13	Th-231	1.8E+18	1.4E+12	3.6E+14
Nb-94	3.3E+11	8.5E+12	1.5E+14	Th-232	1.3E+12	6.7E+09	2.8E+10
Nb-95	2.5E+14	2.1E+13	1.3E+15	Th-234	1.3E+16	3.1E+11	6.7E+12
Tc-99	1.3E+13	1.9E+14	7.0E+11	Pa-231	2.2E+11	6.1E+10	5.3E+11
Ru-103	3.6E+14	1.8E+14	1.9E+14	U-233	1.8E+11	1.2E+12	1.9E+12
Ru-106	3.0E+13	2.7E+13	1.2E+13	U-234	1.9E+11	1.2E+12	1.9E+12
Ag-110m	9.6E+12	1.6E+13	4.2E+11	U-235	2.0E+11	1.3E+12	2.1E+12
Cd-109	1.6E+13	5.2E+12	2.2E+12	U-238	2.1E+11	1.4E+12	2.2E+12
Sb-124	2.1E+13	5.4E+11	1.1E+13	Np-237	2.4E+11	6.4E+10	1.0E+12
Sb-125	4.8E+12	1.9E+12	1.6E+13	Pu-238	2.5E+11	5.5E+10	2.0E+10
Te-129m	9.6E+14	1.7E+12	1.6E+12	Pu-239	2.2E+11	5.9E+10	2.1E+10
Te-132	9.2E+14	1.2E+12	1.0E+13	Pu-240	2.2E+11	5.8E+10	2.1E+10
I-125	1.4E+16	5.4E+13	8.7E+13	Pu-241	2.1E+15	2.2E+14	8.0E+13
I-129	5.4E+13	3.6E+13	2.2E+13	Am-241	4.6E+11	5.1E+10	2.5E+11
I-131	8.1E+15	1.4E+13	9.3E+13	Cm-242	3.1E+13	4.6E+10	7.3E+09
I-132	1.2E+16	7.9E+12	3.1E+15	Cm-243	7.1E+11	4.8E+10	5.4E+09
I-133	2.9E+16	7.6E+12	4.2E+14	Cm-244	9.5E+11	4.9E+10	5.5E+09
				Cf-252	1.5E+11	5.0E+10	2.5E+11

3.5 Naturally occurring doses to RAPs

Naturally occurring radionuclides lead to internal and external doses to all living beings. For most terrestrial plants and animals, the dose rate is less than 1 µGy/h. Estimations identified highest exposure levels for lichen and moss. In natural radionuclide concentrations in the environment, these levels can exceed 10 µGy/h.

The dose conversion factors pursuant to ICRP 2008 contain such daughter nuclides with a half-life of ≤ 10 days and for which an equilibrium may emerge. In order to obtain dose conversion factors for all naturally occurring decay series, the total of several dose conversion factors has to be formed:

- Total of the dose conversion factors for Th-232, Ra-228, and Th-228 for the Th-232 series,
- Total of the dose conversion factors for U-235, Pa-231 and Th-227 for the U-235 series,
- Total of the dose conversion factors for U-238, Th-234, U-234, Th-230, Ra-226, Pb-210 and Po-210 for the U-238 series.

These totalled dose conversion factors can be used to calculate concentrations for Th-232, U-235 and U-238 in water and soil where the lower values of the bands of DCRL defined by the ICRP for individual RAPs are not reached. These concentration values are listed in table 3, but only apply if the decay series are in secular equilibrium.

Table 3: Concentrations in water and soil where the lower values of the bands of DCRL defined by the ICRP are complied with

RAP	Th-232 series	U-235 series	U-238 series	K-40 (*)
Terrestrial habitats (Bq/g dry mass, poss. based on parent nuclide of decay series)				
Reference deer	15	28	3.2	2.6E2
Reference rat	3.4	6.1	0.59	5.6E1
Reference duck	11	6.8	0.72	2.1E2
Reference frog	3.2	2.3	1.3	1.7E3
Reference bee	91	190	1.4	1.4E4
Reference earthworm	110	13	1.4	5.3E2
Reference pine tree	9.3	3.2	2.5	1.8E2
Reference wild grass	2.1	7.8	1.7	1.4E3
Freshwater habitats (Bq/l, poss. based on parent nuclide of decay series)				
Reference duck	0.024	0.14	0.13	1.7E4
Reference frog	10	45	9.2	2.0E6
Reference trout	2.0	10	3.3	4.8E5
Marine habitats (Bq/l, poss. based on parent nuclide of decay series)				
Reference flatfish	0.15	0.91	0.10	4.4E5
Reference crab	2.0	12	2.5	4.8E6
Reference brown seaweed	0.084	0.49	0.44	2.8E5

(*) The values stated here are the results of calculations which can be used to estimate K-40 levels in exposure situations and are generally larger than the maximum possible specific activity of K-40 in naturally occurring materials which is approx. 16 Bq/g (reference: pure KCl).

In its 2011 annual report on environmental radioactivity and radiation exposure, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU 2013) provided a detailed description about naturally occurring environmental radioactivity in the ground, surface water, seawater, etc. in Germany. The corresponding values are shown in table 4. The bandwidth for the soil is based on typical values for the various types of soil set out in (BMU 2013). The bandwidth in waters is the bandwidth stipulated in the BMU's report.

Secular equilibriums can always be assumed within the decay series in the soil. In bodies of water, the decay series' radionuclides are generally not in radioactive equilibrium. This is due to the varying chemical properties of the individual radionuclides that indicate varying levels of mobility in the aquatic system that are dependent upon the given hydrogeological circumstances within the body of water. The U-234 concentrations, which are largely higher than the U-238 concentrations, are the result of recoil processes owing to the alpha decay of U-238 in the stone particles of the aquifers at the juncture between solid and liquid phases as well as the resulting increased leaching of U-234 from the stone particles.

Table 4: Concentrations of naturally occurring radionuclides in the soil, groundwater, surface water and seawater in Germany (BMU 2013). DM - Dry mass

Nuclide	Soil [Bq/g DM]	Groundwater [Bq/l]	Surface water [Bq/l]	Seawater [Bq/l]
K-40	1E-1 – 6.5E-1	1.1E-2 – 1.5E1	3E-2 – 1E0	1.18E1 – 1.23E1
Th-232	7E-3 - 5E-2	4E-4 – 7E-2	<1E-2 – 1E-1	4E-7 – 2.9E-5
Ra-228	N/A (1)	N/A	<1E-3 – 1E-2	8E-4 – 8E-3
Th-228	N/A (1)	N/A	N/A	4E-6 – 3E-4
U-235	N/A (2)	N/A	<1E-2	1.9E-3
U-238	7E-3 - 3.5E-2	1E-3 – 2E-1	<1E-2 – 1E-1	4E-2 – 4.4E-2
Th-234	N/A (1)	N/A	N/A	6E-4 – 6.8E-3
U-234	N/A (1)	N/A	N/A	4.7E-2
Th-230	N/A (1)	N/A	N/A	2.5E-6
Ra-226	1E-2 – 2E-1	<4E-3 – 4E-1	N/A	8E-4 – 8E-3
Pb-210	N/A(3)	N/A	N/A	4E-4 – 2E-3
Po-210	N/A(1)	N/A	N/A	6E-4 – 1.9E-2

N/A: Not applicable; (1) in equilibrium with parent nuclide;
(2) = 0.05 x U-238;
(3) Enriched in the upper soil horizon due to atmospheric deposition;

Table 4 shows that the data available for naturally occurring radionuclides is both incomplete and consists of relatively large value bandwidths.

Annex V - General values of natural environmental radioactivity - of the Calculation Guide Mining (BfS 2010) states that background activity due to mining can be deducted. The values for soil and surface water are shown in table 5.

Table 5: General values of natural environmental radioactivity in the soil and surface water in Germany (BfS 2010). DM - Dry mass

Nuclide	Soil [Bq/g DM]	Surface water [Bq/l]
U-238	5E-2	3.0E-3
U-234	5E-2	5.0E-3
Th-230	5E-2	1.0E-3
Ra-226	5E-2	5.0E-3
Pb-210	5E-2	2.0E-3
Po-210	5E-2	1.5E-3
U-235	2E-3	1.5E-4
Pa-231	2E-3	1.5E-4
Ac-227	2E-3	1.5E-4
Th-232	4E-2	1.0E-3
Ra-228	4E-2	4.5E-3
Th-228	4E-2	1.0E-3

A comparison of tables 4 and 5 shows that the variability of environmental radioactivity in the individual environmental media has to be taken into account during an in-depth assessment.

The SSK used the data from the ICRP recommendations to calculate the percentage of lower values of the bands of DCRL for RAPs due to naturally occurring radioactivity. The soil and surface water concentrations used in the calculations were based on the “general values of natural environmental radioactivity” from (BfS 2010) and the upper limits according to (BMU 2013) for the natural decay series and K-40. The upper limits according to (BMU 2013) were always used as the concentration for seawater. The result of this calculation can be seen in table 6.

The results of the estimates summarised in table 6 show that the lower values of the bands of DCRL for most RAPs were not exceeded due to naturally occurring background activity in Germany. Taking into account a natural variability in activity concentrations in environmental media, the lower values of the bands of DCRL may be locally exceeded for the reference frog, reference flatfish and reference duck.

Table 6: Relative percentage of estimated doses to RAPs due to naturally occurring radioactivity in environmental media in Germany in relation to the lower values of the bands of DRCL defined by the IRCP

RAP	**Relative natural percentage of lower values of the bands of DCRL in %**	**Dominant radionuclide / decay series**
Terrestrial habitats		
Reference deer	2.1%	U-238 series
Reference rat	1.1%	U-238 series
Reference duck	7.7%	U-238 series
Reference frog	53%	U-238 series
Reference bee	3.6%	U-238 series
Reference earthworm	3.6%	U-238 series
Reference pine tree	2.8%	U-238 series
Reference wild grass	5.0%	U-238 series
Freshwater habitats		
Reference duck	6.6%	Th-232 series
Reference frog	0.043%	U-238 series
Reference trout	0.13%	U-238 series
Marine habitats		
Reference flatfish	17%	U-238 series
Reference crab	0.64%	U-238 series
Reference brown seaweed	2.0%	U-238 series

This result is also confirmed by the investigations performed by Beresford et al. (2008) to estimate the natural doses of K-40 to RAPs as defined by ICRP 2008 as well as the decay series of U-238 and Th-232 in terrestrial habitats in England and Wales. The weighted average absorbed dose rate ranges from 0.069 µGy/h (reference deer and reference pine tree) to 0.61 µGy/h (reference earthworm). For these three RAPs, 0.055 µGy/h and 0.087 µGy/h (reference deer), 0.041µGy/h and 0.11 µGy/h (reference pine tree), and 0.22 µGy/h and 1.5 µGy/h (reference earthworm) were stated as the 5th and 95th percentile respectively. The absorbed dose rates are dominated by K-40 and Ra-226.

Hosseini et al. (2010) investigated natural doses to RAPs in aquatic habitats where K-40, Po-210 and Ra-226 were named as dominant radionuclides. The weighted average[1] absorbed dose rate for every naturally occurring radionuclide is stated as ranging from 0.37 µGy/h (reference duck) to 1.9 µGy/h (reference aquatic grass). This investigation also shows that the lower values of the bands of DCRL defined by the ICRP are only exploited to a very minor extent by naturally occurring background activity. This even applies to the 95th percentile of all naturally occurring doses as defined by Hosseini et al. (2010) which range from 0.92 µGy/h to 4.2 µGy/h.

The SSK therefore sees no need for action in these cases. However, further clarification of exposure situations due to increased concentrations of naturally occurring radionuclides is still required for certain RAPs (reference frog, reference flatfish, and reference duck).

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[1] Radiation weighting factors: 10 for alpha radiation, 3 for low-energy beta radiation, and 1 for other types of beta radiation and gamma radiation pursuant to (Ulanowsky et al. 2008)

As the Calculation Guide Mining (BfS 2010) used for naturally occurring radionuclides does not contain a sufficiently comprehensive radioecological submodel to assess discharges into bodies of water, it is not currently possible to make statements with regard to doses to RAPs due to discharges from NORM industries and mining. The SSK therefore holds the opinion that during the further development of calculation guidelines for NORM industries and mining discharges in specific planned exposure situations should be identified for which a screening process is required according to the ICRP assessment approaches and based on current knowledge in order to prove acceptable releases and discharges, for the protection of plants and animals. If doses due to natural and discharge-related radioactivity are lower than the lower values of the bands of DRCL, the SSK also sees no need for action in such cases.

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