RADIATION EXPOSURE OF ANIMALS AND PLANTS IN THE ENVIRONMENT OF THE SITE

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LIST OF ABBREVIATIONS

Abbreviated name	Full name
CR	Concentration Ratio
DCC	Dose conversion coefficient
DCRL	Derived Consideration Reference Level
EIA	Environmental Impact Assessment
EIS	Environmental Impact Study
EMCL	Environmental Media Concentration Limit
EPIC	Environmental risks from Ionising Contaminants in the Arctic
ERICA	Environmental Risks from Ionising Contaminants: Assessment and Management
FASSET	Framework for ASSesment of Environmental impacT
ICRP	International Commission on Radiological Protection
IERPMS	Industrial Environmental Radiation Protection Monitoring System
IL	Indicating Limit
JERMS	Joint Environmental Radiation Monitoring System
LD_{50}	Lethal Dose (50% of the individuals dies at the effect of the specific dose)
PCC	Pearson Correlation Coefficient
PNEDR	Predicted No Effect Dose Rate
RAPs	Reference Animals and Plants
RQ	Risk Quotient
SF	Safety factor
SRCC	Spearman Rank Correlation Coefficient

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21.1 INTERNATIONAL RECOMMENDATIONS TO LIMIT THE RADIATION EXPOSURE OF ANIMALS AND PLANTS

International recommendations

IAEA, 1994. Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments, Technical Reports Series No. 364, IAEA, Vienna.

IAEA, 2001. Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment. IAEA Safety Reports Series 19, 216. STI/PUB/1102.

IAEA, 2010. Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments, Technical Reports Series No. 472, IAEA, Vienna.

ICRP, 2003. A framework for assessing the impact of ionising radiation on non-human species. ICRP Publication 91. Ann. ICRP 33 (3).

ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-3).

ICRP, 2008. Environmental Protection: the Concept and Use of Reference Animals and Plants. ICRP Publication 108. Ann. ICRP 38 (4-6).

ICRP, 2009. Environmental Protection: Transfer parameters for Reference Animals and Plants. ICRP Publication 114. Ann. ICRP 39 (6).

Acts

Act LIII of 1995 on the General Rules of Environmental Protection

Government decrees

Government Decree 314/2005 (of 25.12.) on Environmental Impact Assessment and the Uniform Environment Usage Permission Procedure

21.1.1 NATIONAL AND INTERNATIONAL REGULATION FOR ANIMALS AND PLANTS PROTECTION

The regulations for the environment of the protection are focused primarily on humans, which means that all the legal acts for the protection of the environment are primarily intended to protect the human society in the long run. However, our knowledge in natural sciences relevant to certain parts of environmental protection may be incomplete, so we must also keep the precautionary principle in mind, which means that we must consider the smallest human intervention affecting environmental systems with reservations as long as they are proven to have an insignificant effect on the elements, systems and processes of the environment, and all this recognition adds up to the above.

Animals and plants as an environmental element and the components thereof are in complicated and complex interaction with the other elements of the environmental system, so each intervention can have an indirect or direct influence on them. The protection of animals and plants applies to each living organism, their symbioses and habitats, so these may only be used without endangering the natural processes and relations of the symbioses and without having a detrimental effect on biological diversity (Sections 23 (1) & (2) of Act LIII of 1995 on Environmental Protection - hereinafter Environmental Protection Act). Any economic, husbandry and commercial activity implying the use of wild living organisms should be carried out by protecting the operability of natural values and systems and warranting the conservation of biological diversity (Sect. 9 (1) of Act LIII of 1996 on Nature Conservation).

Accordingly, the usage of the environment should be planned and carried out by causing the least possible load to and usage of the environment, by preventing environmental pollution and eliminating any damage to the environment. The environment should be used by minding the precautionary principle and sparing the environmental elements (Sections 6 (1) & (2) of the Environmental Protection Act). Owing to the consideration of the precautionary principle, some European countries have included in the environmental impact assessment some potential impacts whose detrimental environmental consequences are not yet certain. Here in Hungary, the environmental impact assessment procedure comprises the determination of impacts (generated by certain activities that are subject to impact assessment) on environmental elements (inc. inter alia animals and plants), on the systems, processes and structure of environmental elements (Sect. 6 (1) of Government Decree 314/2005 (of 25.12.) on Environmental Impact Assessment and the Uniform Environment Usage Permission Procedure).

Considering the primary objectives of national regulations on the protection of the environment and the guidance of international trends, the radiation exposure of animals and plants generated by the impact of human activities should reasonably be monitored in relation to some reference level, if not for anything else but to meet the precautionary principle and support the exclusion of any presumably negligible impacts and their detrimental consequences.

21.1.2 INTERNATIONAL RECOMMENDATIONS TO ASSESS THE RADIATION EXPOSURE OF ANIMALS AND PLANTS

The general radiological protection framework developed and revised from time to time by the International Commission on Radiological Protection (ICRP) now already includes guidance and recommendations concerning protection against environmental ionising radiation. The aim of the ICRP recommendations (ICRP, 2007) is that the developed radiological protection system should warrant compliance with expectations for human and environmental radiological protection without unreasonably limiting the human activities that can be correlated with exposure effects.

This aim cannot be achieved on the basis of the knowledge base collected so far with regard to radiation exposure and the health impacts thereof only. Consequently, there is a need to create a model that can meet the above radiological protection ambitions. The ICRP recommendations are built on scientific experience and duly substantiated expert opinions. The scientific data derive from the assessment of exposure-related health risks, still, the social and ecological criteria should additionally also be taken into account upon developing the radiological protection framework. It is of vital importance to make substantiated decisions on the merit about the significance and justification of the various risk quotients, so radiological protection in this sense does not differ from controlling any other activities that generate other types of dangers. So, in the opinion of the Commission, the bases of scientific estimations and value judgements must be identified as much as possible to ensure the transparency and clarity of the individual decisions (ICRP Publication, Sect. (27) in Chapter 103. 2.).

The radiological protection system outlined in the recommendations of the Commission is primarily targeted at human health protection. These health-care objectives are relatively clear-cut: any exposure situations related to ionising radiation should be managed and limited to a reasonable extent, in order to exclude any deterministic impacts and reduce the risk of stochastic impacts.

On the contrary, there is no simple or unique universal approach to the protection of animals and plants. The ideas differ country by country. So in non-human radiological protection, monitoring radiation impacts through mortality, morbidity and reproduction changes seems to be a more practical method. As regards environmental radiological protection, the goal of the Commission is to prevent and reduce to a neglectable level the incidence of radiation effects that can have detrimental impacts on the preservation of biological diversity, the protection of species, the health and condition of natural habitats, communities and ecosystems. In view of achieving this goal, the Commission recognized that although radiation exposure is in most of the cases insignificant in size, still, it must be taken into consideration as a factor with some effect on the environment. The Commission intends to give relevant guidance and advice to facilitate and possibly harmonize the impacts of human activities and the ambitions for environmental protection, by creating the comparability of risk levels.

It is rather difficult to implement a single general regulation, due to the huge variation of potential exposures and the wide scope of application, so the Commission developed a formal system in the field of radiological protection, to follow and use a structured and transparent approach. The system is expected to consider a huge number of exposure sources, regardless of whether the exposure results from existing, planned or emergency emissions. These sources can be interrelated in several manners, so they can lead to the exposure of not merely individuals but also of groups and total populations in both the present and the future. Consequently, the protection system to be developed should create a logical structure-controlled complex network (ICRP Publication, Sections (29), (30) & (31) of Chapter 103. 2).

The most important properties (applicable in both human and environmental radiological protection) of the protection system are summarized hereinafter:

- Characterizing the potential situations of exposure (planned, emergency, existing);
- Categorizing the types of exposures (the ones that will occur by all means, and the potential exposures);
- Identifying the exposed individuals, populations and communities;
- Categorizing the type of assessment (assessment related to source or individual);
- Specifying the principles of protection (justification, protection optimization, application of dose limits);
- Describing the individual doses that call for protection actions or assessments (dose limits, dose restrictions and reference levels);
- Outlining the safety conditions of radiation sources, including safety and emergency stand-by requirements and actions.

The Commission identified the need for a comprehensive framework wherein the interrelations between exposure and dose or between dose and impacts and the consequences thereof on non-human organisms are summarized from a general and joint scientific aspect. This task was first drafted in ICRP Publication 91 (ICRP, 2003) which ended with a summary stating that we need to draw the lesson from the development of systematic frameworks for human radiological protection. This framework, which the Commission intends to transform into practical advice, rests on a considerable knowledge base that leads to quantifiable values in various exposure situations, considering the wide spectrum of possible errors, the uncertainties and the deficiencies of the individual data bases.

In terms of human radiological protection, the development of anatomical and physiological reference models was a great help for the Commission in its approach to the task. All this leads to the conclusion that a similar approach of this type can provide a valuable basis for further development or for guidance, in order to protect the other species. Hence, the Commission created a small group of Reference Animals and Plants (Pentreath, [21-6]) and an accompanying relevant database with the organisms typical in major habitat types. These entities form the basis of structured approach, which helps understand relation between exposure and dose, dose and impacts, impacts and their potential consequences.

Reference Animals and Plants should be considered as hypothetic entities described with the biological properties of certain animal and plant types – like e.g. the family as a taxonomical level determined by anatomical, physiological and lifestyle properties. These in this form do not exist in reality, this is why there is a need for the direct subjects of protection (populations), still, they serve as a reference point and so provide a basis for passing certain decisions. Except for mammals, the information is as a general rule incomplete considering the type of dose-response reactions that can be estimated and considering the ability to sensibly outline the potential consequences, in particular in the case of low dose rates which in turn is typical of most exposure situations.

Relying on the recommendations, ICRP published a report in 2009, expounding therein this concept on the basis of reference animal and plant groups (ICRP, 2009). The notion of Reference Animals and Plants and a small group of them is introduced and defined in this report. The report summarizes the potential routes of pollution dispersion, it compares and discusses the compliance of the best available data. It revises our knowledge of the impacts of radiation on certain organisms, its influence on mortality, morbidity and reproduction processes in the individual populations, and the types of damage caused in the chromosome.

The Commission notes that it is not appropriate to create dose rate limits, though the guidance used in radiological protection and the assessments built on them definitely require quantified values to assess the risk. This means that the risk of occurrence of any potential damage should in some way be compared with the size of impacts. This, however, is not at all simple because although an immense set of information concerning the various types of radiation effects is available, they are mainly related to big dose rate and dose values. Since the impacts related to such a big dose rate are primarily not stochastic by nature, it is quite complicated to set up a scale that can be related to a dose rate value, can closely be connected to the risk based on the occurring impact and can underlie an assessment of any anticipated risks at low dose rates.

The dose rate originating from the natural background radiation of certain animals and plants can provide a reasonable benchmark. So, if the incremental dose rate potentially connected with human activity is just a fraction of the natural rate, it will most probably have no influence on the operation of the environmental systems, especially when they are compared with the dose rates that exceed the background several-fold and that clearly characterized impacts can be related to. Unluckily, as the information concerning natural radiation exposure is incomplete in several animal and plant groups, making such a simplified risk assessment with due accuracy is quite a difficult task. The available to us dose rate from natural radioactivity of various animals and plants living in certain ecosystems is summarized hereinafter, in the below Table 21.1.2-1, based on literature (ICRP, 2008).

So, with the consideration of the above, the generation of dose rate bands that are related to the impact on certain animal and plant groups and that comparison can be made with above the natural background seems a reasonable measure. These selected dose rate bands are in between a value which is unrealistically high in practical life and a value with no effect. Consequently, these Derived Consideration Reference Levels (DCRLs) can be considered a dose rate band wherein, as an impact of ionizing radiation, there can be some adverse effect in some of the reference organisms. A group of reference levels, promising to become more accurate in the course of time as more information will be available, was set up on the basis of the available data. The dose rate band varies from 0.1 mGy/day (4 µGy/h) to 100 mGy/day (~4,000 µGy/h). Although any values in excess of 1 Gy/day can only be realistically present in nature in super rare emergency situations, still, in the impacts monitored, the LD_{50} (50% lethal dose) value falls in this category for some animal and plant, so it is also a set of useful information related to impacts, in addition to the other data (ICRP, 2008).

These two ICRP publications underlay the development of a tool in use to assess the base level in advance, during the work, and then to estimate the potential risks with the consideration of the planned emissions.

Ecosystem	Animal and plant	Dose rate, µGy/h
Maritime	Grown-up benthic fish	0.04-0.4
	Grown-up benthic crabs	0.08-0.6
	Sargassum	0.08-0.5
Freshwater	Pelagic fish	0.02-0.75
Continental	Earthworm	External: 0.08
	Deer, mouse	External: 0.03
	^{210}Po with certain animals	Internal (in tissues): 1.7-3.3
	^{222}Rn animals living underground	Internal (in lungs) : 8-292
	Plants	0.08-0.8

Table 21.1.2-1: Natural radiation exposure in various ecosystems

21.1.3 FOUNDATIONS OF THE RISK ANALYSIS METHOD DEVELOPED AFTER THE RECOMMENDATIONS

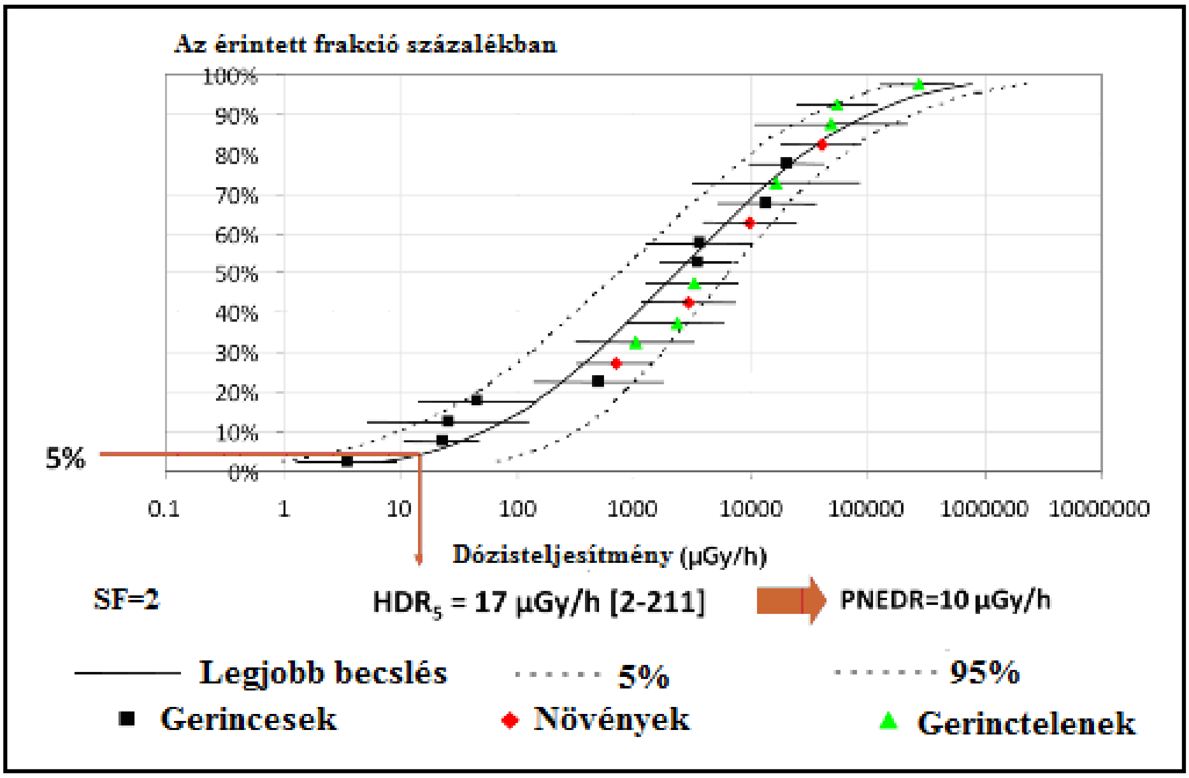
As shown above, it is not appropriate to set strict limits for the radiation exposure of animals and plants, still, the results of the estimation concerning the size of radiation exposure should somehow be related to a quantified criterion. These ratios necessarily have to be matched with some protection goal, while their use can rest on well documented and substantiated methods.

So the screening value is required for quantifying the risk: further analysis will be required if the result exceeds the pre-set value, although this does not necessarily mean a definite risk. In radiological assessments, a so-called Predicted No Effect Dose Rate (PNEDR value) is selected for the reference level and the results of the assessment can be compared to this value. EMCL (Environmental Media Concentration Limit) values are related to activity concentrations measured in the environmental medium (air, soil): they can be used to assess the exposure effects of radionuclides measured in the medium on biotas. A Risk Quotient (RQ) has been introduced to simplify the assessment of results: RQ is the quotient of the dose rate calculated on the basis of the activity concentrations measured in the medium or in animals and plants and the no effect dose rate. If the RQ value happens to be less than 1 when summed up to each of the tested isotopes, the impact generated by exposure on the biota can be considered negligibly small. At present, according to assessments reliant on international recommendations and science-based estimations, the value of the no effect dose rate is 10 µGy/h (Garnier-Laplace [21-4]). This dose rate applies to each biota in the assessment.

The reference animals and plants themselves were selected so that they could represent the various taxonomical levels, the animal and plant groups with various modes of life and physiology within the specific ecosystem. So reference animals and plants include lower and higher-order, small and large statured plants and animals, carnivorous, herbivorous and saprophyte animals, aquatic and terrestrial animals and plants. These hypothetic animals and plants are placed in the sampled environmental medium, and the exposure-borne quantifiable risk is calculated on the basis of the activity concentration data, whether estimated or actually measured in the medium or the animal/plant.

Exposure-derived radiation exposure can, apart from the sensitivity of animals and plants, be influenced by a multitude of other circumstances that must be taken into consideration during the assessment. In case of external exposure, such parameters will be the properties of the loading radionuclide, the geometric connection between the radiation source and the organism, the properties of the medium surrounding the animal/plant, the size and location of the organism within the medium or the length of time the specific animal or plant spends in the sampled medium in each stage of its lifecycle. In case of internal exposure (caused by the accumulation in tissues or organs of radionuclides getting in animals and plants) the size of the load depends on the characteristics of the radionuclide, its biological half-time, the characteristics of decomposition, the level of whole-body or organ-specific activity. Consequently, the results of the assessment are representative for the animal and plant groups most exposed to radiation exposure, while they reflect the sensitivity of any individual animal/plant to a lesser degree, though this was evidently also taken into consideration to assess the screening value.

The reference level was determined by adding various effects (that lead to some sensible change in the natural structure of the population or the characterizing factors (morbidity, mortality, reproductivity)) to the exposure dose rate values within the sampled populations of some reference animals and plants, based on earlier observations and measurements. Then quantifiable values were related to the observed effects, so the activity concentration of the individual isotopes (tested in the specific medium) with 10% effect on the sampled population was specified. This was determined for each of the tested animal and plant groups, which resulted in the sensitivity distribution of species (Figure 21.1.3-1).



Az érintett frakció százalékban - The relevant fraction in percentile ratio, dózisteljesítmény – dose rate (µGy/h), legjobb becslés – best estimation, gerincesek – vertebrates, növények – plants, gerinctelenek - invertebrates

Figure 21.1.3-1: Determination of the reference dose rate value

Here in this graph, the dose rate (HDR_5) related to 5% of animals and plants is the dose rate value that has 10% effect in 5% of the tested animal and plant group. This dose rate is divided with a pre-defined Safety Factor (SF) (determined on the basis of the reliability of the available data and on experience), which resulted in the 10 µGy/h screening dose rate. This, based on our current knowledge, does not have any observable effect in any of the tested animals and plants, so it can be considered duly safe.

In view of achieving the general objectives laid down in environmental protection legislation, the framework facilitating our estimation of the radiation exposure of animals and plants and the identification of the potential risks within this impact assessment was set up as a result of the guidance of international recommendations, science-based research work and assessments.

ERICA [Environmental Risks from Ionising Contaminants: Assessment and Management], a project developed as a part of the 6th EU Framework Programme for Research and Technological Development created a tool suitable for the environmental risk assessment of ionizing radiation. It was launched with consideration to the recommendations in ICRP Publication 103 and uses the reference organizations listed in the register of reference animals and plants in ICRP Publication 108. Additionally, the experts participating in ERICA Project developed a software, an organic part of ERICA Tools capable of estimating the radiation exposure-derived risk of animals and plants.

21.1.4 ERICA INTEGRATED APPROACH AND ERICA TOOLS

Several initiatives have been taken to set up a science-based and authentic system that can assess and support the environmental effects (i.e. covering animals, plants and ecosystems) of ionizing radiations, in e.g. the United States (US DoE, [21-8]), Canada (Environment Canada [21-3]) and the United Kingdom (Copplestone et al. [21-2]). The new recommendations of the International Commission on Radiological Protection comprise the direct consideration of the environment (ICRP, 2007), built on relevant parts in a former publication of the Commission (ICRP, 2003). In its 5th Framework Programme (FP5), the European Union supported two international projects relevant with regard to environmental radiological protection: FASSET (Framework for ASSesment of Environmental impacT) and EPIC (Environmental risks from Ionising Contaminants in the Arctic). After launching FP6, the attention was shifted from a pure assessment nature to rendering help both in decision-making and legislation. This led to ERICA Project (Environmental Risks from Ionising Contaminants: Assessment and Management) which was jointly financed by 15 organizations in the European Union and 7 member states between 2004-2007. The Project was intended to set the environmental aspect of ionizing radiation in an approach facilitating that effects and risks deriving from exposure to ionizing radiation were given proper weight in the decision-making process in issues related to the environment, emphasizing therein the protection of the structure and operation of ecosystems. To this end, some elements connected to risk characterization and effect assessment were integrated into an integral unit named ERICA Integrated Approach (Larsson, [21-5]).

The starting point in using ERICA Integrated Approach is, in general, an environmental situation in need of an action plan. The situations can fall in the categories of planned, emergency or existing, in line with the ICRP definitions detailed in ICRP's latest recommendation (ICRP, 2007). With or without the involvement of any interested parties, relying on the guidance of some monitoring data (if available and relevant) and considering several questions and options, a quick decision can be made as to whether the assessment should be continued, and if so, how. After formulating and circumscribing the problem, the assessment can answer and give feedback to the questions raised during problem formulation. Risk characterization has two kinds of relation with the assessment process:

1.) it provides a scientific base for the filtering conditions that permit the conclusion of the assessment process, provided convincing evidences support the insignificance of environmental effects;

2.) in case of potentially or actually dangerous situations, it can provide the necessary bases to estimate the probability and severity of the effects.

In both cases, ERICA Integrated Approach uses the FREDERICA database as the primary source of scientific information underlying risk characterization. The post-assessment decisions are expected to assess the findings of the assessment together with the other environmental information, so that the EIA could add proper (not too big, not too small) weight to the impact of radiation on the environment.

PROBLEM FORMULATION

Problem formulation is the first step in any environmental risk assessment: it means the determination of economic and social issues, assessment conditions and reference levels that are to be tested during the decision-making process, on the one hand, and the procedures and methods used as well as the persons taking part in the procedure are simultaneously recorded, on the other. This is intended to encourage the assessor to go over the intended impact assessment in detail and document any presumption or decision in a clear and transparent manner. The assessor should plan the tests with care, so it is e.g. important to see if there is an actual need for the entire Environmental Impact Assessment (in our case, the most detailed Tier 3 in ERICA) or if the legislative background requires its use regardless of whether the environmental risks are negligible or not. ERICA Integrated Approach offers information and advice to comply with this legal regulation, and lists some further potential components if so requested by the user. The problem might need to be re-formulated several times, sometimes with the involvement of the stakeholders, during the process ending with decision-making, while taking into consideration the latest information revealed during the assessment. The procedures regulating the participation of stakeholders are rather varied and there is probably no scenario applicable to each group of stakeholders. In practice, provided participation is considered to be an important factor in passing the decision, several methods can be introduced (Zinger et al. [21-10]). ERICA Tools help the user consider the relevant aspects and record the decisions in these issues.

ASSESSMENT

Starting from the actual or estimated concentration of radionuclides in the environmental media, the assessment module of ERICA Integrated Approach (ERICA Tools) permits the quantification of environmental risks, using several databases with reference animal and plant data (FREDERICA). Each reference animal/plant has a specific geometry which is typical of terrestrial, freshwater or marine ecosystems. The approach to reference animals and plants improved over the years and is compatible with the reference animals and plants methodology introduced by ICRP (2007).

The assessment module is divided into three separate tiers. In some cases, the assessment may be concluded at Tier 1 or 2 if the radiological risk of radiation on the biota is low or negligible. If the estimated effects are not negligible, the assessment should be continued at the most detailed level, in Tier 3. The difference among the tiers lies primarily in calculation modes and the volume of input data (Brown et al. [21-1]).

DESCRIPTION OF TIERS

Tier 1 is the most conservative tier, it requires the least input data. Its operation is based on assessing the risk arising with the in-medium activity concentration values of certain isotopes, relative to a pre-set screening dose rate level. In ERICA Integrated Approach the default screening dose rate is the above mentioned 10 µGy/h. The Tool permits the use of other values, e.g. 40 µGy/h for terrestrial animals, or 400 µGy/h for terrestrial plants.

The concentration of the individual isotopes in water or soil is calculated inverse to the possible screening dose rates. As a result of this concentration, the entire (external & internal) radiation exposure will be the specific screening dose rate for one of the reference animals or plants. This is called Environmental Media Concentration Limit (EMCL) which always means a value pair of limiting organism and activity concentration.

In actual Tier 1 assessment, after selecting the habitat type and the radionuclides, the Tool compares the specific, maximally potential (measured or calculated (see below)) in-medium activity concentration values with the EMCL values. Then a risk quotient is determined for the specific isotopes each, after relating the most sensitive animals and plants to them. If the ΣRQ value is less than 1 for each of the tested isotopes, the Tool proposes the user to finish assessment. If, however, the ΣRQ value reaches or exceeds 1, the assessment is recommended to be continued at a higher tier.

Starting from Tier 1, if the necessary activity concentration values are not directly available (e.g. this always applies in the case of a planned facility), an application built in ERICA Tool and based on IAEA SRS-19 models (IAEA, 2001) can be used for estimation. The models built in ERICA Tool are generic, they consider environmental dispersion and dilution, while using a minimal set of location-specific input data.

The following SRS-19 models are available for the three ecosystems (terrestrial, freshwater, marine) in ERICA Tool:

- *Small lake (freshwater)*
- *Big lake (freshwater)*
- *River (freshwater)*
- *Influx (estuary) (freshwater or marine)*
- *Seaside (marine)*
- *Air (terrestrial)*

SRS-19 models are designed in a way to minimize the chance of calculated concentrations in environmental media underestimating the caused (human) doses by over 10-fold. They can give an estimate of average water or air concentrations originating from continuous emission from a single source, presuming that balance or quasi-balance is generated between the emitted radionuclides and the environmental media.

In ***Tier 2***, the Tool calculates a dose rate for a specific (reference or individually defined) animal/plant and compares it with the selected screening dose rate. The result is then presented to the user in a "traffic light" system:

- Green: most certainly negligible risk, the assessment may be finished;
- Yellow: potential risk which should be clarified through an expert or a refined Tier 2 and/or a whole-scale Tier 3 assessment;
- Red: risk occurring with most certainty, where further study is definitely required, mainly at Tier 3.

The estimation of absorbed dose rate (μGy/h) is a fundamental step in ERICA Integrated Approach as it helps interpret the activity concentrations in environmental media and in the individuals of animals and plants as an expression of potential impacts. Owing to radionuclides in the environment, plants and animals are exposed to ionizing radiation from both outside and inside. Internal radiation exposure applies after radionuclide uptake (by digestion or through the root). Its size is determined by activity concentration within the animal/plant, the size of the organism and the type and energy of the emitted radiation. External radiation exposure depends on a number of factors including the pollution levels of the environment, the geometric relation between the radiation source and the animal/plant, the habitat, the size of the animal/plant, the shading properties of the medium and the physical properties of the existent radionuclides.

The geometric relation between the radiation source and the animal/plant subject to radiation exposure is a crucial factor in determining the received absorbed dose rate. The intensity of the radiation field around the source decreases as the distance increases and it is also influenced by the medium between the source and the target. The number of potential source/target configurations in infinite, though in practice just a limited number of typical situations can be taken into account.

The relationship between an individual of an animal or plant or the activity concentration of an environmental medium and the external or internal absorbed dose rates is described by the Dose Conversion Coefficient (DCC; μGy/h per Bq/kg dry and wet mass). In ERICA Tool, see Pröhl et al. [21-7] concerning the description of the method of deriving the DCC values. One of the key volumes for estimating the internal absorbed doses is the absorbed fraction (f) which, by definition, is the fraction of energy (emitted by the radiation source) absorbed by the animal/plant. In ERICA Tool, the absorbed fraction of photon and electron sources of notional uniform distribution, of spherical/ellipsoid geometry and descending into infinite wet medium was calculated with the Monte Carlo simulation. The calculations relevant to the default geometries in ERICA cover the energy range from 10 keV to 5 MeV, the mass range from 1 mg to 1000 kg and the geometry range with various rates of non-spherical symmetry from the sphere to the ellipsoid. A set of re-scaling factors was generated from the calculated absorbed fraction values and, after interpolating this set, the absorbed fraction can be determined with regard to the user-defined animals and plants, within certain size limits.

With regard to aquatic animals and plants, there is no significant difference between the density of the water and the animal/plant, whereas in the case of terrestrial animals and plants, the estimation of external radiation exposure means a much more complicated task. Soil, air and organic matter considerably differ in terms of composition and density. Consequently, the dispersion and interference of radiation cannot be properly described with analytic solutions but the DCC values have to be derived with the Monte Carlo simulation of the dispersion and interference of monoenergetic photons. Some generalized and typical cases defined with the energy of radiation, the polluted medium and the size of the animal/plant were selected for a detailed test. For the circumstances of radiation exposure with no detailed calculations available, the data were generated by interpolation among the other cases. Source-target combinations for calculating the DCC values relevant to external radiation exposure:

- *The radiation exposure of animals and plants living on and above the ground, due to 10 cm thick soil layer uniformly polluted in its volume (µGy/h per Bq/kg ground, dry mass).*
- *The external radiation exposure of animals and plants living in 50 cm thick and uniformly polluted soil layer (µGy/h per Bq/kg animal/plant, wet mass).*

The resulting dose conversion coefficients can be used to estimate the unweighted absorbed dose rates deriving from activity concentrations in the environmental media and the individuals of animals and plants. Radiation effects, however, do not merely depend on the unweighted absorbed dose but also on the type of radiation. For instance the effect with a specific size of unweighted absorbed dose alpha radiation can be much more significant than the same with beta or gamma radiation. So radiation weight coefficients have been introduced in order to take account of the relative biological effect of the various types of radiations. In accordance with the recommendations in FASSET Project (Pröhl et al. [21-7]), 10 and 3 weight coefficients are presumed for alpha radiation and for soft beta radiation, respectively, in Tier 1 assessments. In Tier 2 and 3 assessments, the default values are the same, though the user may change them.

Here in this tier, the program permits the user to select the animals and plants to be tested for the specific area. In case the program did not earlier comprise a proper animal/plant, the user can create it with its own known parameters. Moreover, the program will calculate not only the risk quotient but also the individual's total dose rate, which can then be compared with the earlier measured literature values (if any). The biological effects of radiation (essentially, the output of a chronic exposure situation) (measured within the specific population in the quantifiable values of the rate of occurrence of morbidity, mortality, reproductivity and mutation) relevant to the specific animal/plant can then be concluded from this.

When some activity concentration values are missing (which is especially frequent for the isotopes in the organism of animals and plants), a multi-step process is there to supplement them. CR (Concentration Ratio) is the relevant factor for both terrestrial and aquatic habitats, while the K_d distribution coefficient is designed to derive the missing water activity concentrations in wet habitats (in case the concentrations of the tested isotopes are known for the sediment only). Still, the program permits the user to check and set both the above parameters and any other calculation parameters of the dose rate. This latter means the dry mass % of the soil or the sediment, the above mentioned radiation weight coefficient and the residence factor. (Residence factor: the part of time that the organism spends in a specific place within its habitat; e.g. ground-level residence factor of saprophyte invertebrate: 0.3 and the residence time factor in the ground is 0.7).

Tier 3 assessment is designed to clarify potentially problematic situations. Different from Tiers 1 and 2, it does not end in a simple yes/no answer but makes probability calculations with the Monte Carlo simulation. This renders similar level of flexibility for the user at Tier 3 assessment as in Tier 2, in the sense that the user can edit and review the various parameters himself and use them in any later calculations. Moreover, the selection of the input data, the distribution coefficients, the concentration ratio values and the radiation weight coefficients allow the user to determine the probability distributions. This can be a default probability distribution or one set by the user.

Accordingly, the conclusion from the assessment of a specific situation will mostly differ from the conclusion at Tier 2 in the attachment of some probability distribution to the calculated external/internal/total dose rate values, with the due consideration of all the uncertainty factors. In other words, it shows the size of the dose rate the specific animal/plant is subject to from various sources, at specific percentile probability. Starting from this latter and using two built-in sensitivity test methods (PCC – Pearson Correlation Coefficient; and SRCC – Spearman Rank Correlation Coefficient), a more accurate filtering can be made as to which animal/plant is the most sensitive to changing which factor/coefficient.

21.2 CURRENT RADIATION EXPOSURE OF ANIMALS AND PLANTS IN THE ENVIRONMENT OF THE SITE

Radioactivity as a phenomenon and, as an outcome, ionizing radiation have been present ever since the formation of the Earth, so life, the animals and plants which formed later have always been exposed to its effect. The effect itself is the atomic absorption of the energy of radiation (or a part thereof) in the organism. This, however, does not necessary result in a physiological effect because e.g. recombination and certain repair mechanisms at the cell level mainly eliminate the primary effect. The billion years of life on Earth, the formulated biological diversity evidence that ionizing radiation, at the "ordinary" terrestrial level of radiation exposure, is not a risk quotient with any actual effect on animal and plant species or their populations somewhere living on the Earth, so it is basically considered to have a neutral effect.

Since radiation effect is connected not to the isotope itself but the emitted particle and the absorbed energy, the radiation exposure due to artificial radioactivity (e.g. power plant emission) does not evidently differ from natural exposure, in terms of its effect mechanism. This concludes that the two "sources" cannot in general be differentiated as regards their effect, on the one hand. When a new (planned) source is to be evaluated, the natural and presumably rather long ago existing radiation exposure of animals and plants native in habitats in the environment of that source should reasonably be assessed, on the other hand. This will provide a correct and objective benchmark for assessing the anticipated effect of the planned source.

The International Commission on Radiological Protection is also of the above opinion when, while applying a recommended reference level, it emphasizes the importance of comparison with the radiation level from the specific natural environment in its most recent radiological protection recommendation (ICRP, 2007) concerning animals and plants. Owing to the above and prior to estimating the radiological effect of Paks II on animals and plants, it seems reasonable to give a summary of our knowledge about natural radiation background in Paks and the deriving radiation exposure.

Moreover, it should also be taken into consideration that a reference level proposed for a specific habitat in the above quoted recommendation in relation to radiation exposure caused by human activity applies to all the anthropogenic sources there, so the effect of a planned new source should be assessed together with the existing ones. This concludes, in the current circumstances, that the residual radioactive pollution level originating from nuclear weapon tests (global fall-out) and the current effect of the Chernobyl fall-out on the environment of Paks must be assessed. The four nuclear power units operating for nearly 30 years now also add, due to their atmospheric and aquatic emissions, to the human radiation exposure of animals and plants. These three sources jointly produce the current artificial radiation exposure of animals and plants, which will be estimated in a separate chapter.

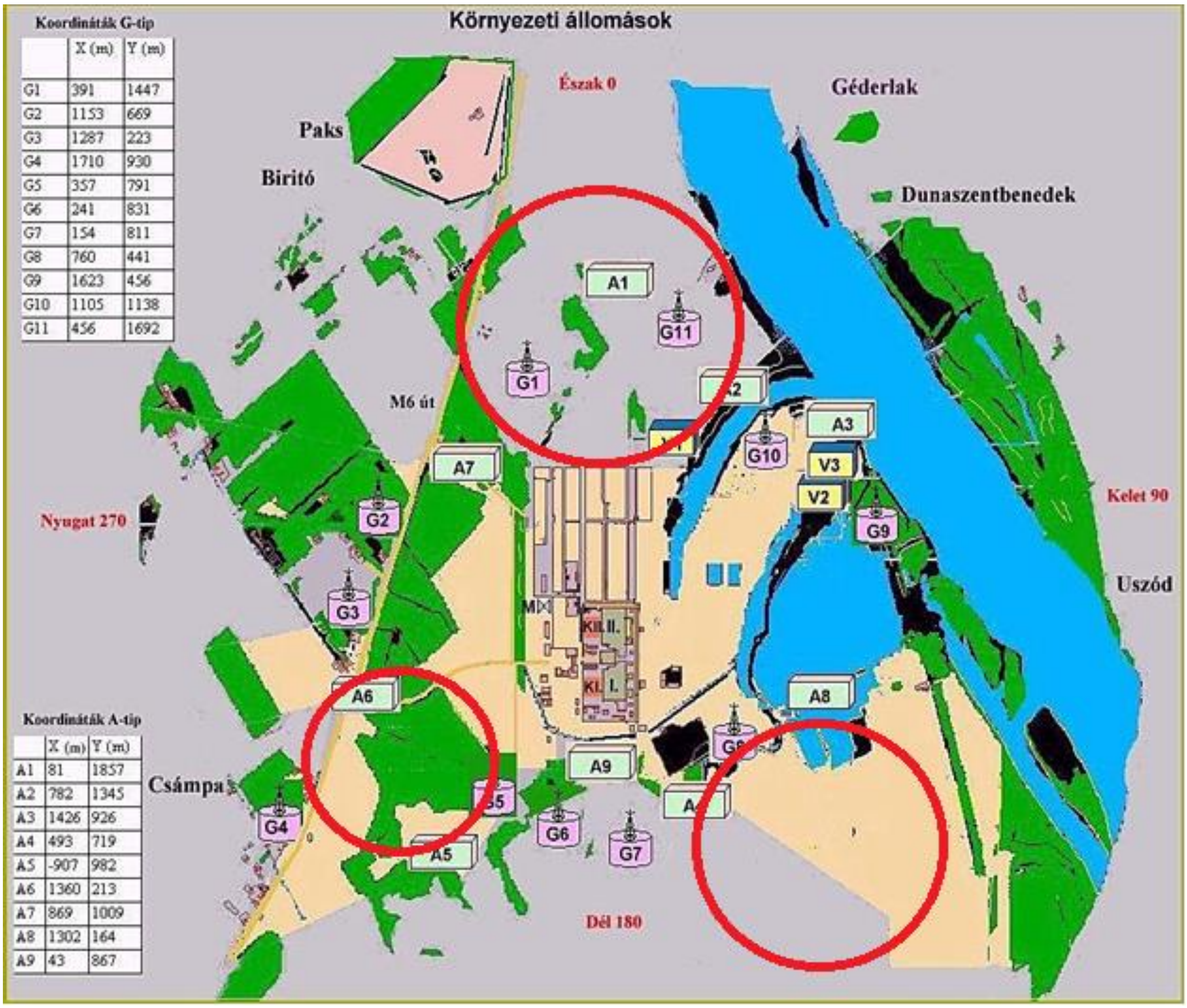
21.2.1 NATURAL RADIATION EXPOSURE OF ANIMALS AND PLANTS

TERRESTRIAL HABITATS

The source of ionizing radiation is the radioactive isotope of some element. This isotope can be within or in the body of the animal/plant subject to this effect. Accordingly, radiation exposure can be external and internal. In case of terrestrial animals and plants, the determinative external source is the radioactivity of the soil, so data should primarily be collected in this regard.

The Environment Monitoring Laboratory in Paks Nuclear Power Plant has from the very beginning been operating its so-called A-type measuring stations, all in approx. 1.5-2 km from the Power plant, in various directions. Since the database available for this environment covers a 20-25-year time span, the environments of 3 measuring stations were selected from among them (based on relevant agreements) to characterize the radiation exposure of terrestrial animals and plants and assess the natural and artificial base level.

Figure 21.2.1-1 shows the radiological protection monitoring network around the Power Plant.



környezeti állomások – environment monitoring sites, észak – North, nyugat – West, dél – South, kelet – East, koordináták – coordinates, A-tip – type A, G tip – type G

Figure 21.2.1-1: Nuclear environment monitoring sites around Paks Nuclear Power Plant

As shown in the figure, the planned expansion can be properly adjusted to this system because Stations A1, A2, A3 and A7 were in those times located around the Power Plant in a position whereby they could also monitor the environment of any new units to be installed directly in the northern vicinity of those operating at present. The red circles in the figure show the selected terrestrial habitats. The figure is also very expedient in illustrating that the tested terrestrial habitats almost cover the entire area between the river Danube and main road 6, i.e. the area encompassing the Power Plant. Since the existing and the planned units can primarily have an effect on these areas, when the animals and plants are to be tested in these locations, the level of radiation exposure to radioisotopes originating from Paks Nuclear Power Plant in any other locations further away from the Power Plant can only be lower than here, under ordinary operating conditions.

The measurement data from ***Stations A1, A6 and A8*** were analyzed for the natural radioactivity of the soil, and were later used to determine the typical U-series, Th-series and ^{40}K activity concentration in the areas.

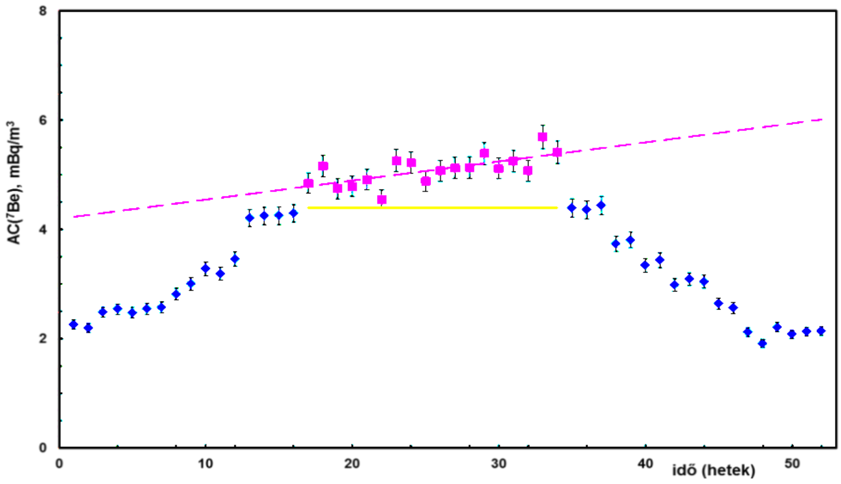
20 years' data line was available for ***Station A8***. The area of A8, a station installed on a land-bridge, is significantly filled, which is its unique characteristic. From among natural isotopes, the U and Th-series values were identical on the average (approx. 23 Bq/kg) – the data have a 30% standard deviation in both cases. This can actually conform to the approx. 10% value for measurement uncertainty, still, there were relatively frequent cases of measured values being significantly lower than the average in both natural radioactive series, and there again the concentration of ^{40}K (and ^{137}Cs) isotopes was also lower relative to the neighbouring data, which was rather conspicuous. These cases can for instance be interpreted by saying that sampling also reached a deeper soil layer.

The radioactivity of the soil (and grass) in the environment of ***Station A1*** installed almost exactly to the north of the Power Plant was tested on the basis of a protocol identical with that for **Station A6**, which resulted in a data set of the same size each. The majority of data from nearly 190 isotope-selective measurements was suitable for deriving the necessary basic data. The following statements can be made for the individual isotopes. ^{40}K activity concentration practically coincides with the value for the soil in the environment of **Station A6** (272 Bq/kg). The standard deviation of the data line (9%) was also favourable, staying within the uncertainty band for the individual measurement data. There were three among the measurement results available for the radioactive series of uranium that significantly differed from the others. Excluding them, the data set had normal distribution with an average 11.4 Bq/kg value, and the standard deviation (of 15%) is fully conformant with the specified measurement uncertainties. There was no deviating datum among the data for the Th-series, the average was (12.8 ± 2.4) Bq/kg. The concentration values for these two radioactive series are similarly identical with the values for the soil in the environment of **Station A6**. These conformities are not really surprising, as the locations are not very far from each other.

So, based on IERPMS data, the soil in the environment of the Power Plant is not homogeneous with regard to radioisotopes in the crust. The activity concentration of U and Th-series to the E and SE of the Power Plant is about two-fold of the value typical for the environment of Stations A1 and A6. This is supported by the measuring results of the layered soil samples taken in a test to assess the depth distribution of ^{137}Cs and ^{90}Sr isotopes and the current fall-out inventory. The 9 samples taken in the quarter in between east and south of the current emission point, except the one at the western corner of Lake Kondor, showed 30 Bq/kg activity concentration each, for the U and Th-series. The ^{40}K activity concentration varied between 350-470 Bq/kg in the same samples. This latter “variability” is presumed to be connected with agricultural cultivation.

The other determinative medium for terrestrial habitats is near-soil air which, even purely due to its density, has considerably less radioactivity than soil, the other key element of the living-space. Nevertheless, the existent radioisotope gets directly in the animal/plant by respiration (incorporation) which can result in any significant dose. A crucial element in the material of animals and plants is the carbon atom whose isotope with mass number 14 (radiocarbon) is naturally existent in the atmosphere, and, owing to the metabolism of plants, it is the source to radiation exposure in practically each living organism (1.71 nGy/h internal radiation exposure (ICRP 2008)). The same applies to tritium which is found in the air in the form of water. ^{7}Be isotope, developing in the uppermost atmosphere, gets close to the surface through deposition, and then it falls on the soil and the flora (fall-out). It can be easily detected due to its well-known 477 keV gamma radiation, so it is a permanent actor in the measuring results of nuclear environment monitoring. Due to continuous tests through air aerosol samples around Paks Nuclear Power Plant, a rather comprehensive database was developed to characterize the concentration of ^{7}Be.

The filters of the sample-catchers are renewed in Stations A1, A6 and A8 with weekly frequency, so 52 measurement data are generated each year. The laboratory in charge of the test has had satisfactory measuring capacity since 1994, so the generated samples are tested separately for each station. This resulted in nearly a thousand data by each station in 18 years. Weather, which is basically rather treacherous, greatly influences and determines the concentration of this atmospheric isotope. Consequently, it is hardly to be expected that long-term most probable activity concentration could be derived from just a few years' data, so the total data line for the 18 years was fully processed. The most important conclusions drawn from the above are shown in Figure 21.2.1-2.



Idő (hetek) - time (weeks)

Figure 21.2.1-2: Change in time in the air activity concentration of ^{7}Be in the environment of Paks Nuclear Power Plant.

The concentration values in the figure were, as seen, grouped in two. This rested on the fact that there was always a sudden concentration increase on the 17th week (end April) and a considerable decrease on the 35th week (early September) in the individually analyzed data lines. The straight line drawn on the purple data between these two points in time duly shows that when the warm season begins, ^{7}Be concentration increases steadily, though slowly. The level of beryllium stagnates, with identical activity concentration, for a few weeks directly before and after these times. In the figure, this is shown with a yellow line at 4,4 mBq/m^3 value. The period covered so far makes up half of the whole year. The lowest activity concentration value is around 2,2 mBq/m^3 and is typical for the ^{7}Be concentration value of near-soil air from around mid-November to mid-January.

The radiation exposure of plants will evidently be determined by higher activity concentration during the vegetation period. The average value was 5.2 mBq/m^3 in the tested area and it applies to each of the three terrestrial habitats. Due to continuous fall-out, ^{7}Be is accumulated, primarily on the leaves. Still, due to its relatively short half-time, diminution due to radioactive disintegration should also be taken into consideration to estimate the average surface activity concentration calculated for the entire vegetative period.

Concluding from the data analyses summarized above, soil and air in the environment of the Power Plant are characterized with the natural isotope concentrations summarized in Table 21.2.1-1

isotope	A1		A6		A8	
	soil	air	soil	air	soil	air
	Bq/kg	Bq/m^3	Bq/kg	Bq/m^3	Bq/kg	Bq/m^3
^{40}K	272		272		360	
^{210}Pb	11.4		11.4		24.1	
^{210}Po	11.4		11.4		24.1	
^{226}Ra	11.4		11.4		24.1	
^{228}Ra	12.8		12.8		22.7	
^{228}Th	12.8		12.8		22.7	
^{230}Th	11.4		11.4		24.1	
^{232}Th	12.8		12.8		22.7	
^{234}Th	11.4		11.4		24.1	
^{234}U	11.4		11.4		24.1	
^{238}U	11.4		11.4		24.1	
^{7}Be	6	0.0052	6	0.0052	8.7	0.0052
^{14}C		0.0437		0.0437		0.0437
T		0.015		0.015		0.015

Table 21.2.1-1: Activity concentrations of natural radionuclides in the tested terrestrial habitats.

The 14 default terrestrial animals and plants of the RAPs (Reference Animals and Plants) list were placed onto the designated habitats, and their radiation exposure was tested at Tier 2 in ERICA Program. The input data were the standard activity concentrations specified in the above table for the relevant environmental medium. Since ERICA Program did not count with the dose rate of natural isotopes to set the screening values (EMCL), it did not seem reasonable to set a risk quotient for the radiation exposure from these radionuclides, so only the external, internal and total dose rates deriving from them are provided.

During estimation, the default Concentration Ratio (CR) values were used for the reference organisms, however, the two isotopes that we have defined (^{40}K and ^{7}Be) were an exception: 1.0 CR value was used for all the reference organisms with both isotopes.

Just in a few cases did we deviate from the default residence factors:

- Birds, on default soil: 0.8 on soil and 0.2 in air, instead of 1.0;
- Flying insects, on default soil: 0.8 on soil and 0.2 in air, instead of 1.0;
- Saprophyte invertebrates (sow-bugs), in default soil: 0.7 in soil and 0.3 on soil, instead of 1.0;
- Mammal (rat), in default soil: 0.7 in soil and 0.3 on soil, instead of 1.0.

The percentile natural dry mass of the soil was considered 90%, which is rather in line with our relatively dry weather.

The dose rates for the environment of Stations A1-A6, i.e. the “western” areas were summarized in Table 21.2.1-2 A comparison between the data in columns 2 and 3 of the table concludes that, disregarding some highly “near-soil” animal and plant, external radiation exposure is approx. one magnitude smaller than internal. The last column in the table shows the total background radiation exposure of certain reference animals and plants due to natural radioactivity.

organism	**dose rate, µGy/h**		
	external	**internal**	**total**
amphibian	$1.65 \cdot 10^{-02}$	$7.45 \cdot 10^{-02}$	$\mathbf{9.11 \cdot 10^{-02}}$
bird	$1.59 \cdot 10^{-02}$	$9.43 \cdot 10^{-02}$	$\mathbf{1.10 \cdot 10^{-01}}$
bird’s egg	$1.65 \cdot 10^{-02}$	$8.85 \cdot 10^{-02}$	$\mathbf{1.05 \cdot 10^{-01}}$
saprophyte invertebrate	$3.59 \cdot 10^{-02}$	$1.80 \cdot 10^{-01}$	$\mathbf{2.16 \cdot 10^{-01}}$
flying insect	$1.52 \cdot 10^{-02}$	$1.79 \cdot 10^{-01}$	$\mathbf{1.94 \cdot 10^{-01}}$
snail	$1.67 \cdot 10^{-02}$	$1.14 \cdot 10^{-01}$	$\mathbf{1.30 \cdot 10^{-01}}$
grasses and herbs	$1.61 \cdot 10^{-02}$	$2.97 \cdot 10^{-01}$	$\mathbf{3.13 \cdot 10^{-01}}$
lichens and mosses	$9.31 \cdot 10^{-03}$	$2.94 \cdot 10^{00}$	$\mathbf{2.94 \cdot 10^{00}}$
big mammal (deer)	$8.85 \cdot 10^{-03}$	$7.00 \cdot 10^{-02}$	$\mathbf{7.89 \cdot 10^{-02}}$
small mammal (rat)	$3.40 \cdot 10^{-02}$	$6.51 \cdot 10^{-02}$	$\mathbf{9.91 \cdot 10^{-02}}$
reptilian	$1.60 \cdot 10^{-02}$	$8.08 \cdot 10^{-02}$	$\mathbf{9.67 \cdot 10^{-02}}$
bush	$1.54 \cdot 10^{-02}$	$1.52 \cdot 10^{-01}$	$\mathbf{1.67 \cdot 10^{-01}}$
soil invertebrate (worm)	$4.39 \cdot 10^{-02}$	$1.80 \cdot 10^{-01}$	$\mathbf{2.24 \cdot 10^{-01}}$
tree	$1.31 \cdot 10^{-02}$	$5.88 \cdot 10^{-02}$	$\mathbf{7.19 \cdot 10^{-02}}$

Table 21.2.1-2: Dose rate of natural radionuclides for reference animals and plants around Stations A1-A6.

As shown in the table, the total radiation exposure value is typically one-two tenth(s) µGy/h, i.e. roughly fifty hundredth of the reference level recommended by the International Commission on Radiological Protection. The only exceptions are lichen and moss which stand out with their nearly 3 µGy/h radiation exposure. The reason is presumed to be the lifestyle of these creatures and the technical problems faced during experimental work in connection with them. Namely, due to having no roots, lichens and mosses meet their minerals needs from the dust trapped from the air, so certain radionuclides in the crust might be accumulated in their body in major volumes. In the radioanalytical test on plants, performed in the frames of a technical project connected to this work, the measuring results (of e.g. the moss sample collected from the 5 different habitats) reached fairly high ^{210}Pb activity concentrations of 95.4, 426, 51.6, 392 and 195 Bq/kg. Additionally, the other members of the U-series had insignificant concentration in the samples, which suggests that the intake of primarily air-derived radon progenies causes the high ^{210}Pb concentration (which results in alpha radiating ^{210}Po progeny after disintegration). Moreover, in earlier experimental works that were intended to determine the concentration ratio of these small plants relevant to individual isotopes, removing the dust from the small funnel-shaped leaves evidently caused major difficulties (especially with the mosses). If this could not be done perfect, the value for CR was higher than realistic, which now leads to the overestimation of radiation exposure.

The natural radiological condition of animals and plants in the area to the E and SE of Paks Nuclear Power Plant is defined with the environmental medium radionuclide concentrations under heading "A8 station" in Table 21.2.1-1, as described above. The results are summarized in Table 21.2.1-3

organism	dose rate, µGy/h		
	external	internal	total
amphibian	$2.72 \cdot 10^{-02}$	$1.39 \cdot 10^{-01}$	$\mathbf{1.67 \cdot 10^{-01}}$
bird	$2.62 \cdot 10^{-02}$	$1.63 \cdot 10^{-01}$	$\mathbf{1.89 \cdot 10^{-01}}$
bird's egg	$2.71 \cdot 10^{-02}$	$1.53 \cdot 10^{-01}$	$\mathbf{1.80 \cdot 10^{-01}}$
saprophyte invertebrate	$5.91 \cdot 10^{-02}$	$3.66 \cdot 10^{-01}$	$\mathbf{4.25 \cdot 10^{-01}}$
flying insect	$2.54 \cdot 10^{-02}$	$3.63 \cdot 10^{-01}$	$\mathbf{3.89 \cdot 10^{-01}}$
snail	$2.74 \cdot 10^{-02}$	$2.24 \cdot 10^{-01}$	$\mathbf{2.52 \cdot 10^{-01}}$
grasses and herbs	$2.64 \cdot 10^{-02}$	$5.29 \cdot 10^{-01}$	$\mathbf{5.56 \cdot 10^{-01}}$
lichens and mosses	$1.55 \cdot 10^{-02}$	$6.09 \cdot 10^{00}$	$\mathbf{6.11 \cdot 10^{00}}$
mammal (deer)	$1.45 \cdot 10^{-02}$	$1.19 \cdot 10^{-01}$	$\mathbf{1.33 \cdot 10^{-01}}$
mammal (rat)	$5.58 \cdot 10^{-02}$	$1.12 \cdot 10^{-01}$	$\mathbf{1.68 \cdot 10^{-01}}$
reptilian	$2.63 \cdot 10^{-02}$	$1.45 \cdot 10^{-01}$	$\mathbf{1.72 \cdot 10^{-01}}$
bush	$2.53 \cdot 10^{-02}$	$2.76 \cdot 10^{-01}$	$\mathbf{3.02 \cdot 10^{-01}}$
soil invertebrate (worm)	$7.23 \cdot 10^{-02}$	$3.64 \cdot 10^{-01}$	$\mathbf{4.37 \cdot 10^{-01}}$
tree	$2.15 \cdot 10^{-02}$	$8.25 \cdot 10^{-02}$	$\mathbf{1.04 \cdot 10^{-01}}$

Table 21.2.1-3: Dose rate of natural radionuclides on the reference organisms, around Station A8.

The resulting, typically 0.2-0.5 µGy/h total background radiation exposure is now just twentieth/fiftieth of the 10 µGy/h screening value recommended by ICRP. Lichens and mosses evidently have an outstanding value here, too, compared to the other living organisms.

We have so far estimated the radiation exposure of reference animals and plants in the terrestrial ecosystems at Tier 2 in ERICA Tool, and for this we greatly relied on the concentration ratios built in the program. These factors were discussed in the professional work underlying this Environmental Impact Assessment in detail, and in general the conclusion was that, due to the rather big volume of the individual values and to the lack of a lot of data, the use of these factors results in major uncertainty in estimating radiation exposure. Moreover, we have also shown that a considerable ratio of the species earlier assigned by the biologist experts for test can be matched with one of the reference creatures in the Tool. Owing to these two factors, we will not hereinafter repeat our former calculations for the designated terrestrial species, invariably using the activity concentrations for the main environmental media only, but will use the isotope concentration data available for the biological samples representing the tested species and measured in this Project and will use them directly as well to calculate internal radiation exposure. Here we should note that the above-mentioned concentration ratios are actually used to calculate the radioactive material content of the individual species from the activity concentrations known for the environmental elements, which is practically inevitable for calculating internal radiation exposure.

In line with the above, the subsequent and total radiation exposure was measured for the animals and plants listed in the tables with a summary of the individual species, the species earlier recommended by the biologist experts for test in the terrestrial ecosystems (for quite many of which we had isotope concentration data from measuring the individuals actually living there), and these were now used in the estimation. For the isotopes and creatures with no underlying local data, we naturally used the necessary concentration ratios.

It is also worth mentioning that the designated species cannot in every case be easily substituted with corresponding reference species because although the program permits the free use of concentration ratios "managing" the lifestyle/physiology of the specific species, dose conversion factors significantly depend on the physical size of the animal/plant. In regard to this, ERICA Tool permits the creation of a new, so far non-existing organism, which decisively means the production of DCC values conformant with the specific size and their relation to the relevant animal/plant. Exploiting this possibility, some organisms missing from the Tool but intended for testing were produced in this work.

The 3 tables hereinafter summarize the natural radiation exposure of the designated species in the terrestrial habitats in the environment of Stations A1, A6 and A8. So these dose rate values show a so-called background radiation level existing regardless of man's presence and activity, expressed in the absorbed dose rate. The star (*) beside some marked organisms in the tables means that the concentration ratio for the specific species was used only for radioisotopes not measured in the specific biota. This in most of the cases applied to two long half-time isotopes of thorium.

organism	dose rate, µGy/h		
	external	internal	total
Bombus agrorum (humble-bee)	$1.45 \cdot 10^{-02}$	$1.83 \cdot 10^{-01}$	**$1.98 \cdot 10^{-01}$**
earthworm	$4.39 \cdot 10^{-02}$	$1.80 \cdot 10^{-01}$	**$2.24 \cdot 10^{-01}$**
snail*	$1.67 \cdot 10^{-02}$	$1.24 \cdot 10^{+00}$	**$1.25 \cdot 10^{+00}$**
frog	$1.65 \cdot 10^{-02}$	$7.45 \cdot 10^{-02}$	**$9.11 \cdot 10^{-02}$**
Lacerta agilis (lizard)	$1.67 \cdot 10^{-02}$	$8.05 \cdot 10^{-02}$	**$9.71 \cdot 10^{-02}$**
wild-duck	$1.59 \cdot 10^{-02}$	$9.43 \cdot 10^{-02}$	**$1.10 \cdot 10^{-01}$**
rat	$3.40 \cdot 10^{-02}$	$6.51 \cdot 10^{-02}$	**$9.91 \cdot 10^{-02}$**
Sus scrofa (wild-boar)	$1.04 \cdot 10^{-02}$	$6.94 \cdot 10^{-02}$	**$7.98 \cdot 10^{-02}$**
lichen/moss*	$3.90 \cdot 10^{-03}$	$4.88 \cdot 10^{00}$	**$4.89 \cdot 10^{00}$**
Asclepias syriaca* (silkweed)	$1.61 \cdot 10^{-02}$	$1.21 \cdot 10^{-01}$	**$1.37 \cdot 10^{-01}$**
Solidago gigantea* (tall golden rod)	$1.61 \cdot 10^{-02}$	$2.01 \cdot 10^{-01}$	**$2.17 \cdot 10^{-01}$**
Pinus sylvestris* (scots pine)	$1.31 \cdot 10^{-02}$	$4.02 \cdot 10^{-01}$	**$4.15 \cdot 10^{-01}$**

Table 21.2.1-4: Natural background radiation level for the designated species, in the environment of Station A1.

Column 4 in Table 21.2.1-4 summarizes external and internal radiation exposure. The values here are, disregarding 2 species, within a rather confined range, broadly reaching tenth µGy/h. This is 1-4% of the reference level recommended by ICRP, so it is expressly low. One of the two exceptions is the snail. The value in the "total" column in the table is ten-fold of the level typical for the majority of the species. Still, the table shows that the dose rate from external sources does not differ from the average in this organism, either. The big load comes from an internal source which is due to the ^{226}Ra and ^{210}Po isotopes. Big radium intake is obviously due to the alkali-earth metal need for building the lime content of the shell. The high ^{210}Po dose is presumably consequent upon the outstanding ^{210}Pb value in the measured snail. The other exception is the moss whose considerably higher than average radiation exposure has already been discussed above. The dose rate value here for the tested moss is calculated from the actually measured isotope concentrations and it exceeds the figure estimated with the concentration ratio of ERICA Tool by nearly a factor of two, which confirms that determining and estimating the radiation exposure of certain species is subject to major uncertainty.

Table 21.2.1-5 and Table 21.2.1-6 summarize the dose rate results (derived similar as above) of the tested species in the habitat around Stations A6 and A8. The comments for Station A1 could practically be repeated here to assess the data here. The moss here should be especially mentioned, given that its total dose rate calculated from the isotope concentrations significantly exceeds 10 µGy/h, the figure recommended as a reference level. This also underlies the outstanding importance of the comments made by the International Commission on Radiological Protection with regard to comparing natural radiation background and radiation exposure caused by human activity.

As a summary concerning the background radiation exposure of terrestrial animals and plants living in the environment of the Power Plant, the size of this exposure is below 0.5 µGy/h in the majority of the species, though creatures accumulating lime and mosses have a considerably higher value that can even exceed the reference level recommended by ICRP. Moreover, the radiation exposure of the specific species might in many cases be underestimated by a factor of two or three if we do not use location-specific concentration ratios to calculate internal radiation exposure.

organism	dose rate, µGy/h		
	external	internal	total
Bombus agrorum (humble-bee)	$1.45 \cdot 10^{-02}$	$1.83 \cdot 10^{-01}$	**$1.98 \cdot 10^{-01}$**
earthworm	$4.39 \cdot 10^{-02}$	$1.80 \cdot 10^{-01}$	**$2.24 \cdot 10^{-01}$**
snail*	$1.67 \cdot 10^{-02}$	$1.24 \cdot 10^{00}$	**$1.25 \cdot 10^{00}$**
frog	$1.65 \cdot 10^{-02}$	$7.46 \cdot 10^{-02}$	**$9.11 \cdot 10^{-02}$**
Lacerta agilis (lizard)	$1.67 \cdot 10^{-02}$	$8.05 \cdot 10^{-02}$	**$9.72 \cdot 10^{-02}$**
wild-duck*	$1.59 \cdot 10^{-02}$	$5.62 \cdot 10^{-02}$	**$7.21 \cdot 10^{-02}$**
rat	$3.40 \cdot 10^{-02}$	$6.51 \cdot 10^{-02}$	**$9.91 \cdot 10^{-02}$**
Sus scrofa (wild-boar)*	$1.04 \cdot 10^{-02}$	$1.58 \cdot 10^{-01}$	**$1.69 \cdot 10^{-01}$**
lichen/moss*	$3.90 \cdot 10^{-03}$	$1.64 \cdot 10^{+01}$	**$1.64 \cdot 10^{+01}$**
Asclepias syriaca* (silkweed)	$1.61 \cdot 10^{-02}$	$9.11 \cdot 10^{-02}$	**$1.07 \cdot 10^{-01}$**
Solidago gigantea* (tall golden rod)	$1.61 \cdot 10^{-02}$	$2.04 \cdot 10^{-01}$	**$2.20 \cdot 10^{-01}$**
Pinus sylvestris* (scots pine)	$1.31 \cdot 10^{-02}$	$3.81 \cdot 10^{-01}$	**$3.94 \cdot 10^{-01}$**

Table 21.2.1-5: Natural background radiation level for the designated species, in the environment of Station A6.

organism	dose rate, µGy/h		
	external	internal	total
Bombus agrorum (humble-bee)	$2.39 \cdot 10^{-02}$	$3.70 \cdot 10^{-01}$	**$3.94 \cdot 10^{-01}$**
earthworm	$7.23 \cdot 10^{-02}$	$3.64 \cdot 10^{-01}$	**$4.37 \cdot 10^{-01}$**
snail	$2.74 \cdot 10^{-02}$	$2.24 \cdot 10^{-01}$	**$2.52 \cdot 10^{-01}$**
frog	$2.72 \cdot 10^{-02}$	$1.39 \cdot 10^{-01}$	**$1.67 \cdot 10^{-01}$**
Lacerta agilis (lizard)	$2.74 \cdot 10^{-02}$	$1.47 \cdot 10^{-01}$	**$1.74 \cdot 10^{-01}$**
wild-duck*	$2.62 \cdot 10^{-02}$	$5.65 \cdot 10^{-02}$	**$8.26 \cdot 10^{-02}$**
rat	$5.58 \cdot 10^{-02}$	$1.12 \cdot 10^{-01}$	**$1.68 \cdot 10^{-01}$**
deer	$1.45 \cdot 10^{-02}$	$1.19 \cdot 10^{-01}$	**$1.33 \cdot 10^{-01}$**
Sus scrofa (wild-boar)*	$1.71 \cdot 10^{-02}$	$1.58 \cdot 10^{-01}$	**$1.76 \cdot 10^{-01}$**
lichen/moss*	$5.16 \cdot 10^{-03}$	$4.01 \cdot 10^{00}$	**$4.02 \cdot 10^{00}$**
Asclepias syriaca* (silkweed)	$2.66 \cdot 10^{-02}$	$1.80 \cdot 10^{-01}$	**$2.07 \cdot 10^{-01}$**
Solidago gigantea* (tall golden rod)	$2.66 \cdot 10^{-02}$	$2.44 \cdot 10^{-01}$	**$2.71 \cdot 10^{-01}$**
Pinus sylvestris* (scots pine)	$2.15 \cdot 10^{-02}$	$4.39 \cdot 10^{-01}$	**$4.61 \cdot 10^{-01}$**

Table 21.2.1-6: Natural background radiation level for the designated species, in the environment of Station A8.

AQUATIC HABITATS

In terms of aquatic habitats, the determinative living-space is the water itself. Water is although known as a good solvent, still, natural waters contain solutes from the crust in usually small volumes only. This applies especially to the U and Th-series as they are mainly found in insoluble minerals, in crystalline form, or on clayey or clay-like minerals, strongly adsorbed. Consequently, their activity concentration in waters is 3-4 magnitudes smaller than in soil. Owing to this fact, generally just a few measurement data are available for natural waters, which applies to the aquatic habitats that can be tested in the environment of Paks. Still, the solute originally comes from the solid crust material bordering the water (mainly from the sediment), so if its radioactivity is known, activity concentration in water can be calculated in the knowledge of the so-called distribution coefficient (K_d) of the specific element.

Three aquatic habitats may be of interest in the environment of Paks Nuclear Power Plant, due to emissions from the Power Plant. Primarily the collector of fluid emissions, the river Danube, including especially its some 100 m long section after the Hot Water Canal. Although the culvert itself is an industrial facility, the animals and plants have, even if in limited diversity, long occupied it, or at least its bank. Additionally, Lake Kondor which is an ox-bow ancient dead branch but can have periodical connection with the Hot Water Canal through the artificial fish ponds can also be considered a separated habitat. From among these three habitats, the focus should obviously be primarily on the Danube as it is a collector for emissions from the existing and the planned Power Plant.

Here again, we intended to have access to various data inevitable for estimating the radiation exposure (deriving from natural radioactivity) of aquatic animals and plants firstly from the archived measuring results of decades-long operational and official control tests. As regards bed sediment, we managed to collect a satisfactory number of activity concentration data for each of the three habitats, which resulted in the isotope inventory introduced below for the individual aquatic habitats.

HOT WATER CANAL

Data on sediment radioactivity are available from the IERPMS database only. As regards ^{40}K and the isotopes of the U and Th-series, the sludge of the culvert seems to be a definitely clayey sediment. Based on the data we considered analyzable, their activity concentration can be taken into account with dry material values of 518, 35.4 and 34.2 Bq/kg, respectively. The 10, 18 and 14% standard deviation of the individual data lines is commensurate with the measurement uncertainties, considering the known measuring time and the sampled volume. The concentration data for ^{7}Be vary within a rather broad range (4-102 Bq/kg), which is not surprising because owing to its relatively short half-time it can be present just in the topmost, perhaps even thinner than a mm layer of the sediment, so its existence in a specific place is strongly influenced by sediment movement in connection with changes in water flow conditions.

DANUBE SECTIONS AFTER THE HOT WATER CANAL

According to IERPMS measuring results from the past 17 years, the activity concentration values of ^{40}K, the U and Th-series refer to a bed sediment of the same composition as seen in the Hot Water Canal. Based on the data, the typical activity concentration of the sediment for the radioisotopes in the crust is 472, 33.8 and 33.0 Bq/kg dry material, respectively. Experience-based deviation in the individual isotopes is somewhat bigger than in the case of the Hot Water Canal. This sediment might be related to its non-identical by depth mineral composition and the difficult reproducibility of sampling (regarding its depth). The observation whereby the individual ^{40}K and U (and Th) data pairs were rather strongly correlated in their deviation from the average supports this idea: the U and Th value of the samples with 6-700 Bq/kg ^{40}K activity concentration is around ~40 Bq/kg, whereas just 20-30 Bq/kg U and Th concentration goes with the 3-400 Bq/kg ^{40}K value. This can be interpreted with a change in the ratio of the sand (quartz) sampled. However, the size distribution of this latter is typically coarser, so it is found in major volumes in the lower layers of the bed sediment. The concentration data for ^{7}Be also vary within a relatively wide band (5-63 Bq/kg). The explanation may be similar to the comments for the Hot Water Canal.

LAKE KONDOR

Lake Kondor has been integrated in the operating control system of Paks Nuclear Power Plant since 1995, mainly due to regular (once a year) measurements for the radioactivity of the lake sediment. In addition to power plant isotopes, plenty of data were available also for the natural isotopes, from the results of these measurements. But the analyses pointed out that the measurements were mainly taken on samples of wet/humid condition, so after all just a restricted data set proved to be suitable to characterize the crust isotope concentration of the sediment. Concluding from this, the base of the lake coincides in its composition with the soil in Stations A1 and A6. As regards the ^{7}Be data, its activity concentration in the sediment is surprisingly almost insignificantly inconsiderable in this dead water, though no redeposition due to current is to be expected here. The phenomenon observed must be due to the retarding effect of the considerable floating organic matter content of the lake.

As mentioned above, the data set available for the water bodies themselves is rather restricted in the case of the radioisotopes at issue. The operational and official controls were logically targeted at the radioactive isotopes from the Power Plant. From sampling to measurement, the circumstances depend on the duly sensitive statement of such isotopes, so a datum for some U or Th-series member will be available rarely only and at random. There are altogether two exceptions, both occurring in nature, too: tritium and ^{40}K.

As regards tritium, it occupies the first place considering total annual emitted activity (within the fluid radioactive emission of the Power Plant), so the live waters tested in this work are logically regularly monitored for tritium, consequently, there are a lot of data available. But the question is whether we can separate it from its natural form. One of the options for this separation is to complete the analysis with a set of official measurements taken from regular tests in the section of the Danube before Paks Nuclear Power Plant, and to rely on the fact that the water of the Hot Water Canal practically comes from the Danube as well.

Based on the 12 years' data lines reviewed, the section of the Danube before and after the Hot Water Canal equally reaches 2.9 Bq/l tritium concentration with 49% standard deviation. This value is approx. twice as big as in highly exact regular measurements of national precipitations. There can be two reasons for the difference: one option can be the tritium concentration increasing effect from the emission of nuclear power plants using the water of the feeders to the Danube abroad, on the one hand. The liquid scintillation technique used in the tests signals not much above the background for such small concentrations (which might also be the reason for the major experimental deviation), so it does not really provide a reliable result, on the other hand. Since no other measurement data were available, we used the above value for the calculations. This on the one hand is a conservative approach and on the other hand it will not practically influence the resulting total radiation exposure, given that this is an isotope with nearly insignificantly small disintegration energy.

The IERPMS database contained some data for tritium in the water of Lake Kondor for the past 14 years. The 56 samplings resulted in 45 definite values for the activity concentration of tritium, which is typically a few Bq/l. Although no measurement uncertainty was stated for the data, the information concerning the applied measurement technique and the resulting concentrations foretell an approx. 70-80% measurement uncertainty for the data. The 11 cases below the indicating limit suggested that the (kh) value is not much less than the lower (in value) quarter of the data set, so these data are presumed to be indeed considerably uncertain. The cases below the indicating limit decisively took place in the most recent years, which is evidently not by mere chance. Moreover, it is also clear that higher concentration values mainly fall in the period from the second half of 1999 to the end of 2004. So it is not impossible that there is a slow but definite (with the lapse of time) decrease of tritium in the water of the lake, which might be correlated with the tritium level that has increased due to nuclear weapon tests. The fact that water supply comes from precipitation only in part (given that water is discharged here from the Cold Water and the Hot Water Canals from time to time) must also play a role in changing the concentration value. Relying on data from the past 4 years and considering that the indicating limit in the relevant period is approx. 10% above the average Hungarian precipitation-tritium concentration, (1.8 ± 0.7) Bq/l concentration is considered the standard tritium concentration of Lake Kondor.

Potassium is present in every live water, even if in small concentration only, so its isotope with mass number 40 can be determined under proper measurement conditions (primarily: low background). However, a problem will be encountered if the water sample contains a significant volume of floating crust material because this will distort the result. After an analysis of the IERPMS data from the past few years, we received an average value of e.g. 91 mBq/l (± 9 %) for the activity concentration of ^{40}K. The average of the K concentration of the 3 Paks water samples taken by us in 2013 in the frame of these tests was 3 mg/l, an equivalent of 86 mBq/l, which supports the above. Following from the two independent tests, we can use a 90 mBq/l value for the water of the Danube. As regards the Hot Water Canal, the activity concentration of the water can also be slightly higher (conformant with the ^{40}K concentration of the sediment which is somewhat higher than in the Danube), given that it is in balance with the sediment in accordance with the distribution coefficient. So here we count with a round value of 100 mBq/l. Since, regarding Lake Kondor, no data are available for the ^{40}K concentration of the water, this shortage was made up for again by calculating with the distribution coefficient, and activity concentration was set at 55 mBq/l.

The lack of data relevant to the U and Th-series members as mentioned above was partly supplemented with the results (received from the South Transdanubian Inspectorate for Environment, Nature and Water) of a radiological test on 40 litres of filtered water each sampled at the Mohács section of the Danube. The 16 analyses received cover the period between 2007-2012. The result from the gamma spectrometry measurements included natural radioisotope concentrations as well, and the measurement uncertainty of the results was typically 5-18%. Based on an in-depth analysis of the above results, the following data were presumed to be the probable, as maximal values, regarding the natural isotope composition of the Danube water: ^{228}Ra (1.3 ± 0.5) mBq/l, ^{228}Th (1.1 ± 0.5) mBq/l, ^{226}Ra (3.9 ± 0.5) mBq/l. The waters of both the Danube and the Hot Water Canal were regularly sampled in 2012-13 in the frames of this work, connected to the test on biological samples. The long-term gamma spectrometry measurements on samples generated from the 30 l filtered water (each) after volume decrease led to additional data relevant to the above isotopes and the ^{238}U isotope. We have supplemented the so far presented environmental medium concentration data required for estimating the background radiation exposure of aquatic animals and plants with these data, and have done the dose rate calculations with the values summarized in Table 21.2.1-7

isotope	Lake Kondor		Hot Water Canal		Danube	
	sludge	Water	sludge	Water	sludge	water
	Bq/kg	mBq/l	Bq/kg	mBq/l	Bq/kg	mBq/l
^{40}K	272	55	518	100	472	90
^{210}Pb	11.4	2.5	35.4	4.2	33.8	4.2
^{210}Po	11.4	2.5	35.4	4.2	33.8	4.2
^{226}Ra	11.4	2.5	35.4	4.2	33.8	4.2
^{228}Ra	12.8	0.7	34.2	1.4	33.0	1.4
^{228}Th	12.8	0.5	34.2	1.1	33.0	1.1
^{230}Th	11.4	-	35.4	-	33.8	-
^{232}Th	12.8	-	34.2	-	33.0	-
^{234}Th	11.4	-	35.4	-	33.8	-
^{234}U	11.4	-	35.4	10.5	33.8	10.5
^{238}U	11.4	-	35.4	10.5	33.8	10.5
^{7}Be	2.6	0.1	29	1	17.5	1
^{3}H		1 800		2 900		2 900

Table 21.2.1-7: Activity concentrations of natural radionuclides in aquatic habitat.

The 11 default aquatic animals and plants of the RAPs list were placed onto the designated habitats and their radiation exposure was studied at Tier 2 (ERICA Program). The input data were the standard activity concentrations specified in the above table for the relevant environmental medium. Since ERICA Program did not count with the dose rate of natural isotopes to set the screening values, it did not seem reasonable to set a risk quotient for radiation exposure from these radionuclides, so only the external, internal and total dose rates deriving from them are provided.

During estimation, the default Concentration Ratio (CR) values were used for the reference organisms, however, the two isotopes that we have defined (^{40}K and ^{7}Be) were an exception: CR = 1.0 value was used for all the reference organisms with both isotopes. Just in a few cases did we deviate from the default residence factors:

- Amphibians, in default water: 0.7 in water and 0.3 on water surface, instead of 1.0;
- Bird, in default water: 0.5 in water and 0.5 on water surface, instead of 1.0;
- Mammal, in default water: 0.5 in water and 0.5 on water surface, instead of 1.0;
- Vascular plant, on the surface of default sediment: 0.7 on the surface of the sediment and 0.3 in water, instead of 1.

The percentile natural dry mass of the sludge was set at 50%.

The results from running the program are summarized in Table 21.2.1-8, Table 21.2.1-9, and Table 21.2.1-10 for the individual habitats. The total dose rate in the last column of the tables should be considered the background radiation exposure of the individual organisms. Immediately conspicuous, the Danube and the Hot Water Canal as habitats do not practically differ regarding radiation exposure caused, given that there is just a minimal difference in radioactive concentrations. To the contrary, radiation exposure typical of the animals and plants at Lake Kondor is double the average, though terrestrial radioactivity there is at a lower level. This obviously calls for some explanation and assessment, which is provided hereinafter.

Aquatic animals and plants are highly variable regarding the ratios of external and internal radiation exposure. Whereas the groundfish shows the same ratio as with terrestrial animals and plants, external radiation exposure is practically negligible versus internal in the case of the pelagic fish. This is mainly caused by water as a radiation absorbent. Those typically living "distant" from the bed are almost only exposed to radiation from the radioactive materials in their organisms, due to the radiation screening effect of the extensive water body. This is the reason for the insignificantly low external radiation exposure of phytoplankton, zooplankton and the amphibians. The reason for the value for birds, which is nearly one magnitude less than in the above cases, is that these creatures spend half of their life on the surface of the water or in the air.

organism	dose rate, µGy/h		
	external	internal	total
amphibian	$1.33\ 10^{-05}$	$1.30\ 10^{-01}$	**$1.30\ 10^{-01}$**
benthic fish	$2.90\ 10^{-02}$	$1.43\ 10^{-01}$	**$1.73\ 10^{-01}$**
bird	$9.81\ 10^{-06}$	$1.49\ 10^{-01}$	**$1.49\ 10^{-01}$**
shellfish	$3.29\ 10^{-02}$	$5.95\ 10^{00}$	**$5.98\ 10^{00}$**
crab	$6.42\ 10^{-02}$	$2.46\ 10^{00}$	**$2.53\ 10^{00}$**
snail	$3.84\ 10^{-02}$	$3.57\ 10^{00}$	**$3.61\ 10^{00}$**
insect larva	$1.28\ 10^{-01}$	$2.46\ 10^{00}$	**$2.59\ 10^{00}$**
mammal	$9.00\ 10^{-06}$	$1.40\ 10^{-01}$	**$1.40\ 10^{-01}$**
pelagic fish	$1.33\ 10^{-05}$	$1.43\ 10^{-01}$	**$1.43\ 10^{-01}$**
phytoplankton	$1.99\ 10^{-04}$	$5.42\ 10^{00}$	**$5.42\ 10^{00}$**
vascular plant	$4.05\ 10^{-02}$	$3.42\ 10^{00}$	**$3.46\ 10^{00}$**
zooplankton	$3.82\ 10^{-05}$	$4.60\ 10^{00}$	**$4.60\ 10^{00}$**

Table 21.2.1-8: Danube – dose rate of natural radionuclides on the reference organisms.

Likewise remarkable, animals and plants can definitely be grouped in two, based on their radiation exposure. The radiation exposure of fishes, aquatic birds, amphibians and aquatic mammals can be characterized with the dose rate typical of terrestrial animals and plants. All the other aquatic creatures form a separate and populous group, with approx. 20-fold value of the previous. In the case of shellfish, crab and snail, the radium accumulated with plenty of alkali-earth metal intaken to build the lime-based casing (house) evidently plays a major role. This is particularly eye-catching with the results for the shellfish, where there is not even any difference between the Danube and Lake Kondor.

organism	dose rate, µGy/h		
	external	internal	total
amphibian	$1.42\ 10^{-05}$	$1.30\ 10^{-01}$	**$1.30\ 10^{-01}$**
benthic fish	$3.08\ 10^{-02}$	$1.43\ 10^{-01}$	**$1.74\ 10^{-01}$**
bird	$1.04\ 10^{-05}$	$1.49\ 10^{-01}$	**$1.49\ 10^{-01}$**
shellfish	$3.49\ 10^{-02}$	$5.95\ 10^{00}$	**$5.98\ 10^{00}$**
crab	$6.88\ 10^{-02}$	$2.46\ 10^{00}$	**$2.53\ 10^{00}$**
snail	$4.09\ 10^{-02}$	$3.57\ 10^{00}$	**$3.61\ 10^{00}$**
insect larva	$1.37\ 10^{-01}$	$2.46\ 10^{00}$	**$2.60\ 10^{00}$**
mammal	$9.58\ 10^{-06}$	$1.40\ 10^{-01}$	**$1.40\ 10^{-01}$**
pelagic fish	$1.42\ 10^{-05}$	$1.43\ 10^{-01}$	**$1.43\ 10^{-01}$**
phytoplankton	$2.03\ 10^{-04}$	$5.42\ 10^{00}$	**$5.42\ 10^{00}$**
vascular plant	$4.34\ 10^{-02}$	$3.42\ 10^{00}$	**$3.46\ 10^{00}$**
zooplankton	$4.14\ 10^{-05}$	$4.60\ 10^{00}$	**$4.60\ 10^{00}$**

Table 21.2.1-9: Background radiation exposure of reference organisms in the Hot Water Canal.

Following from our search for the reason for the beforehand indicated and unexpectedly higher values for Lake Kondor, the following comments are made. Whereas some activity concentrations (applicable to water) were available for each of the potential crust isotopes, disregarding some thorium isotopes, in the case of the Danube and the Hot Water Canal, no measured value was available for uranium at Lake Kondor. In such a case, as described above, ERICA Program generates the value with the K_d value in its database. This obviously differs from the value typical of this sediment by about one magnitude and this is why it distorts the calculated dose rate value. Clearly enough, this distorting effect influences the dose rate data for all the animals and plants located here, but the size of this impact cannot be accurately estimated because the activity concentration differences in the sediment of the individual tested aquatic habitats can basically be traced back to differences in the composition of the mineral and the rock, and we do not have any relevant detailed information. This experience confirms that although today each missing datum can apparently be made up for by model calculations, however, this supplementation will not certainly produce a realistic result. The only control (and, simultaneously, the avoidance of any necessary supplementation) can be the experimental specification of the determinative and most important data. As regards the internal dose rate, this means the isotope-specific test of some individuals (directly coming from the habitat at issue) of the relevant species. These results actually require the use of only and exclusively the relevant DCC values (simple multiplication) to calculate the searched dose rate.

organism	dose rate, µGy/h		
	external	internal	total
amphibian	7.97 10^{-06}	4.26 10^{-01}	**4.26 10^{-01}**
benthic fish	1.27 10^{-02}	4.38 10^{-01}	**4.50 10^{-01}**
bird	5.83 10^{-06}	4.44 10^{-01}	**4.44 10^{-01}**
shellfish	1.45 10^{-02}	5.62 10^{00}	**5.64 10^{00}**
crab	3.04 10^{-02}	7.23 10^{00}	**7.26 10^{00}**
snail	1.71 10^{-02}	4.20 10^{00}	**4.22 10^{00}**
insect larva	6.04 10^{-02}	7.23 10^{00}	**7.29 10^{00}**
mammal	5.34 10^{-06}	4.35 10^{-01}	**4.35 10^{-01}**
pelagic fish	7.94 10^{-06}	4.38 10^{-01}	**4.38 10^{-01}**
phytoplankton	1.27 10^{-03}	4.49 10^{00}	**4.50 10^{00}**
vascular plant	1.89 10^{-02}	3.54 10^{01}	**3.55 10^{01}**
zooplankton	2.33 10^{-05}	3.24 10^{00}	**3.24 10^{00}**

Table 21.2.1-10: Background radiation exposure of reference organisms in Lake Kondor habitat.

Due to the above, the values relevant to aquatic animals and plants at Lake Kondor in Table 21.2.1-10 are rather conservative. The actual background radiation exposure of those living here is significantly smaller and they hardly reach that of the creatures in the Danube.

The animals and plants in the three aquatic habitats discussed here and studied in the technical tests underlying this study were also included in the biological tests. Apart from the direct specification of radiation exposure from artificial isotopes, this provides an opportunity, with a satisfactory volume of samples, to clarify the above discussed problem, provided the measurements and the necessary radiochemical dissociations are subordinated to this aim. The animal and plant samples collected from aquatic habitats in the indicated period reached a volume whereby the concentrations of natural isotopes typical of the species could also be specified. The measurements led to the results summarized in Table 21.2.1-11, concerning the individual species and habitats.

organism	dose rate, µGy/h		
	external	internal	total
sheat-fish (Danube after V2)	2.77 10^{-02}	1.36 10^{-01}	**1.64 10^{-01}**
orfe (Danube after V2)	1.41 10^{-05}	1.11 10^{-01}	**1.11 10^{-01}**
orfe (Lake Kondor)	8.37 10^{-06}	1.11 10^{-01}	**1.11 10^{-01}**
shellfish (Danube after V2)	3.23 10^{-02}	4.56 10^{-01}	**4.89 10^{-01}**
water-snail (Danube after V2)	3.76 10^{-02}	3.40 10^{00}	**3.44 10^{00}**
pondweed (Danube after V2)	1.87 10^{-05}	4.74 10^{-01}	**4.74 10^{-01}**
green alga (Danube after V2)	4.32 10^{-05}	4.84 10^{00}	**4.84 10^{00}**
green alga (V2)	4.70 10^{-05}	2.75 10^{00}	**2.75 10^{00}**
carp (Danube after V2)	2.80 10^{-02}	3.01 10^{-01}	**3.29 10^{-01}**

Table 21.2.1-11: Radiation exposure from natural radionuclides of aquatic animals and plants (own measurements).

The above total dose rate values should reasonably be compared with the value for the relevant reference animals and plants. Several cases prove that there may be a difference of as much as a magnitude between the data, which is definitely due to the inadequacy of the concentration ratios used by ERICA Tool for the Paks application. Still, the grouping mentioned above in the dose rate data was confirmed through a wholly similar tendency showing up from the results calculated from our own isotope concentration measurements, which suggests that the radiation exposure values supplied by ERICA are good data in a big part of the cases.

21.2.2 ARTIFICIAL RADIATION EXPOSURE OF ANIMALS AND PLANTS

We have already mentioned in the introduction that in consequence of human activity the animals and plants in the restricted and extended environment of the planned Power Plant will be subject to radiation exposure to a bigger extent than the original value estimated in the previous section. One of the reasons is the appearance above the area at issue of fission and activation products originating from early ('50s, '60s) atmospheric nuclear weapon tests and getting in the atmosphere and, decisively, their outwash through precipitation (global fall-out). Among them, tritium has practically wholly decomposed, no effect should be anticipated. Radiocarbon has practically been received by the ocean, so today we only have the ^{137}Cs, ^{90}Sr, ^{239}Pu and ^{241}Am isotopes present: mainly in soil and bed sediment.

The so-called peaceful use of nuclear energy means, among others, the operation of hundreds of nuclear power plants all over the world. Some of these facilities have in some cases been damaged and a major volume of radioactive material was emitted from the damaged reactor in a short time. The environment of the plant in Paks was affected by one such incident: the reactor accident at Chernobyl in 1986. Owing to its late effect, some artificial radiation exposure due to the pollution of the soil and the bed sediment with ^{137}Cs isotope should also be counted with today.

The radiological effect of Paks Nuclear Power Plant, in operation for 30 years now, on animals and plants is a likewise existing factor due to continuous atmospheric and fluid emissions, so this should also be taken into consideration in making an inventory of artificial radiation exposure. The totality of these three sources make up the current anthropogenic radiation exposure of animal and plant species. The construction of new nuclear power plant units would result in a similar type of environmental load and thus add to this, still, the dose rate should possibly be kept below the 10 μGy/h reference level. The radiation exposure detailed below and originating from the above anthropogenic sources estimated for the animals and plants of the terrestrial and aquatic habitats represents the base level of the planned power plant units.

TERRESTRIAL HABITATS

As regards the artificial radioactivity of the soil, we collected some data with the method mentioned earlier, from the IERPMS database, and these data were subjected to a detailed analysis. Moreover, we also used the JERMS (Joint Environmental Radiation Monitoring System) database, primarily to expand the data set for ^{90}Sr and extend its area. Additionally, we also made some supplementary tests to gather information about any potential effects (that could distort the actual contamination) of the extensive construction and landscaping works connected with the one-time power plant investment. This was done by testing the layered soil samples taken in areas most exposed to the atmospheric emission of the Power Plant.

The values in the databases were generated in a rather long interval comparable with the half-time of the isotopes at issue, which was taken into consideration to determine the currently standard ^{137}Cs and ^{90}Sr activity concentration in the soil. Consequently, these values can be compared and their current values typical of the relevant area be specified only after some disintegration correction for a specific reference time. This time was chosen to be 01.01.2013. Even after the critical analysis of the corrected data, we had a big enough data set to characterize the individual areas with statistically reliable ^{137}Cs and ^{90}Sr activity concentration.

The layered samples facilitated a stock count of the isotopes at issue (in Bq/m²), at the place of the test. Since this figure acceptably matched the value expected from model calculation, in the areas we found undisturbed, the ^{239}Pu and ^{241}Am contamination of the soil could also be estimated (in Bq/kg). The result of the estimation could be confirmed with on-site samplings within this work (soil, sludge, biological samples) and the subsequent radiochemical separation and alpha-spectrometric measurement. This means that practically the total, currently still existent isotope inventory from global and Chernobyl fall-out can be used to determine the base level radiation exposure of animals and plants. The activity concentration data of the medium used for estimating radiation exposure in the individual terrestrial habitats are summarized in Table 21.2.2-1, however, the following comments are also made.

The data on soil practically represent residual activity concentrations from global and Chernobyl fall-out. Paks Nuclear Power Plant, in operation for 30 years now, can add to this by only an insignificant extent, considering that operational nuclear environment monitoring, a continuous procedure ever since the beginning, detected minor ^{137}Cs fall-out rather rarely in the environment of the stations. This concludes, among others, that the ^{90}Sr atmospheric emission, which is roughly by 2 magnitudes smaller than the above isotope, is non-evincible with the ^{90}Sr contamination (after global fall-out) of the soil. The half-time of the activation products regularly listed in annual emission inventories is relatively short, so their accumulation should not be anticipated even if their total emitted activity is sometimes comparable with the ^{137}Cs emission of the specific year.

isotope	A1		A6		A8	
	soil	air	soil	air	soil	air
	Bq/kg	Bq/m^3	Bq/kg	Bq/m^3	Bq/kg	Bq/m^3
^{137}Cs	11.1		6.6		6.5	
^{90}Sr	0.48		0.62		1.1	
^{239}Pu	0.12		0.12		0.12	
^{241}Am	0.088		0.088		0.088	
T		0.003		0.003		0.003
^{14}C		0.001		0.001		0.001

Table 21.2.2-1: Activity concentrations of artificial radionuclides in the tested terrestrial habitats.

The data in the table relevant to tritium refer to the permanent anthropogenic radioactivity of the air. Owing to the analysis of the multi-year IERPMS data, mentioned several times above, this as a potential maximum was deduced from the HTO measurement data of Stations A1, A6 , A8 and background station B24 for the past 7 years (Veres et. al. [21-9]). Noteworthy, this value is approx. 20% of the natural HTO activity concentration of our domestic near-soil air. Similarly estimated from an analysis of the IERPMS data, the radiocarbon concentration of the atmosphere is approx. 1 mBq/m^3 in excess of the natural level around the Nuclear Power Plant.

The Power Plant has an impact on terrestrial animals and plants also due to its permanent atmospheric radioactive emission. The radioactive cloud as an external radiation source generates a direct impact. Moreover, due to the dispersion of the cloud, the inhalation of the radioactive isotopes should also be anticipated (with animals). Acting as an aerosol, a part of the radioactive material gets on the ground with dry or wet fall-out, and there it partly causes radiation exposure as an external source (primarily through its gamma radiation) and is partly incorporated through the food-chain, either directly or indirectly through the soil. Depending on the species, the individual radiation routes have varied significance and weight in total radiation exposure from the specific source.

Although the total annual atmospheric emission of the 4 operating units may seem significant, still, this is accompanied by high air volumes, so activity concentration in the air coming from the chimneys is not big. This is further decreased due to dispersion and soon becomes non-evincible in near-soil air. An eloquent evidence is that type A stations around the Power Plant could rarely indicate power plant-originating radioactivity in the air in their 30-year operation. The measuring results of the stations also show that settlement is also insignificantly scarce, so not even after 30 years can the effect of the Power Plant be detected in the soil.

All this also means that the increment of the Power Plant to radiation exposure can only be estimated by modelling. ERICA Tool provides a possibility for this. The emission speed of the individual radioactive isotopes, the effective height of the chimney and the meteorological parameters should be set as input data, and the output of the module shall be the activity concentration of the individual isotopes and the settlement speed in near-soil air at the point at issue.

The Emission Control Laboratory is, practically, continuously measuring aeriform emission with the measuring gauges built in the air chimneys in sections I and II. The activity values for the individual isotopes, cumulated for the relevant year, are also available in the publication summarizing radiological protection activities in the relevant year. The atmospheric emission inventory, which is to be used to estimate the radiation exposure of animals and plants in the individual habitats, was completed with the use of the above. The initial data were the total emitted activity of tritium, radiocarbon, rare gases, activation products (^{54}Mn, ^{58}Co, ^{60}Co and ^{110m}Ag) as well as some fission products (^{90}Sr, ^{131}I,^{134}Cs and ^{137}Cs) for the 11-year period from 2000 to 2010.

Emission, considered to be of constant speed in the relevant year, leaves the 100 m high chimney in the direction of the actually prevailing wind conditions and after covering a big distance it may cause the incremental radiation exposure of animals and plants (e.g. the population) even if far from the source. Consequently, the meteorological characteristics should inevitably be continuously measured in the environment of the site to control radiological protection. The 120 m high meteorological test tower measuring, among others, the current wind speed and direction at 20, 50 and 120 m heights, is designed to serve this aim. These data are input data for standard operational atmospheric dispersion calculations. The wind direction frequency distribution for the relevant year (which, similar to the percentile distribution of atmosphere stability categories, is also documented in the above mentioned summaries) is also calculated from the 10-minute cycle period and archived measurement data. Using these data as well for the 11-year period at issue and considering the position of Measuring Stations A1, A6 and A8 relative to the emission point, we specified the annual average emission speed in the direction of the relevant terrestrial habitats for each isotope (Bq/s). The three habitats cover ¼ (90º) of the potential emission area.

The concentration of radioisotopes leaving through the chimney and by the winds continuously decreases with distance from the emission point: partly due to dispersion and partly to settlement. Under average (nearly the most frequent) atmospheric conditions (Pasquill D) in near-soil air, the biggest activity concentration of power plant-originating isotopes are actually expected in the environment of the tested terrestrial habitats (type A environment control stations are evidently installed here not by mere chance). As referred to above, even despite this “exposure” only very rarely can the radioisotopes emitted from the Power Plant into the atmosphere be detected by direct measurement at the stations. Having made an analysis of the emission data, the average of emission data from the past 5 years seemed reasonable to be used as input data, given that the trend analysis of the emission time series suggested that a decreasing tendency is rather typical, due to experience in the long-term operation of the facility and the permanent development of safety culture. The artificial radiation exposure of the biota in the above mentioned terrestrial habitats was estimated at Tier 2 in ERICA Program with the use of these data and the environmental medium activity concentration values summarized in Table 21.2.2-1

We made some modifications in ERICA’s default concentration ratios for the reference animals and plants in our model calculations. The reason is that during the specific tests in preparation for this EIS, according to the results of our experimental work on the biological and soil samples, our calculated CR values apply to the terrestrial animals and plants in Table 21.2.2-2 (based on several data pairs for each animal/plant) in the terrestrial environment of Paks Nuclear Power Plant.

organism	**element**	**CR (kg_{dry}/kg_{wet})**	
		ERICA	**PA terrestrial**
grasses and herbs	Sr	0.21	1.49
	Cs	0.69	0.023
lichens and mosses	Sr	8.68	1.81
	Cs	5.61	1.69
mammal (deer)	Sr	1.74	5.63
	Cs	2.87	0.004
tree	Sr	0.49	0.53
	Cs	0.16	0.005

Table 21.2.2-2: Location-specific concentration ratio values of terrestrial reference organisms.

The dose rates received for the reference creatures are given in “western” and “south-eastern” breakdown versus the N-S longitudinally extending power plant site in Table 21.2.2-3 and Table 21.2.2-4

organism	total dose rate, µGy/h			risk quotient (RQ)
	total global	power plant	total	
amphibian	$1.86 \cdot 10^{-03}$	$3.82 \cdot 10^{-06}$	$1.86 \cdot 10^{-03}$	$1.86 \cdot 10^{-04}$
bird	$2.32 \cdot 10^{-03}$	$4.32 \cdot 10^{-06}$	$2.32 \cdot 10^{-03}$	$2.32 \cdot 10^{-04}$
bird's egg	$1.38 \cdot 10^{-03}$	$5.11 \cdot 10^{-06}$	$1.38 \cdot 10^{-03}$	$1.38 \cdot 10^{-04}$
saprophyte invertebrate	$2.24 \cdot 10^{-03}$	$6.94 \cdot 10^{-06}$	$2.24 \cdot 10^{-03}$	$2.24 \cdot 10^{-04}$
flying insect	$1.04 \cdot 10^{-03}$	$3.33 \cdot 10^{-06}$	$1.04 \cdot 10^{-03}$	$1.04 \cdot 10^{-04}$
snail	$1.04 \cdot 10^{-03}$	$3.33 \cdot 10^{-06}$	$1.04 \cdot 10^{-03}$	$1.04 \cdot 10^{-04}$
grasses and herbs	$1.80 \cdot 10^{-03}$	$3.75 \cdot 10^{-06}$	$1.80 \cdot 10^{-03}$	$1.80 \cdot 10^{-04}$
lichens and mosses	$6.84 \cdot 10^{-03}$	$4.01 \cdot 10^{-06}$	$6.84 \cdot 10^{-03}$	$6.84 \cdot 10^{-04}$
mammal (deer)	$9.69 \cdot 10^{-03}$	$9.16 \cdot 10^{-06}$	$9.70 \cdot 10^{-03}$	$9.70 \cdot 10^{-04}$
mammal (rat)	$6.74 \cdot 10^{-03}$	$9.61 \cdot 10^{-06}$	$6.75 \cdot 10^{-03}$	$6.75 \cdot 10^{-04}$
reptilian	$1.02 \cdot 10^{-02}$	$7.39 \cdot 10^{-06}$	$1.02 \cdot 10^{-02}$	$1.02 \cdot 10^{-03}$
bush	$5.81 \cdot 10^{-03}$	$6.73 \cdot 10^{-06}$	$5.82 \cdot 10^{-03}$	$5.82 \cdot 10^{-04}$
soil invertebrate (worm)	$2.51 \cdot 10^{-03}$	$8.36 \cdot 10^{-06}$	$2.51 \cdot 10^{-03}$	$2.51 \cdot 10^{-04}$
tree	$1.36 \cdot 10^{-03}$	$4.25 \cdot 10^{-06}$	$1.36 \cdot 10^{-03}$	$1.36 \cdot 10^{-04}$

Table 21.2.2-3: Radiation exposure from an artificial source of reference animals and plants at the western side of the Power Plant.

When comparing the dose rate data, coming from two sources, on the western side, we conclude that the increment of the Power Plant is practically insignificant versus global and Chernobyl-caused radiation exposure. There is no major difference among the dose rates for individual flora and fauna groups with any of the sources as they are practically within a single magnitude. The only potentially observed "grouping" is related to higher values with some higher-order animals. The explanation most probably lies in their nutrition and their vertebrate character (Sr and Pu accumulation). This does not apply to any increment due to the Power Plant, as the dose rate from this source is much more balanced with the individual reference animals and plants. External and internal dose rates are not given separately in the table, for the sake of perspicuity and comparability. Regarding these dose rates, whereas those from the Power Plant add nearly identical increment to the total value, those from global sources are rather varied. It is definitely the incorporated isotopes that determine the radiation exposure (> 90%) of the above highlighted vertebrates, and the same applies to lichens/mosses (99.99%). The situation is just the opposite for those living or partly living in the soil (e.g. soil invertebrate). Internal radiation exposure in their case results in just ~10% increment. Regarding the other reference creatures not mentioned here, the two sources have nearly identical weight in total dose rate.

organism	total dose rate, µGy/h			risk quotient (RQ)
	total global	power plant	total	
amphibian	$1.98 \cdot 10^{-03}$	$3.98 \cdot 10^{-06}$	$2.01 \cdot 10^{-03}$	$2.01 \cdot 10^{-04}$
bird	$2.21 \cdot 10^{-03}$	$4.51 \cdot 10^{-06}$	$2.25 \cdot 10^{-03}$	$2.25 \cdot 10^{-04}$
bird's egg	$1.85 \cdot 10^{-03}$	$5.34 \cdot 10^{-06}$	$1.88 \cdot 10^{-03}$	$1.88 \cdot 10^{-04}$
saprophyte invertebrate	$2.33 \cdot 10^{-03}$	$7.25 \cdot 10^{-06}$	$2.34 \cdot 10^{-03}$	$2.34 \cdot 10^{-04}$
flying insect	$1.28 \cdot 10^{-03}$	$3.48 \cdot 10^{-06}$	$1.29\ 10^{-03}$	$1.29 \cdot 10^{-04}$
snail	$1.83 \cdot 10^{-03}$	$3.48 \cdot 10^{-06}$	$1.84 \cdot 10^{-03}$	$1.84 \cdot 10^{-04}$
grasses and herbs	$1.64 \cdot 10^{-03}$	$3.91 \cdot 10^{-06}$	$1.67 \cdot 10^{-03}$	$1.67 \cdot 10^{-04}$
lichens and mosses	$2.85 \cdot 10^{-03}$	$4.19 \cdot 10^{-06}$	$2.87 \cdot 10^{-03}$	$2.87 \cdot 10^{-04}$
mammal (deer)	$4.60 \cdot 10^{-03}$	$9.55 \cdot 10^{-06}$	$4.64 \cdot 10^{-03}$	$4.64 \cdot 10^{-04}$
mammal (rat)	$6.05 \cdot 10^{-03}$	$1.00 \cdot 10^{-06}$	$6.09 \cdot 10^{-03}$	$6.09 \cdot 10^{-04}$
reptilian	$1.26 \cdot 10^{-02}$	$7.67 \cdot 10^{-06}$	$1.27 \cdot 10^{-02}$	$1.27 \cdot 10^{-03}$
bush	$4.49 \cdot 10^{-03}$	$7.02 \cdot 10^{-06}$	$4.51 \cdot 10^{-03}$	$4.51 \cdot 10^{-04}$
soil invertebrate (worm)	$2.42 \cdot 10^{-03}$	$8.73 \cdot 10^{-06}$	$2.44 \cdot 10^{-03}$	$2.44 \cdot 10^{-04}$
tree	$1.09 \cdot 10^{-03}$	$4.43 \cdot 10^{-06}$	$1.13 \cdot 10^{-03}$	$1.13 \cdot 10^{-04}$

Table 21.2.2-4: Dose rate of artificial isotopes in reference organisms, SE of the Power Plant.

Practically the same applies to current artificial radiation exposure estimated for the terrestrial habitat tested SE of the Power Plant and to the components thereof. The some tenth hundredths increment from the Power Plant is not constant, subject to time and position versus the Power Plant (emission point) and due to changes in actual meteorological characteristics. Since 11 years' meteorological data were processed to model the effect of atmospheric emission, the incremental dose rate originating from the Power Plant and given in the table can be considered a long-term average value which is expected to remain in effect until the stoppage of the first unit.

However, the global increment which makes up the majority of the herein discussed artificial component will have a decreasing tendency in time because the half-time of the ^{137}Cs and ^{90}Sr isotopes (that determine its value) is comparable with the lifecycle of the units. By the launch of the first new unit planned by 2025, the herein estimated dose rates will fall by 25%, so ¾ of the value in the first data column of the above tables should be considered the prevailing base level in the individual groups of species.

As regards the base value of artificial sources, we should also note that it can be considered the valid value for the entire area around the Power Plant, i.e. between main road 6 and the Danube, given that the results of relevant measurements did not refer to any significant differences in soil activity concentrations underlying the estimation. Additionally, we also need to note that the radiation exposure values (with no major differences and just approx. 1% added to the natural background) for the individual groups of species mean there is none among the species requiring special attention due to exposure.

AQUATIC HABITATS

Similar to terrestrial animals and plants, the current radiation exposure from anthropogenic sources of aquatic animals and plants primarily originates from the ^{137}Cs, ^{90}Sr, ^{239}Pu and ^{241}Am isotopes spilled from atmospheric nuclear weapon tests mainly in the 60's and from the ^{137}Cs isotope that settled at around the time of the Chernobyl reactor accident. The potential anticipation nowadays of these effects in a river carrying such a big water body as the Danube can be deduced to two facts. Due to its good adsorption property as mentioned earlier, the sediment of the river "stores" some of the material existing in the water as a solute (to the extent determined by the distribution coefficient), so it permits the water to contain the specific radioisotope (even if in very small activity concentration) for quite a long time, which thus permits its intake by aquatic animals and plants, on the one hand. The water can transport terrestrial global contamination and thereby relocate it in time to an area (river bed) less effected by a one-time global or Chernobyl fall-out, on the other hand. Considerable transport is managed on the Danube, compared to Hungarian conditions, because the Alps and their vicinity get significantly more precipitation than Hungary, so global fall-out there was much bigger. Moreover, due to stronger erosion in mountainous areas, the Danube brings a major volume of fine-grain material with rather good adsorption capacities, and a considerable part of this volume can demix in the low-gradient bed on the Great Plain. In consequence, the clearing effect of the flowing water, which would otherwise be expected, cannot prevail in such an environment. In addition to the two contamination cases mentioned here, radioactivity from the fluid emission of Paks Nuclear Power Plant should also be anticipated at the Danube.

The actually measurable activity concentrations of the relevant isotopes in the sediment of the Danube and regular fluid emissions in Paks must be known to estimate the radiation exposure (due to the above) of aquatic animals and plants (anthropogenic base level). Emission and environment monitoring in the Power Plant covers regular measurements in this regard: the water of the Danube and that of the Hot Water Canal are tested, so there were plenty of archive data available (primarily the IERPMS database) to state the typical activity concentrations and identify the multi-year tendencies. Simultaneously, the range of radioisotopes adding some increment to the anthropogenic radiation exposure of aquatic animals and plants could also be delimited. We made use of the measurement data collected from the South Transdanubian Inspectorate for Environment, Nature and Water during our test, in order to have fairly reliable data on the Cs-137 activity concentration of the flowing water.

Based on a detailed analysis of the data, the values (concerning the global and power plant-originating isotope concentrations of V2 and the Danube) in the below tables were considered to represent the current situation (Veres et al. [21-9]). Still worth mentioning in connection with the data: they were generated from measuring results covering years/decades and partly from trend analysis. Consequently, the data, in particular those originating from the Power Plant, are highly uncertain, so unsurprisingly e.g. the K_d values calculated from the data for ^{137}Cs do not coincide in the case of the Danube and V2 (excellent correlation in the case of ^{90}Sr).

isotope	V2		Danube	
	sludge	water	sludge	water
	Bq/kg	mBq/l	Bq/kg	mBq/l
^{137}Cs	20	0.5	20	0.5
^{90}Sr	0.39	0.94	0.39	0.94

Table 21.2.2-5: Activity concentrations of global radionuclides in aquatic habitat.

isotope	V2		Danube	
	sludge	water	sludge	water
	Bq/kg	mBq/l	Bq/kg	mBq/l
^{137}Cs	10	0.7		
^{90}Sr	0.15	0.36		
^{60}Co	2	7.3		
T		1 200		

Table 21.2.2-6: Activity concentrations of radionuclides originating from power plant, in aquatic habitat.

We placed the 12 default aquatic animals and plants in their designated habitats and studied their radiation exposure at Tier 2 of the assessment. At Tier 2 in the assessment, we used the default CR values for the reference organisms. Just in a few cases did we deviate from the default residence factors:

- **Amphibians**, in default water: 0.7 in water and 0.3 on water surface, instead of 1.0;
- **Bird**, in default water: 0.5 in water and 0.5 on water surface, instead of 1.0;
- **Mammal**, in default water: 0.5 in water and 0.5 on water surface, instead of 1.0;
- **Vascular plant**, on the surface of default sediment: 0.7 on the surface of the sediment and 0.3 in water, instead of 1.0.

The percentile natural dry mass of the sludge was set at 50%. The results from running the program are summarized in the tables below, separate for the individual habitats.

organism	dose rate, μGy/h			risk quotient (RQ)
	external	internal	total	
amphibian	$1.86\cdot10^{-07}$	$7.07\cdot10^{-04}$	**$7.07\cdot10^{-04}$**	$7.07\cdot10^{-05}$
benthic fish	$1.40\cdot10^{-03}$	$6.09\cdot10^{-04}$	**$2.01\cdot10^{-03}$**	$2.01\cdot10^{-04}$
bird	$1.19\cdot10^{-07}$	$2.95\cdot10^{-04}$	**$2.95\cdot10^{-04}$**	$2.95\cdot10^{-05}$
shellfish	$1.55\cdot10^{-03}$	$1.89\cdot10^{-04}$	**$1.74\cdot10^{-03}$**	$1.74\cdot10^{-04}$
crab	$1.89\cdot10^{-03}$	$5.37\cdot10^{-04}$	**$2.43\cdot10^{-03}$**	$2.43\cdot10^{-04}$
snail	$1.66\cdot10^{-03}$	$3.31\cdot10^{-04}$	**$1.99\cdot10^{-03}$**	$1.99\cdot10^{-04}$
insect larva	$3.79\cdot10^{-03}$	$5.49\cdot10^{-04}$	**$4.33\cdot10^{-03}$**	$4.33\cdot10^{-04}$
mammal	$1.07\cdot10^{-07}$	$9.87\cdot10^{-04}$	**$9.87\cdot10^{-04}$**	$9.87\cdot10^{-05}$
pelagic fish	$1.68\cdot10^{-07}$	$6.49\cdot10^{-04}$	**$6.49\cdot10^{-04}$**	$6.49\cdot10^{-05}$
phytoplankton	$8.46\cdot10^{-07}$	$2.96\cdot10^{-10}$	**$8.46\cdot10^{-07}$**	$8.46\cdot10^{-08}$
vascular plant	$1.32\cdot10^{-03}$	$1.23\cdot10^{-04}$	**$1.44\cdot10^{-03}$**	$1.44\cdot10^{-04}$
zooplankton	$6.74\cdot10^{-07}$	$6.72\cdot10^{-05}$	**$6.79\cdot10^{-05}$**	$6.79\cdot10^{-06}$

Table 21.2.2-7: Global radiation exposure of reference organisms in the water of the Danube.

organism	dose rate, µGy/h			risk quotient (RQ)
	external	internal	total	
amphibian	$1.86 \cdot 10^{-07}$	$7.07 \cdot 10^{-04}$	**$7.07 \cdot 10^{-04}$**	$7.07 \cdot 10^{-05}$
benthic fish	$1.40 \cdot 10^{-03}$	$6.09 \cdot 10^{-04}$	**$2.01 \cdot 10^{-03}$**	$2.01 \cdot 10^{-04}$
bird	$1.19 \cdot 10^{-07}$	$2.95 \cdot 10^{-04}$	**$2.95 \cdot 10^{-04}$**	$2.95 \cdot 10^{-05}$
shellfish	$1.55 \cdot 10^{-03}$	$1.89 \cdot 10^{-04}$	**$1.74 \cdot 10^{-03}$**	$1.74 \cdot 10^{-04}$
crab	$1.89 \cdot 10^{-03}$	$5.37 \cdot 10^{-04}$	**$2.43 \cdot 10^{-03}$**	$2.43 \cdot 10^{-04}$
snail	$1.66 \cdot 10^{-03}$	$3.31 \cdot 10^{-04}$	**$1.99 \cdot 10^{-03}$**	$1.99 \cdot 10^{-04}$
insect larva	$3.79 \cdot 10^{-03}$	$5.49 \cdot 10^{-04}$	**$4.33 \cdot 10^{-03}$**	$4.33 \cdot 10^{-04}$
mammal	$1.07 \cdot 10^{-07}$	$9.87 \cdot 10^{-04}$	**$9.87 \cdot 10^{-04}$**	$9.87 \cdot 10^{-05}$
pelagic fish	$1.68 \cdot 10^{-07}$	$6.49 \cdot 10^{-04}$	**$6.49 \cdot 10^{-04}$**	$6.49 \cdot 10^{-05}$
phytoplankton	$8.46 \cdot 10^{-07}$	$2.96 \cdot 10^{-10}$	**$8.46 \cdot 10^{-07}$**	$8.46 \cdot 10^{-08}$
vascular plant	$1.32 \cdot 10^{-03}$	$1.23 \cdot 10^{-04}$	**$1.44 \cdot 10^{-03}$**	$1.44 \cdot 10^{-04}$
zooplankton	$6.74 \cdot 10^{-07}$	$6.72 \cdot 10^{-05}$	**$6.79 \cdot 10^{-05}$**	$6.79 \cdot 10^{-06}$

Table 21.2.2-8: Radiation exposure from global sources of the reference organisms, in V2 habitat.

organism	dose rate, µGy/h			risk quotient (RQ)
	external	internal	total	
amphibian	$8.90 \cdot 10^{-06}$	$1.10 \cdot 10^{-03}$	**$1.11 \cdot 10^{-03}$**	$1.11 \cdot 10^{-04}$
benthic fish	$7.26 \cdot 10^{-04}$	$1.59 \cdot 10^{-03}$	**$2.31 \cdot 10^{-03}$**	$2.31 \cdot 10^{-04}$
bird	$7.27 \cdot 10^{-06}$	$1.18 \cdot 10^{-03}$	**$1.19 \cdot 10^{-03}$**	$1.19 \cdot 10^{-04}$
shellfish	$7.85 \cdot 10^{-04}$	$6.02 \cdot 10^{-04}$	**$1.39 \cdot 10^{-03}$**	$1.39 \cdot 10^{-04}$
crab	$8.15 \cdot 10^{-04}$	$1.28 \cdot 10^{-03}$	**$2.10 \cdot 10^{-03}$**	$2.10 \cdot 10^{-04}$
snail	$7.92 \cdot 10^{-04}$	$2.18 \cdot 10^{-03}$	**$2.97 \cdot 10^{-03}$**	$2.97 \cdot 10^{-04}$
insect larva	$1.62 \cdot 10^{-03}$	$4.53 \cdot 10^{-03}$	**$6.15 \cdot 10^{-03}$**	$6.15 \cdot 10^{-04}$
mammal	$6.71 \cdot 10^{-06}$	$2.43 \cdot 10^{-03}$	**$2.44 \cdot 10^{-03}$**	$2.44 \cdot 10^{-04}$
pelagic fish	$9.70 \cdot 10^{-06}$	$1.58 \cdot 10^{-03}$	**$1.59 \cdot 10^{-03}$**	$1.59 \cdot 10^{-04}$
phytoplankton	$1.56 \cdot 10^{-05}$	$1.09 \cdot 10^{-09}$	**$1.56 \cdot 10^{-05}$**	$1.56 \cdot 10^{-06}$
vascular plant	$5.71 \cdot 10^{-04}$	$1.33 \cdot 10^{-03}$	**$1.90 \cdot 10^{-03}$**	$1.90 \cdot 10^{-04}$
zooplankton	$1.14 \cdot 10^{-05}$	$3.41 \cdot 10^{-04}$	**$3.53 \cdot 10^{-04}$**	$3.53 \cdot 10^{-05}$

Table 21.2.2-9: Incremental radiation exposure (from the Power Plant) of reference organisms, in V2.

The probability method used with terrestrial habitats and potentially applicable to Tier 3 was also used with aquatic habitats, similarly to have a fairly reliable assessment of the effect of artificial radionuclides. Here in these cases we used the concentration data that resulted from measurements, were collected for anthropogenic isotopes and were measured by us in this Project, and supplemented them with the ERICA default CR values where necessary. The radiation exposure data provided in the tables below similarly summarize the results of 10,000 runs.

organism	total dose rate, µGy/h			risk quotient (RQ)		
	5 %	average	95 %	5 %	average	95 %
orfe	$1.59 \cdot 10^{-4}$	$2.45 \cdot 10^{-4}$	$3.29 \cdot 10^{-4}$	$1.59 \cdot 10^{-5}$	$2.45 \cdot 10^{-5}$	$3.29 \cdot 10^{-5}$
carp	$1.11 \cdot 10^{-4}$	$1.44 \cdot 10^{-3}$	$4.25 \cdot 10^{-3}$	$1.11 \cdot 10^{-5}$	$1.44 \cdot 10^{-4}$	$4.25 \cdot 10^{-4}$
shellfish	$7.69 \cdot 10^{-4}$	$2.35 \cdot 10^{-3}$	$5.54 \cdot 10^{-3}$	$7.69 \cdot 10^{-5}$	$2.35 \cdot 10^{-4}$	$5.54 \cdot 10^{-4}$

Table 21.2.2-10: Dose rate of artificial radionuclides in the Danube habitat.

organism	total dose rate, µGy/h			risk quotient (RQ)		
	5 %	average	95 %	5 %	average	95 %
orfe	$1.57 \cdot 10^{-4}$	$1.89 \cdot 10^{-4}$	$2.21 \cdot 10^{-4}$	$1.57 \cdot 10^{-5}$	$1.89 \cdot 10^{-5}$	$2.21 \cdot 10^{-5}$
sheat-fish	$1.24 \cdot 10^{-4}$	$1.44 \cdot 10^{-3}$	$4.21 \cdot 10^{-3}$	$1.24 \cdot 10^{-5}$	$1.44 \cdot 10^{-4}$	$4.21 \cdot 10^{-4}$
shellfish	$5.58 \cdot 10^{-4}$	$2.26 \cdot 10^{-3}$	$5.46 \cdot 10^{-3}$	$5.58 \cdot 10^{-5}$	$2.26 \cdot 10^{-4}$	$5.46 \cdot 10^{-4}$
pondweed	$2.41 \cdot 10^{-4}$	$2.59 \cdot 10^{-4}$	$2.77 \cdot 10^{-4}$	$2.41 \cdot 10^{-5}$	$2.59 \cdot 10^{-5}$	$2.77 \cdot 10^{-5}$
green alga	$2.53 \cdot 10^{-5}$	$3.71 \cdot 10^{-5}$	$4.94 \cdot 10^{-5}$	$2.53 \cdot 10^{-6}$	$3.71 \cdot 10^{-6}$	$4.94 \cdot 10^{-6}$

Table 21.2.2-11: Dose rate of artificial radionuclides for the Danube habitat after the Hot Water Canal.

organism	total dose rate, µGy/h			risk quotient (RQ)		
	5 %	average	95 %	5 %	average	95 %
green alga	$1.95 \cdot 10^{-4}$	$4.10 \cdot 10^{-4}$	$9.90 \cdot 10^{-4}$	$1.95 \cdot 10^{-5}$	$4.10 \cdot 10^{-5}$	$9.90 \cdot 10^{-5}$

Table 21.2.2-12: Dose rate from artificial radionuclides in V2 habitat.

21.3 Effect of the installation of Paks II on the radiation exposure of animals and plants in the environment of the site

21.3.1 Effects of the installation of Paks II

The radiation effect of the new nuclear power plant units will only be an issue after the supply of the first fuel assembly and its placement in the reactor vessel in the last phase of installation prior to commercial operation.

21.3.1.1 Direct impacts

The fresh fuel supplied at a time which we can still consider the installation phase has such a low radioactive radiation that it could even be touched with threaded gloves. In solid oxide form, uranium itself is hermetically closed in a casing of zirconium, so it cannot get out. For these reasons, the direct radiation exposure from fuel elements of animals and plants is excluded, so no direct impact should be counted with. The other direct impact is the radioactive (gamma) radiation upon checking the welding seams. The activity of the applied isotopes is selected by having no effect outside the site, still, the casing of the radiation source guarantees that the applied isotope will not get in the environment.

21.3.1.2 Indirect impacts

Since there is no direct impact according to the above, no indirect impact can be at issue, either.

21.3.1.3 Cross-border environmental effects

Since the fuel elements delivered to the new site in the last phase of installation have no radioactive material emission, no radiation effect spreading to over the country border and affecting the animals and plants there should be expected.

21.3.2 Impact area of the installation of Paks II

21.3.2.1 Area of direct impacts

Since there is no direct impact according to the above, no impact area can be at issue, either.

21.3.2.2 Area of indirect impacts

Since there is no indirect impact according to the above, no impact area can be at issue, either.

21.3.2.3 Cross-border environmental effects

Since, according to the above, not even in the direct environment of the Power Plant is there any impact, no cross-border impact can be at issue, either.

21.4 EFFECT OF PAKS II OPERATION ON THE RADIATION EXPOSURE OF ANIMALS AND PLANTS IN THE ENVIRONMENT OF THE SITE

The radiological effect on animals and plants of the 2 new Russian type units with 1200 MW electric output, planned in the direct vicinity of the now already operating Paks Nuclear Power Plant in the interest of the national extension of nuclear energetics-based electric power production, will be studied in three separate sections. One of the reasons is that the effect in the future operation of the currently yet hypothetic facility will, for the sake of transparency, have to be estimated in the environment of the specific site, during the presumed operating time and under conditions whereby no other factor with similar effects could influence the potential effects, on the one hand. This can be implemented by taking account of the so-called design parameters and the actual (expected) local impact factors and so modelling the operation of the Power Plant, its impact on the environment, including specifically its prognosticated effect (in particular, expected radiation exposure) on the animals and plants of the environment around Paks. On the other hand, one must also take into consideration that the 4 * 500 MW units of Paks Nuclear Power Plant Zrt. have been in operation for 30 years now at the designated site and are planned to remain in operation for approx. 20 more years, and these units can likewise have an effect on nearby animals and plants. This must also be considered in assessing the effect of the planned units, given that radiological effect does not make any difference between source and source. The two power plants are jointly recommended to meet the currently proposed effect ceiling, so we also need to check if this can be realized. The maximal effects produced by the individual emitters do not necessarily add up, so presumed joint operation should also be subject to impact assessment, which will be covered in a separate chapter. Although nuclear power plants are typical for their especially high safety, still, certain conditions that fall in the so-called category of design and post-design breakdown and can occur, though with minor probability, should also be borne in mind. Emission in the environment is significantly changed in these cases and, compared to ordinary operation, this can entail bigger environmental load (partly due to the more significant effect of short half-time isotopes).

21.4.1 ORDINARY OPERATION

The radiological effect of the Power Plant on animals and plants can occur due to prompt or delayed ionizing radiation in the reactor. The source of radiation and the place of generation of radioactive materials determinatively coincides with the place of primary energy production. This is the reactor vessel itself or its restricted environment. This is a space which is hermetically closed from the environment, is duly dimensioned toward the external world and is supplied with massive radiological protection. The environment of the building comprising the reactor (containment) and the industrial buildings closely and organically connected to the former are suitable for long-term human stay. To the contrary, the fence bordering the plant and separating it from the environment is several hundred meters off: there the direct radiation effect of the reactor can only be sensed in nGy/h dose rate.

Consequently, the planned units result in undetectably minor radiation exposure through direct radiation for the animals and plants in the closest environment of the site. So this type of theoretically possible effect is neutral with regard to animals and plants.

Practically speaking, the technologies applied in the Power Plant continuously emit materials in the environment, on two routes. Originally, these are not radioactive materials, given that considering their material nature they are decisively air and water (based on mass). The former is there to ventilate the hall and the other industrial rooms, and the latter is the cooling water itself, it condenses the steam leaving the turbine, thereby warrants proper pressure conditions in the secondary circuit.

21.4.1.1 Effect of atmospheric emission

Due to big neutron flux in the environment of the reactor, some air components are activated, the rare gases and other highly volatile fission products coming out of the rod-shaped fuel elements partly similarly get in the air, during cooling water treatment, and are later emitted through the air chimney. So reactor operation implies the emission of a big volume of air partly containing radioactive material. This in general terminology is called atmospheric emission. Owing to unusually high air volume, compared to other industrial activities, and with the aim of increasing the distance from radioactive materials, emission is managed through a 100 m high chimney. Based on data supply from the Russian party, another atmospheric emission point is the ventilation system (at 40 m height) of the turbine hall.

The emitted air leaves the environment of the Power Plant along a route subject to actual meteorological conditions. Its fate is managed and determined by this external factor. The aerosols in the emitted air drift in a direction determined by the wind and will sooner or later get on the surface of the ground, on other terrain features. In times with much precipitation, the leaching effect of the rain also prevails, so in such times aerosols get to a smaller on the average distance from the emission point. The radioactive "cloud" itself moves in the direction of the wind, due to turbulent diffusion, and gradually disperses to the directions perpendicular to the wind. The extent of this extension depends on the atmospheric stability condition which is subject to the temperature conditions of the atmosphere and is also in close relation with wind speed. The gradual dispersion of the cloud onto radioactive gases results in decreased concentration. The concentration of radioactive materials with aerosol properties is decreased by both dry and wet fall-out in the cloud.

The above foreshadows, on the one hand, that it is not easy to foretell the fate of emitted radioactive materials, due to meteorological conditions which vary both in time and from place to place. But on the other hand, based on everyday experience, we know that emissions (that are perceptible to the eye) from high chimneys (smoke) can be arranged into typical categories and their dispersion can be fairly well predicted. Relying on this empirical fact and some theoretical considerations, several dispersion models have been developed and, using the currently available computing technique, they are now available in off-the-shelf programs to model the dispersion, fall-out and leaching of the emitted material.

The model recommended in volume 19 in the safety report series of the International Atomic Energy Agency (IAEA, 2001) is widely used to model atmospheric emission: this, as (among others) one of ERICA Program modules, can also manage such emissions. Its current disadvantage is that just one emission point can be defined, so the effect of Paks Nuclear Power Plant and Paks II cannot be jointly managed with it. Yet another restriction is that it simulates the fate of the cloud along a single pre-determined wind direction.

Owing to these disadvantages, it seems more expedient to use PC-CREAM 08, a program similarly backed with EU recommendation, developed by the English Health Protection Agency and regularly used in Hungary. For dispersion model calculations it similarly uses the Gaussian plume model which is still widely used owing to its simple implementation and the quantitative determination of its input parameters (such a parameter is e.g. wind speed or cloud coverage).

Reflection from the surface of the ground or from the topmost mixing layer is also taken into consideration in the final implemented model. Additionally, location-specific meteorological data can be used as input data (by Pasquill categories).

The program has some limitations which should also be emphasized. The Gaussian plume model is not suitable for modelling windless meteorological conditions. During run, an average wind speed (which must not be less than 0.5 m/s) must be set to each Pasquill category. The set meteorological data are related to the emission point.

Using the place of emission as a base point, the program breaks the tested area into sectors which may be 32 the most (360^0 / 32 = 11.25^0 sectors represent the individual sectors). An essential requirement is that during time dispersion the material moving in the plume does not move from one sector to the other. Another significant approach in the program is that it presumes flat soil surface with minor surface unevenness only. This does not cause any disadvantage in models close to the emission point but may lead to significant discrepancies in big-distance modelling.

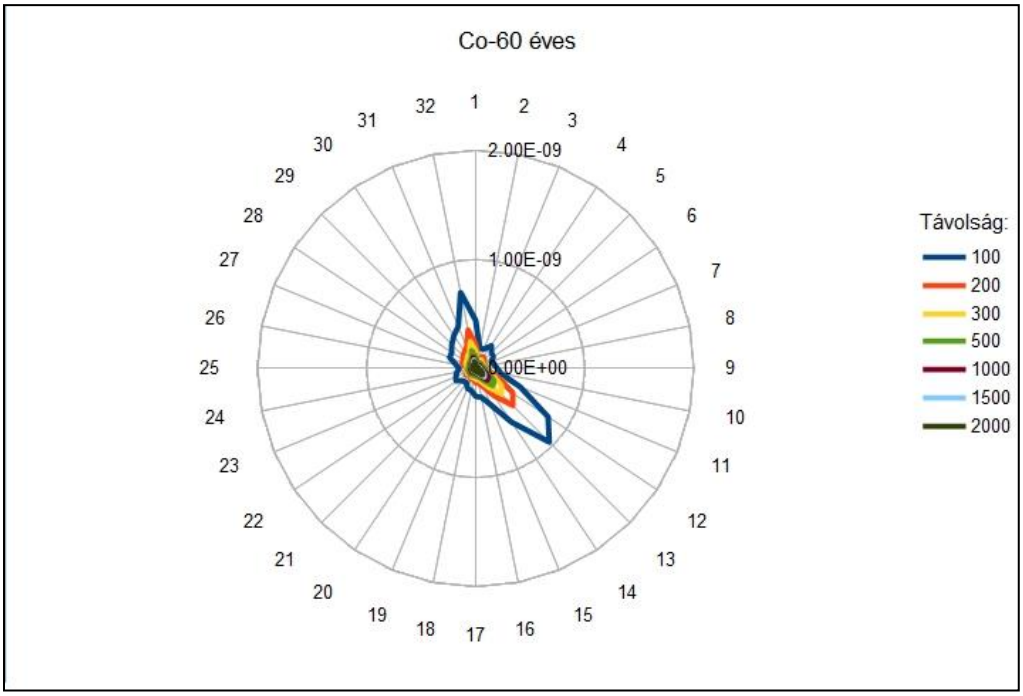
Nevertheless, the in-air activity concentration of the tested radionuclides and/or the size of fall-out can be estimated in a finer time scale, in various distances and at various observation heights. Yet another positive feature is that the results of the runs with finer time resolution become comparable with annual resolution and with the results produced by applying the prevailing wind direction, and can provide a guidance to determining the parameters of potential dispersion modelling.

This latter advantage can become significant if the nearly constant source strength does not apply in an emission point and there is no absolutely prevailing wind direction or no typical wind direction. Both statements hold true for the environment in Paks, based on meteorological observations in the past decades. NW wind direction can be considered prevailing though not exclusive. Additionally, e.g. S or SE wind is also rather frequent. All this will gain significance if there is major fluctuation in emission speeds over the year. In this case, the weather and emission parameters averaged for the whole year "spread" the radioactive material around the Power Plant. The territorial distribution of radioisotopes (primarily of ^{137}Cs) in the environment might actually be homogeneous after several decades of operation when the above mentioned fluctuations had their effect randomized, in all directions of the wind rose.

To perceive this problem and study the potential effect of such scenarios, we will, for the sake of comparison, present the results of fall-out modelling made with the 2010 meteorological and emission data for two cases that all in all use the same input data but where the difference was the time resolution of modelling only.

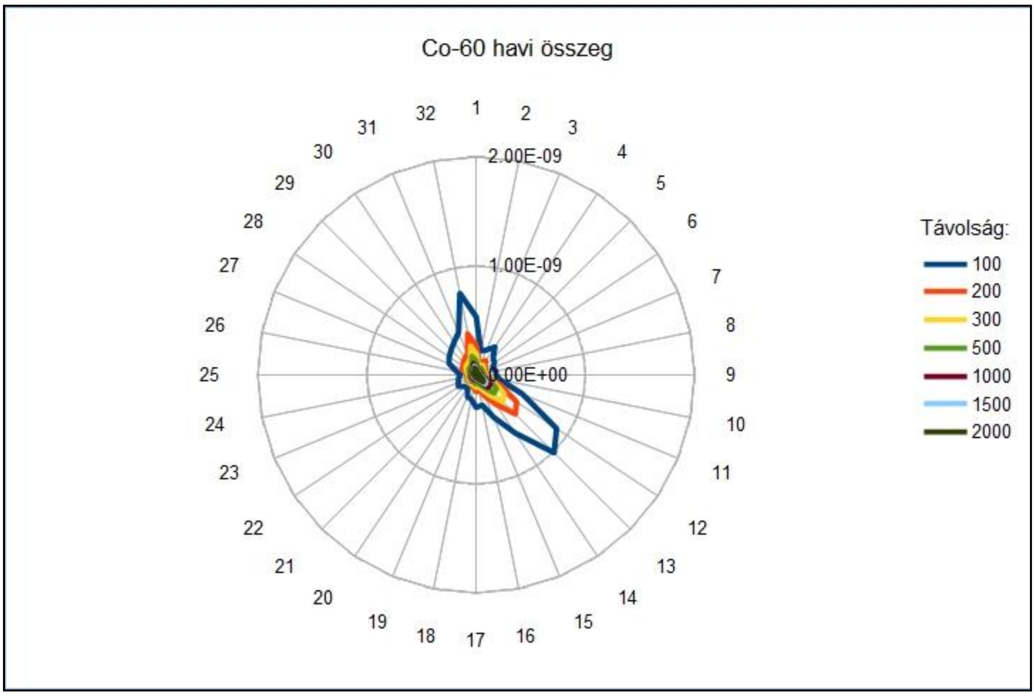
The first case monitored the effect of emission in the given year with an ordinary approach. We combined the values of atmospheric emission (taken from the annual report of Paks Nuclear Power Plant) relevant to ^{60}Co and ^{137}Cs isotopes given in Bq/year unit with the frequency matrix produced from the data of the relevant year, grouped into 32 sectors from the detailed meteorological parameters of 10-minute time resolution and so performed a run to specify the fall-out speed estimated by the sectors, for each isotope.

The results relevant to ^{60}Co are illustrated in Figure 21.4.1-1 and Figure 21.4.1-2. In the figures, "sector 1" denotes north; the vertices of the coloured polygons show the annual average fall-out speed expected in the specific sector, in Bq/m^{2}s unit and in the function of distance.



60 éves – for 60 years, Távolság - distance

Figure 21.4.1-1: ^{60}Co fall-out speed in 2010, estimated from annual averages.

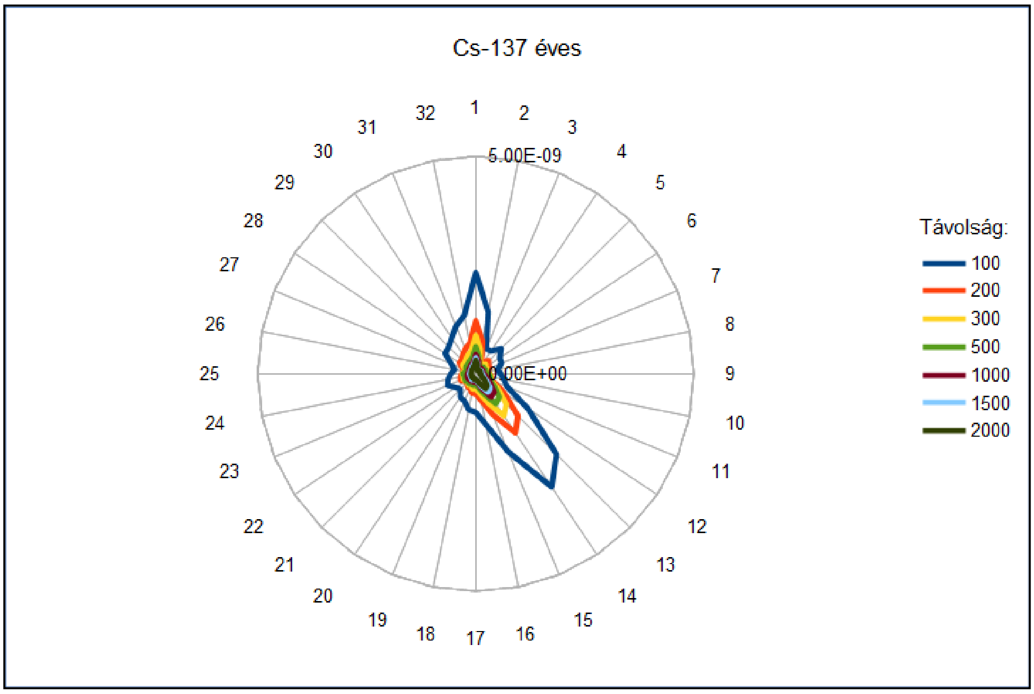


CO-60 havi összeg – aggregated Co for 60 months, Távolság - distance

Figure 21.4.1-2: ^{60}Co fall-out speed in 2010, estimated from monthly data.

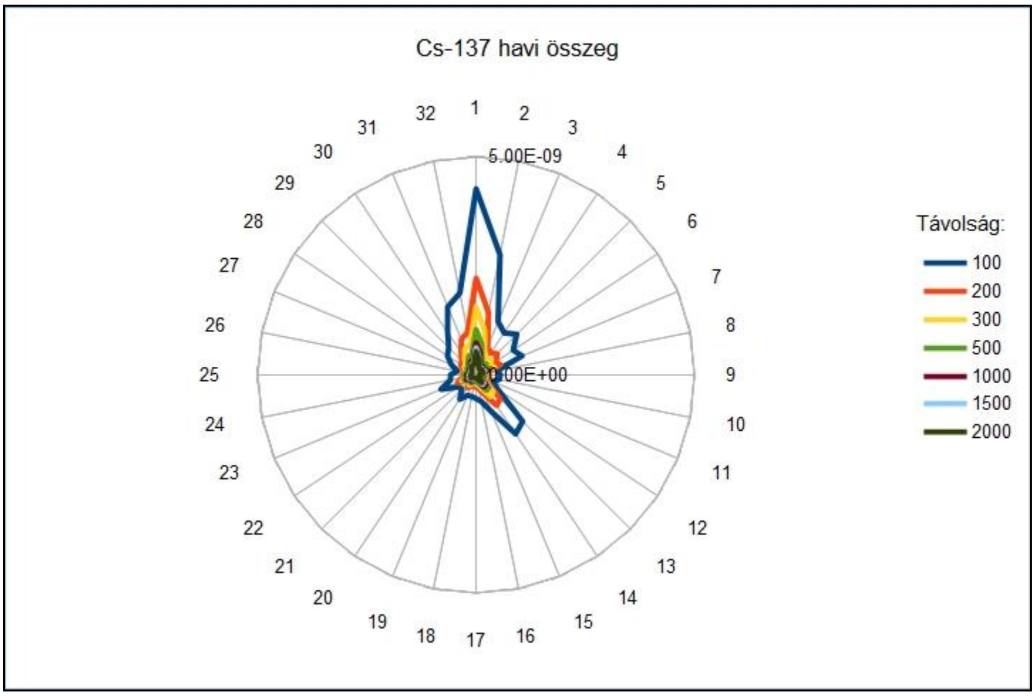
When comparing the two figures, it is perceptible to the eye that there is no difference in the results. This was actually anticipated because, according to the data, ^{60}Co emission was rather even in that year.

The results for ^{137}Cs are illustrated in Figure 21.4.1-3 and Figure 21.4.1-4.



137 éves – for 137 years, Távolság - distance

Figure 21.4.1-3: ^{137}Cs fall-out speed in 2010, estimated from annual averages.



137 havi összeg – aggregated for 137 months, Távolság - distance

Figure 21.4.1-4: ^{137}Cs fall-out speed in 2010, estimated from monthly averages.

The figure with ^{137}Cs clearly demonstrates that the rise in ^{137}Cs emission at around year end took place in a period when southern wind was typical around Paks for a lengthy time, so the majority of total annual fall-out (roughly the area enclosed with the blue line) affected the area north of the emission point. To the contrary, the fall-out map estimated from the annual average predicts ^{137}Cs appearance to SE-S, though with somewhat lesser intensity.

The findings from the above comparison suggest that it would be reasonable to test the dynamics of actual emission speeds, on account of the precautionary principle prescribed in connection with environment protection. Naturally enough, the above example does not imply the modelling of any potential effect from the atmospheric emission of the planned units on animals and plants, since now it can only be estimated from the design-level emission data. However, only annual levels are available to us in this regard.

Further on in this chapter, we will estimate the presumed territorial distribution of radioactive materials getting in the terrestrial environment around the industrial area, using as a starting point the annual emission inventory compiled from the supplier's data supply and the meteorological data of Paks in the past 8 years. This covers the radioactivity of the surrounding air and the test of soil as a recipient agent. In both media, we designate the specific locations with maximum concentration and will in the second phase of impact assessment use the data applicable to these locations as input data in ERICA Program, to estimate the radiation exposure of the reference animals and plants located here.

The activity (during ordinary operation and at annual level) of isotopes leaving, under controlled circumstances, the two emission points is summarized in Table 21.4.1-1, based on the data collected by MVM Paks II Zrt. from the Russian party.

radionuclide	ventilation system in reactor building	special gas purification systems		ventilation system in auxiliary building	total emission	emission from turbine building
		KPL-2	KPL-3			
	GBq/year×unit					
^{3}H	$3.90\cdot10^{3}$	-	-	$5.00\cdot10^{1}$	$3.90\cdot10^{3}$	$1.20\cdot10^{0}$
^{14}C	-	-	-	-	$3.00\cdot10^{2}$	-
^{83m}Kr	$5.58\cdot10^{2}$	-	$1.10\cdot10^{2}$	$2.90\cdot10^{0}$	$6.71\cdot10^{2}$	$2.70\cdot10^{1}$
^{85m}Kr	$2.03\cdot10^{3}$	$3.60\cdot10^{-1}$	$2.40\cdot10^{2}$	$8.42\cdot10^{0}$	$2.28\cdot10^{3}$	$6.10\cdot10^{0}$
^{85}Kr	$5.47\cdot10^{0}$	$3.50\cdot10^{2}$	$2.60\cdot10^{-1}$	$1.63\cdot10^{-2}$	$3.56\cdot10^{2}$	$6.60\cdot10^{-2}$
^{87}Kr	$1.12\cdot10^{3}$	-	$2.50\cdot10^{2}$	$6.58\cdot10^{0}$	$1.38\cdot10^{3}$	$6.40\cdot10^{1}$
^{88}Kr	$4.43\cdot10^{3}$	-	$5.80\cdot10^{2}$	$2.05\cdot10^{1}$	$5.03\cdot10^{3}$	$1.50\cdot10^{2}$
^{131m}Xe	$1.02\cdot10^{2}$	$1.40\cdot10^{2}$	$6.60\cdot10^{0}$	$3.08\cdot10^{-1}$	$2.49\cdot10^{2}$	$1.60\cdot10^{0}$
^{133}Xe	$2.60\cdot10^{4}$	$2.10\cdot10^{2}$	$1.80\cdot10^{3}$	$7.90\cdot10^{1}$	$2.81\cdot10^{4}$	$4.70\cdot10^{2}$
^{135}Xe	$6.23\cdot10^{3}$	-	$1.30\cdot10^{3}$	$2.22\cdot10^{1}$	$7.55\cdot10^{3}$	$3.30\cdot10^{2}$
^{138}Xe	$1.65\cdot10^{2}$	-	$1.20\cdot10^{2}$	$1.45\cdot10^{0}$	$2.86\cdot10^{2}$	$3.10\cdot10^{1}$
^{131}I	$1.64\cdot10^{-2}$	-	$2.00\cdot10^{-2}$	$3.63\cdot10^{-2}$	$7.27\cdot10^{-2}$	$3.10\cdot10^{-3}$
^{132}I	$3.28\cdot10^{-2}$	-	-	$6.41\cdot10^{-2}$	$9.69\cdot10^{-2}$	$1.00\cdot10^{-2}$
^{133}I	$4.33\cdot10^{-2}$	-	-	$9.44\cdot10^{-2}$	$1.38\cdot10^{-1}$	$9.30\cdot10^{-3}$
^{134}I	$2.43\cdot10^{-2}$	-	-	$4.17\cdot10^{-2}$	$6.60\cdot10^{-2}$	$2.80\cdot10^{-3}$
^{135}I	$3.64\cdot10^{-2}$	-	-	$7.68\cdot10^{-2}$	$1.13\cdot10^{-1}$	$7.10\cdot10^{-3}$
^{51}Cr	$3.40\cdot10^{-6}$	-	-	$7.53\cdot10^{-5}$	$7.87\cdot10^{-5}$	$1.50\cdot10^{-7}$
^{54}Mn	$2.09\cdot10^{-7}$	-	-	$4.62\cdot10^{-6}$	$4.83\cdot10^{-6}$	$2.10\cdot10^{-7}$
^{60}Co	$1.34\cdot10^{-6}$	-	-	$2.97\cdot10^{-5}$	$3.10\cdot10^{-5}$	$2.40\cdot10^{-6}$
^{89}Sr	$1.33\cdot10^{-5}$	-	-	$3.12\cdot10^{-4}$	$3.25\cdot10^{-4}$	$1.40\cdot10^{-5}$
^{90}Sr	$2.57\cdot10^{-8}$	-	-	$5.70\cdot10^{-7}$	$5.96\cdot10^{-7}$	$4.40\cdot10^{-8}$
^{134}Cs	$8.63\cdot10^{-4}$	-	-	$1.91\cdot10^{-2}$	$2.00\cdot10^{-2}$	$1.00\cdot10^{-3}$
^{137}Cs	$1.31\cdot10^{-3}$	-	-	$2.90\cdot10^{-2}$	$3.03\cdot10^{-2}$	$1.30\cdot10^{-3}$

Table 21.4.1-1: Annual radioactive gas and aerosol emission by units, in nominal operating condition [21-11]

Since the chimneys of the two units are not too far from each other, the dispersion of the radioactive material leaving at 100 m and 40 m heights was considered to start from an identical point and was so modelled for each year. As meteorological data, we used the wind speed measured at 120 and 50 m in the test tower in Paks, the wind direction, Pasquill category, and the annual average data generated from the 10-minute precipitation-related measurement data in 32-sector resolution. In the space around the chimney, the fall-out speed, the dose rate of the cloud and the radioactive isotope concentration of near-soil air were tested for the individual isotopes in 100 m resolution.

The annual average meteorological data will evenly distribute the rainy periods within the whole year, so air concentration and fall-out will monotonously decrease with distance from the source. In reality, dry periods dominate in the Carpathian basin, in particular in flat and plain-type areas distant from the mountainous regions, just as the surroundings of Paks. For this reason, the leaching effect of the rain does not influence the dispersion of most of the emitted material. This results in the creation of accumulation points in the dry deposition, subject to other meteorological conditions. This is significant inasmuch as the maximum effect of emission is regularly concentrated onto a smaller or bigger area within the area subject to the specific prevailing wind direction. Here in this very point the meteorological properties collected for Paks over long decades indicate such a place, moreover, the most exposed direction is SE and its restricted environment.

With regard to this fact, the pattern of the effect around the Power Plant was tested in our model by proportionally breaking down the specific year into no-precipitation and rainy periods. The results of rainy period runs could easily specify the outstanding role of sections 12, 13 and 14, moreover, a maximum was also found to appear in a 500-1000 m distance range from the emission point, subject to meteorological conditions. The activity concentration of some important isotopes expected in the indicated receptor area and their volume accumulating in the soil due to long-term operation (emission) is summarized in Table 21.4.1-2

isotope	air, Bq/m^3			soil, Bq/kg	
	5 %	average	95 %	average	deviation
^{3}H	$7.29 \cdot 10^{-03}$	$4.42 \cdot 10^{-02}$	$2.68 \cdot 10^{-01}$		
^{14}C	$5.59 \cdot 10^{-04}$	$3.39 \cdot 10^{-03}$	$2.06 \cdot 10^{-02}$		
^{85}Kr	$6.04 \cdot 10^{-03}$	$1.94 \cdot 10^{-03}$	$6.26 \cdot 10^{-03}$		
^{85m}Kr	$3.94 \cdot 10^{-03}$	$1.26 \cdot 10^{-02}$	$4.03 \cdot 10^{-02}$		
^{87}Kr	$3.17 \cdot 10^{-03}$	$9.55 \cdot 10^{-03}$	$2.87 \cdot 10^{-02}$		
^{88}Kr	$2.12 \cdot 10^{-02}$	$3.43 \cdot 10^{-02}$	$1.05 \cdot 10^{-01}$		
^{131m}Xe	$4.46 \cdot 10^{-04}$	$1.42 \cdot 10^{-03}$	$4.49 \cdot 10^{-03}$		
^{133}Xe	$5.46 \cdot 10^{-02}$	$1.70 \cdot 10^{-01}$	$5.27 \cdot 10^{-01}$		
^{135}Xe	$1.73 \cdot 10^{-02}$	$5.23 \cdot 10^{-02}$	$1.5 \cdot 108^{-01}$		
^{60}Co	$8.83 \cdot 10^{-11}$	$2.52 \cdot 10^{-10}$	$7.64 \cdot 10^{-10}$	$1.64 \cdot 10^{-06}$	$6.07 \cdot 10^{-07}$
^{131}I	$1.66 \cdot 10^{-07}$	$5.04 \cdot 10^{-07}$	$1.53 \cdot 10^{-06}$	$5.41 \cdot 10^{-05}$	$1.53 \cdot 10^{-05}$
^{132}I	$2.83 \cdot 10^{-07}$	$8.52 \cdot 10^{-07}$	$2.57 \cdot 10^{-06}$	$1.06 \cdot 10^{-06}$	$3.06 \cdot 10^{-07}$
^{133}I	$3.56 \cdot 10^{-07}$	$1.07 \cdot 10^{-06}$	$3.20 \cdot 10^{-06}$	$1.22 \cdot 10^{-05}$	$3.43 \cdot 10^{-06}$
^{134}I	$1.48 \cdot 10^{-07}$	$4.47 \cdot 10^{-07}$	$1.36 \cdot 10^{-06}$	$2.17 \cdot 10^{-07}$	$6.13 \cdot 10^{-08}$
^{134}Cs	$4.75 \cdot 10^{-08}$	$1.45 \cdot 10^{-07}$	$4.42 \cdot 10^{-07}$	$3.86 \cdot 10^{-04}$	$1.44 \cdot 10^{-04}$
^{135}I	$2.85 \cdot 10^{-07}$	$8.56 \cdot 10^{-07}$	$2.57 \cdot 10^{-06}$	$3.11 \cdot 10^{-06}$	$8.77 \cdot 10^{-07}$
^{137}Cs	$9.28 \cdot 10^{-08}$	$2.88 \cdot 10^{-07}$	$8.96 \cdot 10^{-07}$	$5.49 \cdot 10^{-03}$	$1.89 \cdot 10^{-03}$

Table 21.4.1-2: Statistical distribution of activity concentrations in the receptor area.

Cloud dose rate for the same area: 5%: 22.4 pGy/h; average: 65.8 pGy/h; 95%: 193 pGy/h for big-bodied mammals. Subject to size and place of stay, the figures mainly differ with the other animals and plants.

Together with the two other quantitative values for maximum locations, several dozen data sets were generated by isotope from the 2*8-year simulation, and these could be processed with ERICA Program with an interpretation that considers the cumulated external and internal radiation exposure a probability variable. The result of the estimation made over a 60-year continuous emission period on the basis of 10,000 randomized samplings and relevant to the external dose rate affecting the individual reference animals and plants is summarized in Table 21.4.1-3, specifying therein the average figure and the values for the 5% and 95% confidence limits. So any triad of data means the following, e.g. relevant to amphibians: the external radiation exposure of individuals (nearly) permanently staying in the specific area is with high probability 0.16 nGy/h, and there is a 90% chance for the external dose rate to fall between 49 pGy/h and 0.56 nGy/h.

organism	dose rate, µGy/h			max. risk quotient, RQ
	5 %	average	95 %	
amphibian	$4.90\cdot10^{-05}$	$1.66\cdot10^{-04}$	$5.62\cdot10^{-04}$	$5.62\cdot10^{-05}$
bird	$6.60\cdot10^{-05}$	$2.23\cdot10^{-04}$	$7.58\cdot10^{-04}$	$7.58\cdot10^{-05}$
bird's egg	$4.90\cdot10^{-05}$	$1.66\cdot10^{-04}$	$5.62\cdot10^{-04}$	$5.62\cdot10^{-05}$
saprophyte invertebrate	$1.73\cdot10^{-05}$	$5.72\cdot10^{-05}$	$1.92\cdot10^{-04}$	$1.92\cdot10^{-05}$
flying insect	$9.62\cdot10^{-05}$	$3.26\cdot10^{-04}$	$1.11\cdot10^{-03}$	$1.11\cdot10^{-04}$
snail	$1.05\cdot10^{-04}$	$3.55\cdot10^{-04}$	$1.21\cdot10^{-03}$	$1.21\cdot10^{-04}$
grasses and herbs	$6.00\cdot10^{-05}$	$2.03\cdot10^{-04}$	$6.86\cdot10^{-04}$	$6.86\cdot10^{-05}$
lichens and mosses	$5.43\cdot10^{-05}$	$1.84\cdot10^{-04}$	$6.23\cdot10^{-04}$	$6.23\cdot10^{-05}$
mammal (deer)	$2.13\cdot10^{-05}$	$7.21\cdot10^{-05}$	$2.44\cdot10^{-04}$	$2.44\cdot10^{-05}$
mammal (rat)	$6.65\cdot10^{-06}$	$2.13\cdot10^{-05}$	$7.00\cdot10^{-05}$	$7.00\cdot10^{-06}$
reptilian	$2.73\cdot10^{-05}$	$9.22\cdot10^{-05}$	$3.12\cdot10^{-04}$	$3.12\cdot10^{-05}$
bush	$6.00\cdot10^{-05}$	$2.03\cdot10^{-04}$	$6.86\cdot10^{-04}$	$6.86\cdot10^{-05}$
soil invertebrate (worm)	$1.03\cdot10^{-06}$	$1.87\cdot10^{-06}$	$3.12\cdot10^{-06}$	$3.12\cdot10^{-07}$
tree	$5.99\cdot10^{-05}$	$2.02\cdot10^{-04}$	$6.86\cdot10^{-04}$	$6.86\cdot10^{-05}$

Table 21.4.1-3: Statistical distribution of external dose rate increment and maximum risk quotient values.

The values (from the above detailed dose estimation) for internal radiation exposure are summarized in Table 21.4.1-4

organism	dose rate, µGy/h			max. risk quotient, RQ
	5 %	average	95 %	
amphibian	$6.49\cdot10^{-06}$	$2.32\cdot10^{-04}$	$8.84\cdot10^{-04}$	$8.84\cdot10^{-05}$
bird	$8.99\cdot10^{-06}$	$2.49\cdot10^{-04}$	$9.06\cdot10^{-04}$	$9.06\cdot10^{-05}$
bird's egg	$3.80\cdot10^{-06}$	$1.88\cdot10^{-04}$	$6.37\cdot10^{-04}$	$6.37\cdot10^{-05}$
saprophyte invertebrate	$2.71\cdot10^{-06}$	$1.29\cdot10^{-04}$	$4.84\cdot10^{-04}$	$4.84\cdot10^{-05}$
flying insect	$3.34\ 10^{-06}$	$1.21\cdot10^{-04}$	$4.64\ 10^{-04}$	$4.64\cdot10^{-05}$
snail	$3.99\cdot10^{-06}$	$1.26\cdot10^{-04}$	$4.50\cdot10^{-04}$	$4.50\cdot10^{-05}$
grasses and herbs	$4.31\cdot10^{-06}$	$1.74\cdot10^{-04}$	$6.68\cdot10^{-04}$	$6.68\cdot10^{-05}$
lichens and mosses	$4.42\cdot10^{-06}$	$1.70\cdot10^{-04}$	$5.83\cdot10^{-04}$	$5.83\cdot10^{-05}$
mammal (deer)	$6.39\cdot10^{-06}$	$2.48\cdot10^{-04}$	$9.56\cdot10^{-04}$	$9.56\cdot10^{-05}$
mammal (rat)	$8.05\cdot10^{-06}$	$2.71\cdot10^{-04}$	$1.07\cdot10^{-03}$	$1.07\cdot10^{-04}$
reptilian	$7.15\cdot10^{-06}$	$2.52\cdot10^{-04}$	$9.43\cdot10^{-04}$	$9.43\cdot10^{-05}$
bush	$6.78\cdot10^{-06}$	$1.87\cdot10^{-04}$	$6.70\cdot10^{-04}$	$6.70\cdot10^{-05}$
soil invertebrate (worm)	$5.16\cdot10^{-06}$	$1.22\cdot10^{-04}$	$4.54\cdot10^{-04}$	$4.54\cdot10^{-05}$
tree	$7.76\cdot10^{-06}$	$2.45\cdot10^{-04}$	$8.92\cdot10^{-04}$	$8.92\cdot10^{-05}$

Table 21.4.1-4: Statistical distribution of internal dose rate increment and maximum risk quotient values.

The summation of external and internal dose rates shows the total radiation exposure of the individual terrestrial reference animals and plants over the long-term operation of the two units of Paks II. This is given in Table 21.4.1-5. The values suggest the emergence of low radiation exposure that does not even approximate the current base level for, practically speaking, all the reference animals and plants. We should also remember that the data in the table hold valid in a 500-1000 m range from the emission point, i.e. within the site. The dose rates in the environment outside the site are expected to be smaller, as shown through the data in Table 21.4.1-6 which summarizes the radiation exposures of the reference animals and plants, estimated for the habitat to the most exposed SE direction around Lake Kondor which is adjacent to the borderline of the site and for an area further off, mainly used for agricultural purposes.

organism	dose rate, µGy/h			max. RQ
	5 %	average	95 %	
amphibian	$5.55 \cdot 10^{-05}$	$\mathbf{3.97 \cdot 10^{-04}}$	$1.45 \cdot 10^{-03}$	$1.45 \cdot 10^{-04}$
bird	$7.50 \cdot 10^{-05}$	$\mathbf{4.72 \cdot 10^{-04}}$	$1.66 \cdot 10^{-03}$	$1.66 \cdot 10^{-04}$
bird's egg	$5.28 \cdot 10^{-05}$	$\mathbf{3.53 \cdot 10^{-04}}$	$1.20 \cdot 10^{-03}$	$1.20 \cdot 10^{-04}$
saprophyte invertebrate	$2.00 \cdot 10^{-05}$	$\mathbf{1.86 \cdot 10^{-04}}$	$6.76 \cdot 10^{-04}$	$6.76 \cdot 10^{-05}$
flying insect	$9.96 \cdot 10^{-05}$	$\mathbf{4.46 \cdot 10^{-04}}$	$1.57 \cdot 10^{-03}$	$1.57 \cdot 10^{-04}$
snail	$1.09 \cdot 10^{-04}$	$\mathbf{4.81 \cdot 10^{-04}}$	$1.66 \cdot 10^{-03}$	$1.66 \cdot 10^{-04}$
grasses and herbs	$6.43 \cdot 10^{-05}$	$\mathbf{3.77 \cdot 10^{-04}}$	$1.35 \cdot 10^{-03}$	$1.35 \cdot 10^{-04}$
lichens and mosses	$5.80 \cdot 10^{-05}$	$\mathbf{3.54 \cdot 10^{-04}}$	$1.21 \cdot 10^{-03}$	$1.21 \cdot 10^{-04}$
mammal (deer)	$2.77 \cdot 10^{-05}$	$\mathbf{3.21 \cdot 10^{-04}}$	$1.20 \cdot 10^{-03}$	$1.20 \cdot 10^{-04}$
mammal (rat)	$1.47 \cdot 10^{-05}$	$\mathbf{2.93 \cdot 10^{-04}}$	$1.14 \cdot 10^{-03}$	$1.14 \cdot 10^{-04}$
reptilian	$3.45 \cdot 10^{-05}$	$\mathbf{3.44 \cdot 10^{-04}}$	$1.26 \cdot 10^{-03}$	$1.26 \cdot 10^{-04}$
bush	$6.68 \cdot 10^{-05}$	$\mathbf{3.90 \cdot 10^{-04}}$	$1.36 \cdot 10^{-03}$	$1.36 \cdot 10^{-04}$
soil invertebrate (worm)	$6.19 \cdot 10^{-06}$	$\mathbf{1.24 \cdot 10^{-04}}$	$4.57 \cdot 10^{-04}$	$4.57 \cdot 10^{-05}$
tree	$6.77 \cdot 10^{-05}$	$\mathbf{4.48 \cdot 10^{-04}}$	$1.58 \cdot 10^{-03}$	$1.58 \cdot 10^{-04}$

Table 21.4.1-5: Statistical distribution of total dose rate increment and maximum risk quotient values.

organism	1500 meters		3000 meters	
	dose rate, µGy/h	risk quotient, RQ	dose rate, µGy/h	risk quotient, RQ
Amphibian	$2.91 \cdot 10^{-04}$	$2.91 \cdot 10^{-05}$	$1.34 \cdot 10^{-04}$	$1.34 \cdot 10^{-05}$
Bird	$3.29 \cdot 10^{-04}$	$3.29 \cdot 10^{-05}$	$1.51 \cdot 10^{-04}$	$1.51 \cdot 10^{-05}$
Bird's egg	$2.45 \cdot 10^{-04}$	$2.45 \cdot 10^{-05}$	$1.13 \cdot 10^{-04}$	$1.13 \cdot 10^{-05}$
Saprophyte invertebrate	$1.35 \cdot 10^{-04}$	$1.35 \cdot 10^{-05}$	$6.25 \cdot 10^{-05}$	$6.25 \cdot 10^{-06}$
Flying insect	$2.83 \cdot 10^{-04}$	$2.83 \cdot 10^{-05}$	$1.29 \cdot 10^{-04}$	$1.29 \cdot 10^{-05}$
Snail	$3.04 \cdot 10^{-04}$	$3.04 \cdot 10^{-05}$	$1.39 \cdot 10^{-04}$	$1.39 \cdot 10^{-05}$
Grasses and herbs	$2.66 \cdot 10^{-04}$	$2.66 \cdot 10^{-05}$	$1.22 \cdot 10^{-04}$	$1.22 \cdot 10^{-05}$
Lichens and mosses	$2.55 \cdot 10^{-04}$	$2.55 \cdot 10^{-05}$	$1.17 \cdot 10^{-04}$	$1.17 \cdot 10^{-05}$
Mammal (deer)	$2.42 \cdot 10^{-04}$	$2.42 \cdot 10^{-05}$	$1.12 \cdot 10^{-04}$	$1.12 \cdot 10^{-05}$
Mammal (rat)	$2.16 \cdot 10^{-04}$	$2.16 \cdot 10^{-05}$	$1.00 \cdot 10^{-04}$	$1.00 \cdot 10^{-05}$
Reptilian	$2.56 \cdot 10^{-04}$	$2.56 \cdot 10^{-05}$	$1.18 \cdot 10^{-04}$	$1.18 \cdot 10^{-05}$
Bush	$2.68 \cdot 10^{-04}$	$2.68 \cdot 10^{-05}$	$1.23 \cdot 10^{-04}$	$1.23 \cdot 10^{-05}$
Soil invertebrate (worm)	$1.04 \cdot 10^{-04}$	$1.04 \cdot 10^{-05}$	$4.83 \cdot 10^{-05}$	$4.83 \cdot 10^{-06}$
Tree	$3.13 \cdot 10^{-04}$	$3.13 \cdot 10^{-05}$	$1.44 \cdot 10^{-04}$	$1.44 \cdot 10^{-05}$

Table 21.4.1-6: Total dose rate increment and risk quotient values in 1500 m and 3000 m distance.

The data in Table 21.4.1-5 should reasonably be compared with the maximum increment related to the base level of the operating Nuclear Power Plant. This max. increment was estimated similar to the above, though the emission inventory set by Pa Zrt. for the relevant year was used as atmospheric emission data. Since the meteorological data matched those used for modelling Paks II effect, the maximum effect logically came from sectors 12-13-14 and within the 500-1000 m range. The data summarized in Table 21.4.1-7 suggest that in terms of effect the planned power plant does not significantly differ from the plant already in operation. The tendency of having approx. 2 factors bigger estimated dose rate data as an effect of the new units is evidently due to the conservative nature of the set design emission data, moreover, higher installed capacity also contributes to the greater effect. Even by planned launch in 2025, the two power plants would have a less than 20-30% increment to the then still existing global radiation exposure. Noteworthy, this assessment disregards that the atmospheric places of emission of the two power plants do not coincide, there will be nearly 600 m distance between them, so radiation exposure estimated as a maximum value in both cases for the animals and plants will not prevail in identical locations, either. Table 21.4.1-7 summarizes the effect of the planned new power plant on terrestrial animals and plants, together with radiation exposure from the earlier described artificial and natural sources.

organism	dose rate, μGy/h			
	Paks II.	Paks Nuclear Power Plant	global	natural
amphibian	**$3.97 \cdot 10^{-04}$**	$1.95 \cdot 10^{-04}$	$1.52 \cdot 10^{-03}$	$1.67 \cdot 10^{-01}$
bird	**$4.72 \cdot 10^{-04}$**	$2.44 \cdot 10^{-04}$	$1.70 \cdot 10^{-03}$	$1.89 \cdot 10^{-01}$
bird's egg	**$3.53 \cdot 10^{-04}$**	$1.79 \cdot 10^{-04}$	$1.42 \cdot 10^{-03}$	$1.80 \cdot 10^{-01}$
saprophyte invertebrate	**$1.86 \cdot 10^{-04}$**	$7.51 \cdot 10^{-05}$	$1.79 \cdot 10^{-03}$	$4.25 \cdot 10^{-01}$
flying insect	**$4.46 \cdot 10^{-04}$**	$2.82 \cdot 10^{-04}$	$9.78 \cdot 10^{-04}$	$3.89 \cdot 10^{-01}$
snail	**$4.81 \cdot 10^{-04}$**	$3.05 \cdot 10^{-04}$	$1.41 \cdot 10^{-03}$	$2.52 \cdot 10^{-01}$
grasses and herbs	**$3.77 \cdot 10^{-04}$**	$2.05 \cdot 10^{-04}$	$1.18 \cdot 10^{-03}$	$5.56 \cdot 10^{-01}$
lichens and mosses	**$3.54 \cdot 10^{-04}$**	$1.90 \cdot 10^{-04}$	$5.73 \cdot 10^{-03}$	$6.10 \cdot 10^{00}$
mammal (deer)	**$3.21 \cdot 10^{-04}$**	$1.30 \cdot 10^{-04}$	$6.28 \cdot 10^{-03}$	$1.33 \cdot 10^{-01}$
mammal (rat)	**$2.93 \cdot 10^{-04}$**	$9.60 \cdot 10^{-05}$	$4.66 \cdot 10^{-03}$	$1.68 \cdot 10^{-01}$
reptilian	**$3.44 \cdot 10^{-04}$**	$1.49 \cdot 10^{-04}$	$9.70 \cdot 10^{-03}$	$1.72 \cdot 10^{-01}$
bush	**$3.90 \cdot 10^{-04}$**	$2.05 \cdot 10^{-04}$	$3.46 \cdot 10^{-03}$	$3.02 \cdot 10^{-01}$
soil invertebrate (worm)	**$1.24 \cdot 10^{-04}$**	$3.18 \cdot 10^{-05}$	$1.86 \cdot 10^{-03}$	$4.37 \cdot 10^{-01}$
tree	**$4.48 \cdot 10^{-04}$**	$2.35 \cdot 10^{-04}$	$1.07 \cdot 10^{-03}$	$1.04 \cdot 10^{-01}$

Table 21.4.1-7: Radiation exposure from anthropogenic sources of terrestrial reference species, SE of Paks site.

21.4.1.2 Effect of aquatic emission

Technological water treatment in the planned new units implies, based on data supply, the production of annual 58,000 m^3 waste water which has to be drained by first collecting it in containers and then letting it, under control, in the Hot Water Canal and then the Danube. The isotope inventory by units is summarized in Table 21.4.1-8. Fully unambiguous, tritium makes up 99.99% of total activity. Both in terms of ratio and size, this is rather close to the fluid emission inventory (supported by regular measurements) of Paks Nuclear Power Plant. Regarding this latter, radiocarbon, which is not included among the data for the planned Power Plant, is the 2nd concerning emitted activity. Although there may even be significant differences in the water treatment technology of the new and old units, the ^{14}C emission of the planned units is not presumed to be negligibly low, either. Annual emission is estimated in details in the hydrological chapter of this EIS. Accordingly, the annual presumed ^{14}C emission of the two units is $2.1 \cdot 10^9$ Bq.

radionuclide	waters not included in the water balance ZKD	regeneration water LCQ	regeneration water LD	total
	GBq/year			
^{3}H	$9.1 \cdot 10^{3}$			$9.1 \cdot 10^{3}$
^{131}I	$6.3 \cdot 10^{-4}$	$1.3 \cdot 10^{-2}$	$2.1 \cdot 10^{-2}$	$3.5 \cdot 10^{-2}$
^{132}I	$1.3 \cdot 10^{-3}$	$5.2 \cdot 10^{-4}$	$4.5 \cdot 10^{-4}$	$2.3 \cdot 10^{-3}$
^{133}I	$1.6 \cdot 10^{-3}$	$4.2 \cdot 10^{-3}$	$5.8 \cdot 10^{-3}$	$1.2 \cdot 10^{-2}$
^{134}I	$1.2 \cdot 10^{-3}$	$5.3 \cdot 10^{-5}$	$9.6 \cdot 10^{-5}$	$1.4 \cdot 10^{-3}$
^{135}I	$1.4 \cdot 10^{-3}$	$1.0 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$3.9 \cdot 10^{-3}$
^{89}Sr	$7.5 \cdot 10^{-6}$	$3.7 \cdot 10^{-6}$	$8.0 \cdot 10^{-4}$	$8.1 \cdot 10^{-4}$
^{90}Sr	$9.0 \cdot 10^{-8}$	$1.5 \cdot 10^{-8}$	$2.2 \cdot 10^{-6}$	$2.3 \cdot 10^{-6}$
^{134}Cs	$1.4 \cdot 10^{-2}$	$3.1 \cdot 10^{-5}$	$6.6 \cdot 10^{-2}$	$8.0 \cdot 10^{-2}$
^{137}Cs	$2.2 \cdot 10^{-2}$	$4.0 \cdot 10^{-5}$	$1.0 \cdot 10^{-1}$	$1.2 \cdot 10^{-1}$
^{51}Cr	$4.0 \cdot 10^{-4}$	$2.8 \cdot 10^{-6}$	$1.5 \cdot 10^{-4}$	$5.5 \cdot 10^{-4}$
^{54}Mn	$6.0 \cdot 10^{-4}$	$5.3 \cdot 10^{-8}$	$1.4 \cdot 10^{-5}$	$6.1 \cdot 10^{-4}$
^{60}Co	$2.4 \cdot 10^{-3}$	$6.5 \cdot 10^{-7}$	$9.7 \cdot 10^{-5}$	$2.5 \cdot 10^{-3}$
^{58}Co	$3.4 \cdot 10^{-4}$	$8.1 \cdot 10^{-8}$	$2.2 \cdot 10^{-4}$	$5.6 \cdot 10^{-4}$

Table 21.4.1-8: Fluid radioactive emissions in the Danube, by units [21-12]

The following data were used to model the effect of the planned two new units on aquatic habitats: annual standard industrial water emission data for the future two new units (extended with ^{14}C), converted to the emission ratios in Bq/s; 232 m^3/s volume flow rate in the Hot Water Canal with 33.5 m medium width and 4.5 m medium depth. The receptor point (the place where the Hot Water Canal flows in the Danube, V2 habitat) was set at 100 m distance from the emission point, and total mixing was presumed with the water of the Hot Water Canal and negligible mixing with that of the Danube. Based on various documents (IAEA-TRS-364, IAEA-TRS-472 and IAEA-SRS-19) and our own in-situ data, the following modifications were made to the default distribution coefficient (K_d) values: Sr: 400 l/kg, instead of 2000 l/kg; Cs: 30,000 l/kg, instead of 137,000 l/kg; Co: 44,000 l/kg, instead of 106,000 l/kg.

Some modifications (versus the default values) were similarly made in the concentration ratio values of the reference animals and plants because, according to the results of our experimental work performed on biological samples during the specific tests in preparation for this EIS, our calculated CR values are valid for the aquatic animals and plants in Table 21.4.1-9, in the environment of the Danube (Veres et. al. [21-9]).

organism	element	CR (l/kg)	
		ERICA	**Danube**
benthic fish	Sr	17	310
	Cs	6300	450
shellfish	Sr	270	1250
	Cs	460	190
pelagic fish	Sr	17	310
	Cs	7100	400
phytoplankton	Sr	40	360
	Cs	4700	940
vascular plant	Sr	250	390
	Cs	1160	570

Table 21.4.1-9: Location-specific concentration ratio values of reference oragnisms

The dose rate values calculated for the reference animals and plants are summarized in Table 21.4.1-10. For comparison, the table also shows the natural background dose rate data and their relative increment estimated for Paks II.

organism	dose rate, µGy/h			risk quotient RQ	background dose rate, µGy/h	relative increment, %
	external	internal	total			
amphibian	$3.48 \cdot 10^{-08}$	$9.96 \cdot 10^{-05}$	**$9.96 \cdot 10^{-05}$**	$9.96 \cdot 10^{-06}$	$1.30 \cdot 10^{-01}$	**0.08**
benthic fish	$4.19 \cdot 10^{-04}$	$3.06 \cdot 10^{-05}$	**$4.50 \cdot 10^{-04}$**	$4.50 \cdot 10^{-05}$	$1.74 \cdot 10^{-01}$	**0.26**
bird	$2.73 \cdot 10^{-08}$	$6.10 \cdot 10^{-05}$	**$6.10 \cdot 10^{-05}$**	$6.10 \cdot 10^{-06}$	$1.49 \cdot 10^{-01}$	**0.04**
shellfish	$4.59 \cdot 10^{-04}$	$2.90 \cdot 10^{-05}$	**$4.88 \cdot 10^{-04}$**	$4.88 \cdot 10^{-05}$	$5.98 \cdot 10^{00}$	**0.01**
crab	$5.12 \cdot 10^{-04}$	$7.69 \cdot 10^{-05}$	**$5.89 \cdot 10^{-04}$**	$5.89 \cdot 10^{-05}$	$2.53 \cdot 10^{00}$	**0.02**
snail	$4.79 \cdot 10^{-04}$	$4.68 \cdot 10^{-05}$	**$5.26 \cdot 10^{-04}$**	$5.26 \cdot 10^{-05}$	$3.61 \cdot 10^{00}$	**0.01**
insect larva	$1.02 \cdot 10^{-03}$	$7.79 \cdot 10^{-05}$	**$1.10 \cdot 10^{-03}$**	$1.10 \cdot 10^{-04}$	$2.60 \cdot 10^{00}$	**0.04**
mammal	$2.52 \cdot 10^{-08}$	$1.49 \cdot 10^{-04}$	**$1.49 \cdot 10^{-04}$**	$1.49 \cdot 10^{-05}$	$1.40 \cdot 10^{-01}$	**0.11**
pelagic fish	$3.74 \cdot 10^{-08}$	$2.99 \cdot 10^{-05}$	**$2.99 \cdot 10^{-05}$**	$2.99 \cdot 10^{-06}$	$1.43 \cdot 10^{-01}$	**0.02**
phytoplankton	$8.59 \cdot 10^{-06}$	$5.43 \cdot 10^{-05}$	**$6.29 \cdot 10^{-05}$**	$6.29 \cdot 10^{-06}$	$5.42 \cdot 10^{00}$	**0.001**
vascular plant	$3.58 \cdot 10^{-04}$	$2.79 \cdot 10^{-05}$	**$3.86 \cdot 10^{-04}$**	$3.86 \cdot 10^{-05}$	$3.46 \cdot 10^{00}$	**0.01**
zooplankton	$4.78 \cdot 10^{-08}$	$3.16 \cdot 10^{-05}$	**$3.16 \cdot 10^{-05}$**	$3.16 \cdot 10^{-06}$	$4.60 \cdot 10^{00}$	**0.001**

Table 21.4.1-10: Incremental radiation exposure (from the new units) of reference organisms, in V2 habitat.

As seen in the table, the estimated total dose rate increment for insect larvae that fully live in the sediment, i.e. that are the most exposed to artificial isotopes accumulating in the sediment is just 1 nGy/h, which means a 0.0001 risk quotient.

Relative to natural background, fishes living near the river bed suffer the biggest relative dose rate increment, though this is just max. 0.3% in magnitude. While being mixed with the Danube, the activity concentration of the water (and, simultaneously, of the sediment) continues to decrease, which means that even lesser dose rate increments can be expected further off from the outlet of the Hot Water Canal.

21.4.2 IMPACT AREAS OF THE OPERATION OF PAKS II

Appendix 7 to Government Decree 314/2005 (of 25.12.) determines the types of impact areas and the criteria of delimiting impact areas. As regards the types of impact areas, it specifically mentions the areas of direct and indirect impacts.

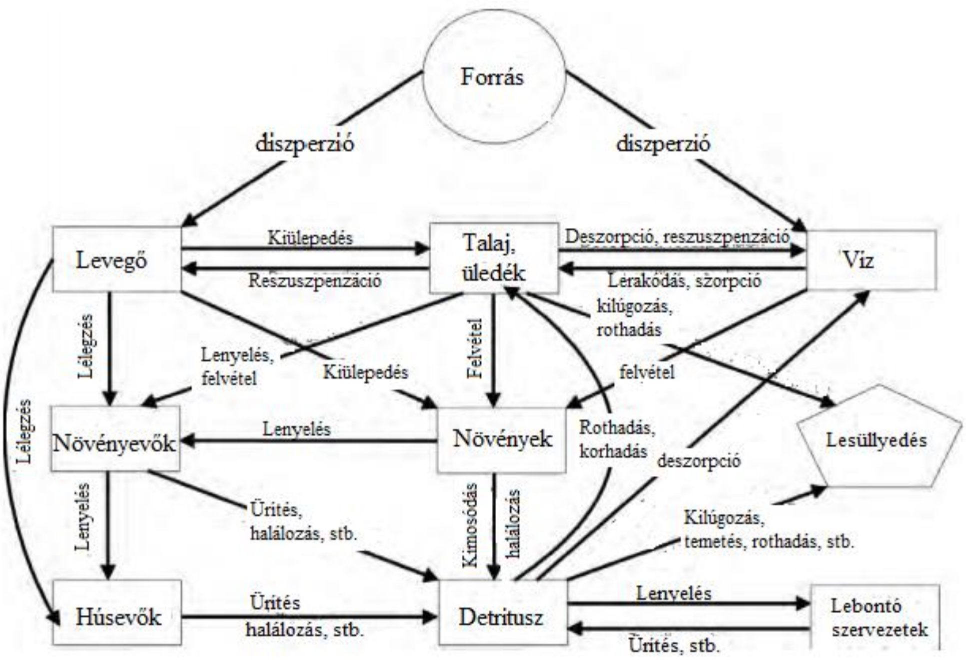
As concerns the radiation exposure of animals and plants, the area of direct impacts means, according to the terminology used in the legal regulation, an area that can be related to the radiation effect and is the dispersion area of emission into some environmental element (water, air), whereas the area of indirect impacts means the dispersion area of processes that advance in consequence of changes of state in the area of direct impacts.

The legal regulation also defines that a direct impact area is an area where emission is still detectable and that is presumed to cause some change in the state of the relevant environmental element. Moreover, the area of direct use of the environment can also be considered a direct impact area, however, this cannot be interpreted in this case with regard to the radiation exposure of animals and plants. The areas of indirect impacts can be delimited by estimation in the knowledge of the effects presumed in the direct impact area, considering the transmitting power and sensitivity of the affected environmental element or system.

This definition presumes two factors:

- the accurate, easily confinable and separable knowledge of direct and indirect impacts;
- the occurring direct impact causes some observable change in the tested environmental element or system.

In view of these considerations, we must clarify that radiation (as an effect on animals and plants in a specific environmental context) is coupled with a source (which can be some physical entity (e.g. the medium surrounding the animal/plant) or a process (e.g. nutrition or respiration)) which results in a determinative dose load. The radiation exposure of animals and plants is generated by ionizing radiation from various sources in the environment. During their life processes, they may be subject to several types of exposure situations. The factors potentially influencing the absorbed dose may be rather varied in every case. It should be noted here that the routes of exposure can also be highly varied within a specific environmental system, as demonstrated in Figure 21.4.2-1.



Forrás-Source
Diszperzió-Dispersion
Levegő-Air
Talaj, üledék-Soil, sediment
Víz-Water
Növényevők-Herbivores
Növények-Plants
Lesüllyedés-Subsidence
Húsevők-Carnivores
Detritusz-Detritus
Lebontó szervezetek-Saprophyte organisms
Kiülepedés-Settlement
Reszuszpenzáció-Resuspension
Deszorpció, reszuszpenzáció-Desorption, resuspension
Lerakódás, szorpció-Alluviation, sorption
Lélegzés-Respiration
Lenyelés, felvétel-Ingestion, intake
Kilúgozás, rothadás-Leaching, rotting
Felvétel-Intake
Lenyelés-Ingestion
Rothadás, korhadás-Rotting, putrefaction
Deszorpció-Desorption
Ürítés, halálozás stb.-Dejection, decease etc.
Kimosódás, halálozás-Wash-out, decease
Kilúgozás, temetés, rothadás stb.-Leaching, burial, rotting etc.
Ürítés stb.-Dejection etc.

Figure 21.4.2-1: Processes determining the movement of radionuclides in the ecosystem

The routes of exposure, which now again can be characterized with respect to a great number of factors, are rather important with regard to the radiation exposure of animals and plants (Figure 21.4.2-2). Depending on their life processes, individual animals and plants may be subject to radiation exposure along the most diverse routes. This impact can be direct when animals and plants get in contact with the medium that contains the emitted radionuclides and primarily transports them: external exposure from air or water; contamination of the skin, hair or feathering; inhalation of radionuclides or their direct intake from water, in case of aquatic organisms. In other cases, when radionuclides get into a secondary medium (from water to sediment, from air onto soil surface, and so subjecting the animals and plants in contact with the medium to a dose load; or getting in the food-chain in any secondary way: from plant to animal – herbivores; from animal to animal – carnivores), the impact is indirect.

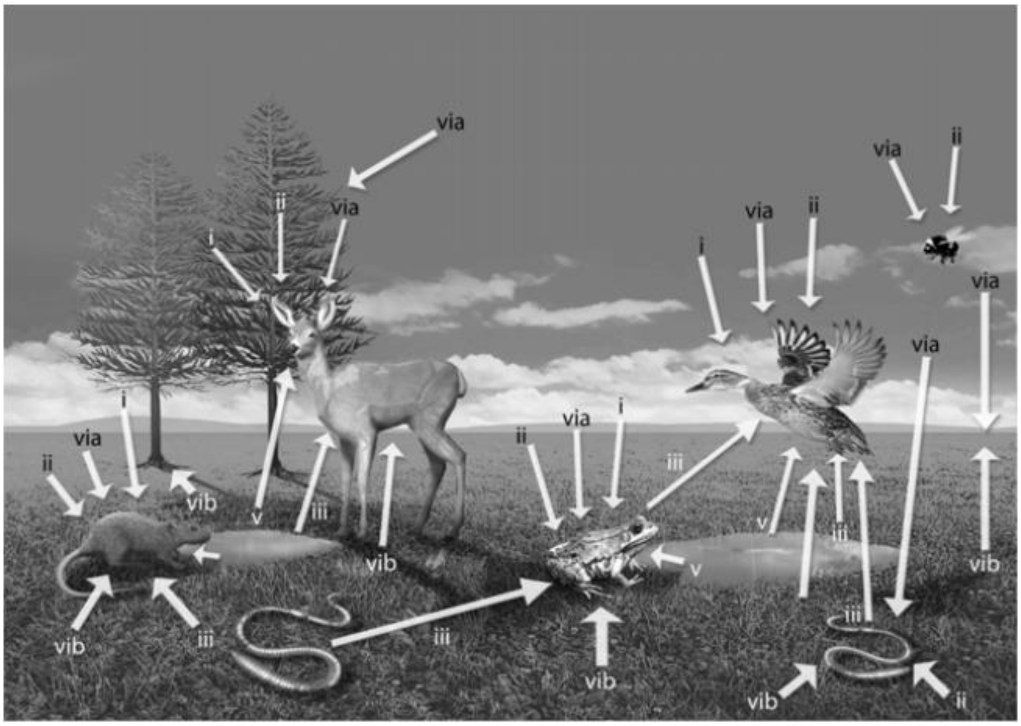


Figure 21.4.2-2: Terrestrial exposure routes

i: inhalation of particles or gas;
ii: contamination of hair, feather or skin;
iii: consuming the lower levels of the food-chain;
v: drinking polluted water;
vi: external exposure through air (a) or soil (b).

So the problem is that it is rather difficult to separate the direct and indirect impacts, considering that the aeriform or fluid radioactive materials that get in the environment enter the terrestrial or aquatic food-chain after or, in many cases, during their dispersion with air or water. Regarding atmospheric emissions, the key entry point to the food-chain is settlement onto the flora and the soil surface. Insects and birds may be subject to external and internal radiation exposure through air and by inhalation, respectively. In aquatic emissions, during dispersion and dilution processes, the external radiation exposure of aquatic animals and plants and the intake of radionuclides are both going on continuously. A part of the radionuclides settling on the plants has a direct impact, while some of those depositing on the soil are absorbed through the roots and indirectly cause the exposure of the plant due to atmospheric load. So the question arises: where can we draw a sharp borderline between indirect or direct impacts? The dose rate which in a specific moment causes direct external or internal exposure in air or water should, after settlement, be considered indirect impact.

The other problem in delimiting the impact area is: where should we draw the borderline wherein the impacts will bring about some change in the current conditions of animals and plants? What is considered an impact that causes a change? Since only recommendations are given in this matter at present and since there is no strict limit value, one of the options is to rely on the screening value which is in fact the no effect dose rate stated in 10 μGy/h value (based on our current knowledge) and potentially observed in animals and plants. However, the dose rate from standard operating emission, estimated for animals and plants, does not seem to reach this value in any location in the environment of the Power Plant, as concluded from the base level assessment, and the same applies to planned emissions. Proceeding from the fact that in human radiological protection (relevant to the population) the basic dose limit is set at a certain fraction of natural radiation exposure, a similar consideration could perhaps be acceptable for animals and plants in general. We could perhaps set a tenth of the background radiation exposure of the specific species at a specific place as the desired limit. Compared to the 0.2-0.5 μGy/h dose rate estimated for terrestrial animals and plants, this means ~10^{-2} μGy/h which, based on the data in Table 21.4.1-7, total anthropogenic radiation exposure will use to just ~ 10%, even after the commissioning of the new units. The estimated increment of the planned units (relative to the dose rate from natural sources) is shown in the below figures, in impact area maps for some animals and plants.

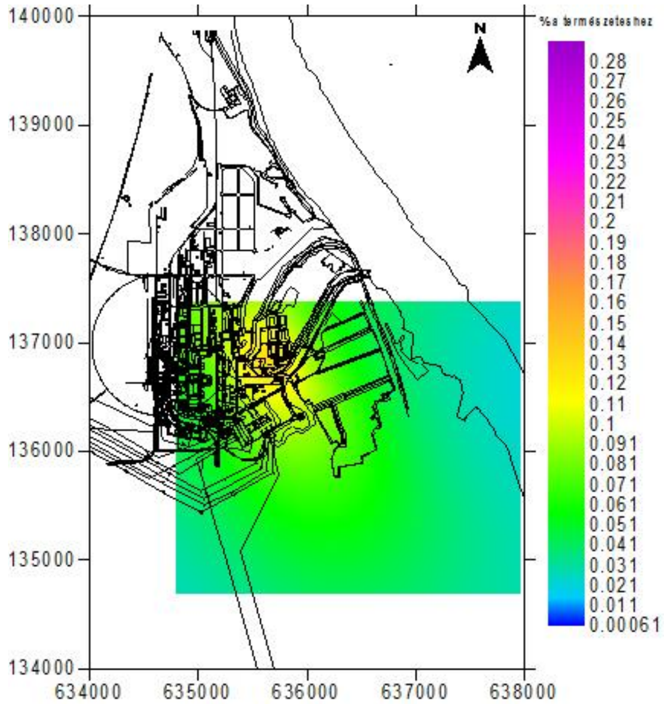


Figure 21.4.2-3: Territorial trends in the incremental radiation exposure of big mammals, in ordinary operation, relative to the natural background.

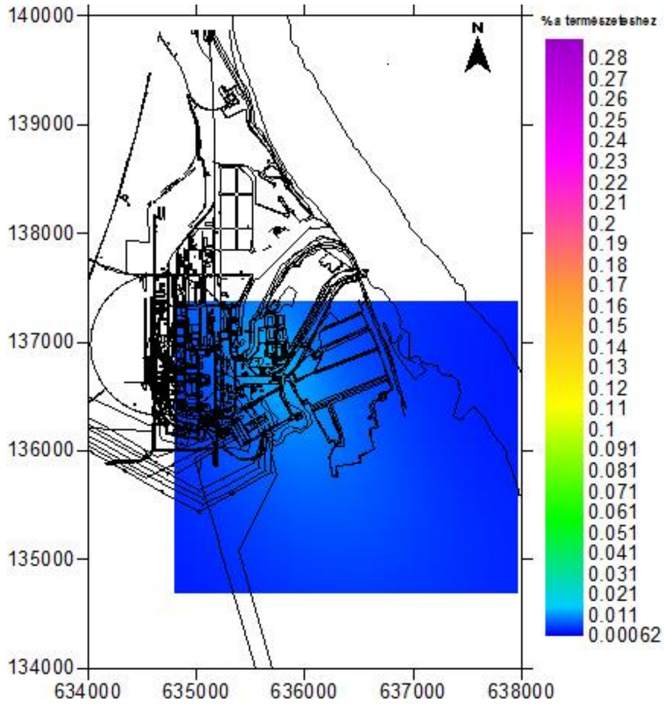


Figure 21.4.2-4: Territorial trends in the incremental radiation exposure of worms, in ordinary operation, relative to the natural background.

The maps depict the most exposed quarter (between E and S). The relation to the background dose rate is shown with an identical colour scale in each figure. The figure highlights that even with the most exposed trees the maximum increment of the planned power plant units is just around 0.25% of background radiation exposure, this being expressly within the site. Nowhere along the direct borderline of the site (in any other direction) does it reach a thousandth of the natural background load. The figures are even “better” with other terrestrial creatures: practically speaking, just a thousandth of natural radiation exposure applies even within the site.

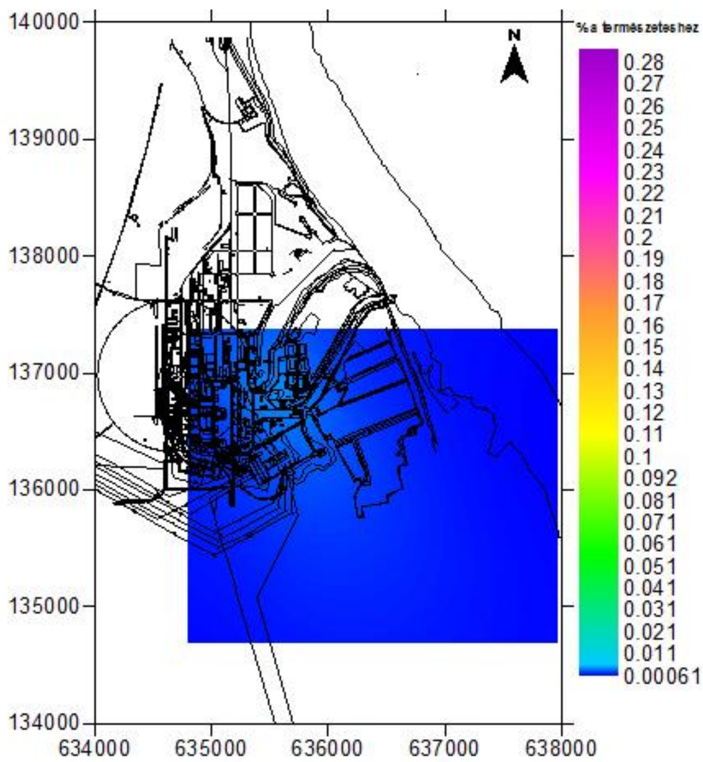


Figure 21.4.2-5: Territorial trends in the incremental radiation exposure of mosses/lichens, in ordinary operation, relative to the natural background.

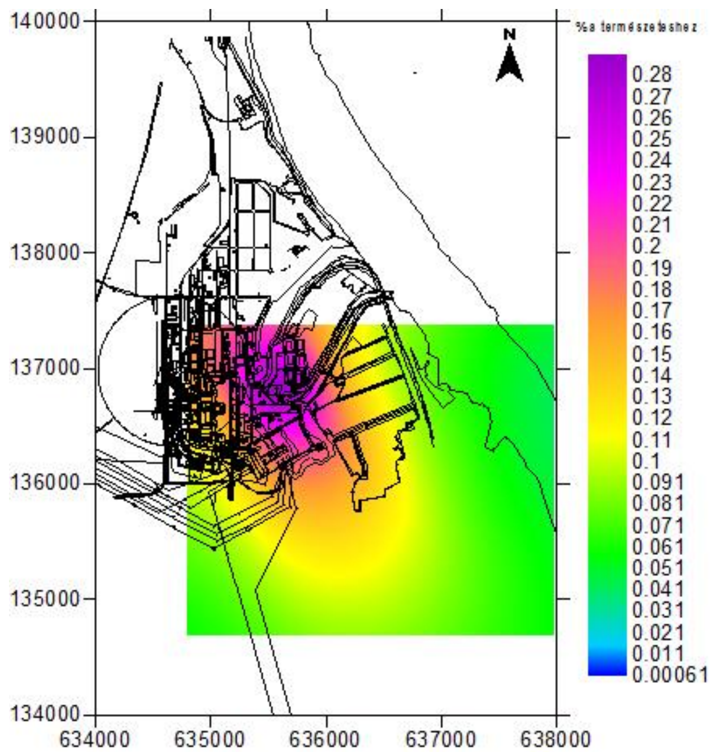


Figure 21.4.2-6: Territorial trends in the incremental radiation exposure of trees, in ordinary operation, relative to the natural background.

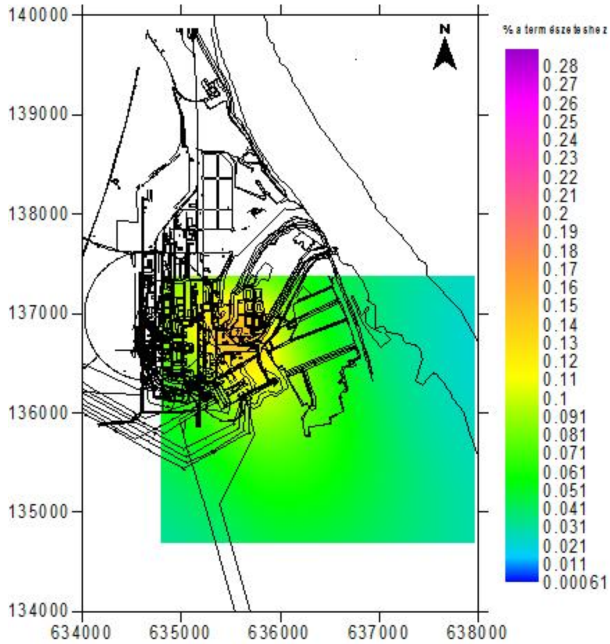


Figure 21.4.2-7: Territorial trends in the incremental radiation exposure of snails, in ordinary operation, relative to the natural background.

According to the results presented above, the newly installed units will add insignificant incremental dose rate to actual natural radiation exposure, but even relative to global load by the time of commissioning, their increment is estimated to reach a thousandth in magnitude. So we can state that even under these discretionary conditions (which are strict even relative to expectations in human radiological protection) the new units will have a neutral impact on nearby animals and plants, so under ordinary operating conditions the units will not, even in the areas most exposed to expected radiation exposure, influence the condition of the animals and plants in the surrounding terrestrial areas.

A similar concept was used to delimit the impact area of aquatic emissions. Based on the activity concentrations of the radionuclides emitted into the Danube and using the conditions, accumulation and leaching parameters typical of the Danube section after V2, we identified the bed section with the maximum activity concentration of radionuclides in the specific medium. The designated section is a habitat 100 m from the emission point. The dose rate increments characterizing the condition of reference animals and plants were calculated for this point. Just as for terrestrial habitats, here again we presumed that animals and plants would spend their entire lifecycle in this designated area. The results led to the statement that under ordinary operating conditions the presumable dose rate increment is, even with the most exposed animals and plants, so small that it fails to cause any observable change in their condition.

21.4.2.1 Area of direct impacts

Considering the dispersion routes of emissions anticipated under ordinary operating conditions, the area of direct impacts was characterized with the presumed maximum load values for both terrestrial and aquatic habitats. The incremental radiation exposure of animals and plants was estimated for these areas and, concluding from that, we stated, relying on the terminology in the legal regulation, that under ordinary operating conditions a direct impact area cannot be delimited from the aspect of animals and plants because, although emission is still perceptible in the tested areas, it does not make any change in the condition of the affected environmental element (which in this case means animals and plants).

21.4.2.2 Area of indirect impacts

Since no direct impact area can be delimited under ordinary operating conditions, no indirect impact area can be delimited, either. For the reasons mentioned earlier, we could only study direct and indirect impacts together, noting however that the size of load presumed in the tested areas fails to reach the level whereby, even if proceeding through any impact process, it could make any change in the condition of animals and plants in other areas.

21.4.2.3 Area of cross-border environmental effects

The size of the incremental dose rate of animals and plants does not influence the condition of animals and plants in the direct environment of the Power Plant, not even in the most exposed habitats, so, under ordinary operating conditions, we do not have to count with any impacts in the radiation exposure of animals and plants that could potentially cross the country border.

21.4.3 EFFECT OF THE JOINT OPERATION OF PAKS II AND PAKS NUCLEAR POWER PLANT

Relying on 8 years' archived detailed meteorological data and the Russian party's design-phase atmospheric emission inventory, in Section 21.4.1 we identified the area where the planned power plant units can cause maximum radiation exposure in ordinary operation. The operation of the two neighbouring power plants evidently implies the presence of constantly parallel dispersing radioactive plumes that winds deliver in a way determined by the approx. 600 m distance between the emission points. Due to the relatively big distance between the source points, the two plumes can meet only with N or S wind. In this case, which is otherwise rather rare, the impacts of the two plumes add up, nevertheless, the radioactive concentrations specifying the individual components of external radiation exposure (Bq/m^3, Bq/m^2s) strongly depend by location in a some hundred meter environment of the emission points, so the joint impact will only increase to a slight extent in the direction of the wind, though the maximum widens and monotonous decrease flattens out. This area practically covers the industrial buildings of the power plant units to the N and S. For any other wind direction, the joint impact can only be estimated for a relatively long period because changes in wind direction generate an impact in a specific area, but at different times.

Figure 21.4.3-1 clearly illustrates that e.g. emission from Paks Nuclear Power Plant will affect the maximum exposure area of the planned units (sectors 12, 13 and 14 in the 500-1000 m range) if W-SW winds blow and the plume heads toward sectors 5-6-7-8-9-10-11. In this case the area most affected by Paks II is 250-850 m from the emission point.

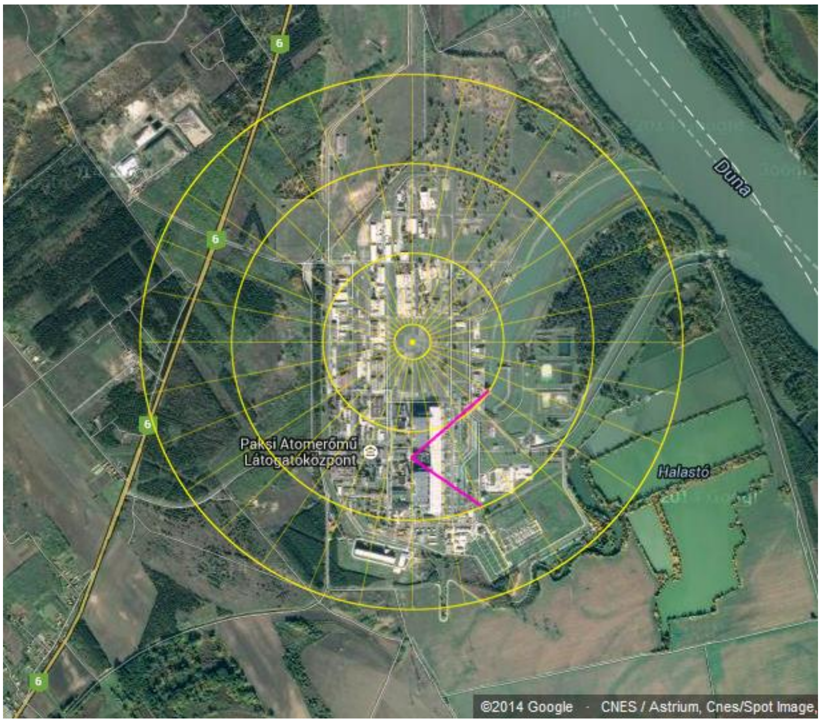


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Figure 21.4.3-1: Illustrating the joint impact of Paks II and Paks Nuclear Power Plant.

The purple "duck beak" in the figure within the 500 m and 1000 m range covers indicated sector 3: the fall-out and leaching reaching this area from Paks Nuclear Power Plant and the cloud dose here make up the increment of the Nuclear Power Plant. To determine this figure, we performed some runs with the detailed meteorological data of the past 8 years, as described in Section 21.4.1, and from the results we studied the radioactivity of the cloud dose, the dry/wet fall-out and the soil in 5 distances each. The statistical distribution of data resulting from several decades of operation, relevant to the receptor area and concerning the radioactivity of near-soil air or soil, is summarized in Table 21.4.3-1, in a breakdown to the individual isotopes listed in the emission inventory.

emitted isotope	air, Bq/m³			soil, Bq/kg	
	5 %	average	95 %	average	deviation
^{3}H	$6.86 \cdot 10^{-04}$	$3.39 \cdot 10^{-03}$	$1.68 \cdot 10^{-02}$		
^{14}C	$1.09 \cdot 10^{-04}$	$5.46 \cdot 10^{-04}$	$2.75 \cdot 10^{-03}$		
^{41}Ar	$2.36 \cdot 10^{-03}$	$1.19 \cdot 10^{-02}$	$5.95 \cdot 10^{-02}$		
^{85}Kr	$2.81 \cdot 10^{-05}$	$3.79 \cdot 10^{-04}$	$5.11 \cdot 10^{-03}$		
^{85m}Kr	$5.71 \cdot 10^{-04}$	$2.99 \cdot 10^{-03}$	$1.57 \cdot 10^{-02}$		
^{87}Kr	$2.23 \cdot 10^{-04}$	$1.84 \cdot 10^{-03}$	$1.52 \cdot 10^{-02}$		
^{88}Kr	$3.55 \cdot 10^{-04}$	$2.38 \cdot 10^{-03}$	$1.60 \cdot 10^{-02}$		
^{133}Xe	$5.52 \cdot 10^{-04}$	$3.73 \cdot 10^{-03}$	$2.53 \cdot 10^{-02}$		
^{135}Xe	$6.89 \cdot 10^{-04}$	$3.97 \cdot 10^{-03}$	$2.29 \cdot 10^{-02}$		
^{24}Na	$1.50 \cdot 10^{-08}$	$7.10 \cdot 10^{-08}$	$3.37 \cdot 10^{-07}$	$2.44 \cdot 10^{-07}$	$1.36 \cdot 10^{-07}$
^{54}Mn	$3.95 \cdot 10^{-10}$	$6.01 \cdot 10^{-09}$	$9.12 \cdot 10^{-08}$	$3.22 \cdot 10^{-05}$	$7.37 \cdot 10^{-05}$
^{58}Co	$2.59 \cdot 10^{-10}$	$3.35 \cdot 10^{-09}$	$4.32 \cdot 10^{-08}$	$2.68 \cdot 10^{-06}$	$5.24 \cdot 10^{-06}$
^{60}Co	$1.69 \cdot 10^{-09}$	$2.17 \cdot 10^{-08}$	$2.79 \cdot 10^{-07}$	$4.96 \cdot 10^{-04}$	$9.50 \cdot 10^{-04}$
^{65}Zn	$1.02 \cdot 10^{-09}$	$5.09 \cdot 10^{-09}$	$2.54 \cdot 10^{-08}$	$6.98 \cdot 10^{-06}$	$4.43 \cdot 10^{-06}$
^{89}Sr	$1.43 \cdot 10^{-11}$	$7.86 \cdot 10^{-11}$	$4.33 \cdot 10^{-10}$	$2.19 \cdot 10^{-08}$	$1.38 \cdot 10^{-08}$
^{90}Sr	$1.77 \cdot 10^{-11}$	$9.92 \cdot 10^{-11}$	$5.56 \cdot 10^{-10}$	$4.36 \cdot 10^{-06}$	$3.11 \cdot 10^{-06}$
^{95}Nb	$3.40 \cdot 10^{-10}$	$3.33 \cdot 10^{-09}$	$3.27 \cdot 10^{-08}$	$9.20 \cdot 10^{-07}$	$1.37 \cdot 10^{-06}$
^{103}Ru	$4.53 \cdot 10^{-10}$	$2.16 \cdot 10^{-09}$	$1.03 \cdot 10^{-08}$	$4.72 \cdot 10^{-07}$	$2.71 \cdot 10^{-07}$
^{106}Ru	$1.26 \cdot 10^{-09}$	$9.94 \cdot 10^{-09}$	$7.87 \cdot 10^{-08}$	$2.91 \cdot 10^{-05}$	$3.27 \cdot 10^{-05}$
^{110m}Ag-	$1.12 \cdot 10^{-09}$	$7.86 \cdot 10^{-09}$	$5.52 \cdot 10^{-08}$	$1.28 \cdot 10^{-05}$	$1.33 \cdot 10^{-05}$
^{131}I equivalent	$1.63 \cdot 10^{-08}$	$1.30 \cdot 10^{-07}$	$1.04 \cdot 10^{-06}$	$2.62 \cdot 10^{-05}$	$3.14 \cdot 10^{-05}$
^{134}Cs	$2.22 \cdot 10^{-10}$	$2.84 \cdot 10^{-09}$	$3.65 \cdot 10^{-08}$	$2.52 \cdot 10^{-05}$	$4.85 \cdot 10^{-05}$
^{135}Cs	$3.57 \cdot 10^{-16}$	$2.34 \cdot 10^{-15}$	$1.53 \cdot 10^{-14}$	$1.44 \cdot 10^{-10}$	$1.05 \cdot 10^{-10}$
^{137}Cs	$3.15 \cdot 10^{-09}$	$2.58 \cdot 10^{-08}$	$2.12 \cdot 10^{-07}$	$1.47 \cdot 10^{-03}$	$1.97 \cdot 10^{-03}$

Table 21.4.3-1: Statistical distribution of activity concentrations from Paks Nuclear Power Plant, in the max. impact area of Paks II

organism	dose rate, µGy/h			max. risk quotient (RQ)
	5 %	average	95 %	
amphibian	$1.84 \cdot 10^{-05}$	**$1.14 \cdot 10^{-04}$**	$5.12 \cdot 10^{-04}$	$5.12 \cdot 10^{-05}$
bird	$2.53 \cdot 10^{-05}$	**$1.43 \cdot 10^{-04}$**	$6.49 \cdot 10^{-04}$	$6.49 \cdot 10^{-05}$
bird's egg	$1.92 \cdot 10^{-05}$	**$1.04 \cdot 10^{-04}$**	$4.59 \cdot 10^{-04}$	$4.59 \cdot 10^{-05}$
saprophyte invertebrate	$8.13 \cdot 10^{-06}$	**$4.09 \cdot 10^{-05}$**	$1.71 \cdot 10^{-04}$	$1.71 \cdot 10^{-05}$
flying insect	$3.34 \cdot 10^{-05}$	**$1.70 \cdot 10^{-04}$**	$8.19 \cdot 10^{-04}$	$8.19 \cdot 10^{-05}$
snail	$3.66 \cdot 10^{-05}$	**$1.84 \cdot 10^{-04}$**	$8.81 \cdot 10^{-04}$	$8.81 \cdot 10^{-05}$
grasses and herbs	$2.24 \cdot 10^{-05}$	**$1.19 \cdot 10^{-04}$**	$5.41 \cdot 10^{-04}$	$5.41 \cdot 10^{-05}$
lichen/moss	$2.09 \cdot 10^{-05}$	**$1.12 \cdot 10^{-04}$**	$5.08 \cdot 10^{-04}$	$5.08 \cdot 10^{-05}$
big mammal	$1.07 \cdot 10^{-05}$	**$6.98 \cdot 10^{-05}$**	$2.72 \cdot 10^{-04}$	$2.72 \cdot 10^{-05}$
small mammal	$5.20 \cdot 10^{-06}$	**$4.43 \cdot 10^{-05}$**	$1.58 \cdot 10^{-04}$	$1.58 \cdot 10^{-05}$
reptilian	$1.45 \cdot 10^{-05}$	**$7.73 \cdot 10^{-05}$**	$3.12 \cdot 10^{-04}$	$3.12 \cdot 10^{-05}$
bush	$2.39 \cdot 10^{-05}$	**$1.18 \cdot 10^{-04}$**	$5.39 \cdot 10^{-04}$	$5.39 \cdot 10^{-05}$
soil invertebrate (worm)	$2.63 \cdot 10^{-06}$	**$1.62 \cdot 10^{-05}$**	$4.36 \cdot 10^{-05}$	$4.36 \cdot 10^{-06}$
tree	$2.32 \cdot 10^{-05}$	**$1.25 \cdot 10^{-04}$**	$5.62 \cdot 10^{-04}$	$5.62 \cdot 10^{-05}$

Table 21.4.3-2: Statistical distribution of total dose rate increment, and maximum risk quotient values.

Cloud dose rate for this area: 5%: 6.58 pGy/h; average: 32.4 pGy/h; 95%: 159 pGy/h for big mammals. The total incremental radiation exposure (from Paks Nuclear Power Plant) of the individual reference animals and plants is given in Table 21.4.3-2.

Although the average values in the table above represent very little increment, the joint impact on any group of species can be assessed from the cumulated impact of the two power plants, which is shown in Table 21.4.3-3. The last column in the same table lists the relative increment of Paks Nuclear Power Plant which seems to be consequently at around 30%.

organism	dose rate, µGy/h			joint risk quotient (RQ)	Paks Nuclear Power Plant / Paks II
	Paks Nuclear Power Plant	Paks II	cumulated		
amphibian	$1.14 \cdot 10^{-04}$	$3.97 \cdot 10^{-04}$	$5.11 \cdot 10^{-04}$	$5.11 \cdot 10^{-05}$	0.29
bird	$1.43 \cdot 10^{-04}$	$4.72 \cdot 10^{-04}$	$6.15 \cdot 10^{-04}$	$6.15 \cdot 10^{-05}$	0.30
bird's egg	$1.04 \cdot 10^{-04}$	$3.53 \cdot 10^{-04}$	$4.59 \cdot 10^{-04}$	$4.59 \cdot 10^{-05}$	0.29
saprophyte invertebrate	$4.09 \cdot 10^{-05}$	$1.86 \cdot 10^{-04}$	$2.27 \cdot 10^{-04}$	$2.27 \cdot 10^{-05}$	0.22
flying insect	$1.70 \cdot 10^{-04}$	$4.46 \cdot 10^{-04}$	$6.16 \cdot 10^{-04}$	$6.16 \cdot 10^{-05}$	0.38
snail	$1.84 \cdot 10^{-04}$	$4.81 \cdot 10^{-04}$	$6.65 \cdot 10^{-04}$	$6.65 \cdot 10^{-05}$	0.38
grasses and herbs	$1.19 \cdot 10^{-04}$	$3.77 \cdot 10^{-04}$	$4.96 \cdot 10^{-04}$	$4.96 \cdot 10^{-05}$	0.32
lichen/moss	$1.12 \cdot 10^{-04}$	$3.54 \cdot 10^{-04}$	$4.66 \cdot 10^{-04}$	$4.66 \cdot 10^{-05}$	0.32
big mammal	$6.98 \cdot 10^{-05}$	$3.21 \cdot 10^{-04}$	$3.91 \cdot 10^{-04}$	$3.91 \cdot 10^{-05}$	0.22
small mammal	$4.43 \cdot 10^{-05}$	$2.93 \cdot 10^{-04}$	$3.36 \cdot 10^{-04}$	$3.36 \cdot 10^{-05}$	0.15
reptilian	$7.73 \cdot 10^{-05}$	$3.44 \cdot 10^{-04}$	$4.21 \cdot 10^{-04}$	$4.21 \cdot 10^{-05}$	0.22
bush	$1.18 \cdot 10^{-04}$	$3.90 \cdot 10^{-04}$	$5.08 \cdot 10^{-04}$	$5.08 \cdot 10^{-05}$	0.30
soil invertebrate (worm)	$1.62 \cdot 10^{-05}$	$1.24 \cdot 10^{-04}$	$1.40 \cdot 10^{-04}$	$1.40 \cdot 10^{-05}$	0.13
tree	$1.25 \cdot 10^{-04}$	$4.48 \cdot 10^{-04}$	$5.73 \cdot 10^{-04}$	$5.73 \cdot 10^{-05}$	0.28

Table 21.4.3-3: Comparison of total average dose rate increments in common receptor area.

It should be noted in connection with the analysis of joint impact that this analysis is conservative because several decades-long common operation was presumed for Paks Nuclear Power Plant as well, though, as well known, the units are expected to be finally stopped with a gradual start from 2032 and, concurrently, the incremental radiation exposure defined herein will discontinue in 4 steps.

The joint effect of the existing and planned power plant units should also be studied by estimating the anticipated effect of the two new units for the area of Paks Nuclear Power Plant with maximum exposure. Although true, this area, which is 500-1000 m SE from the current atmospheric emission points, is as much as approx. 1500 m from the planned chimneys, still, it is in the prevailing wind direction so (considering a somewhat bigger emission speed) the additional effect can be bigger than in the situation discussed earlier.

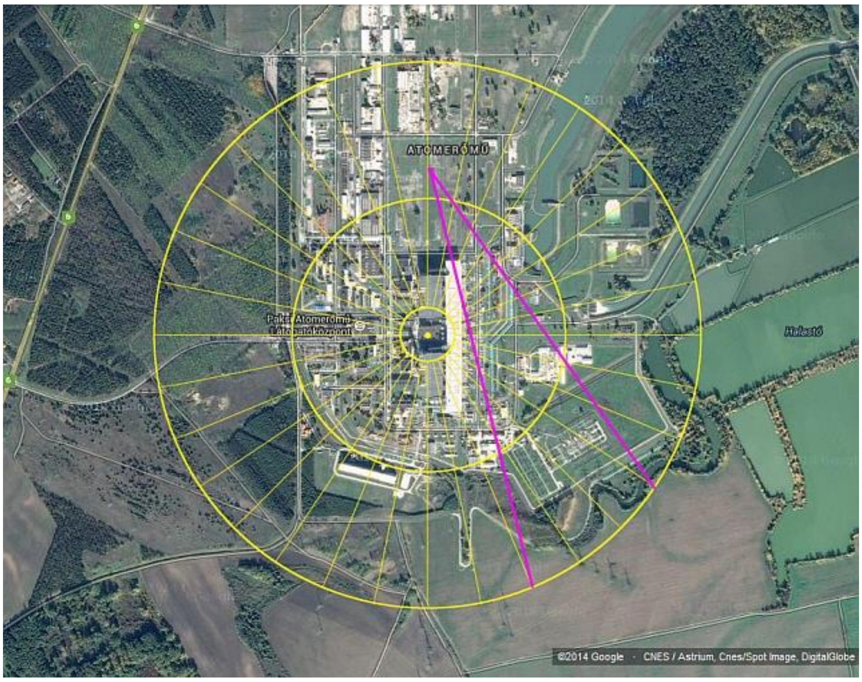

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Figure 21.4.3-2: Illustrating the joint impact of Paks Nuclear Power Plant and Paks II.

Figure 21.4.3-2 illustrates this case similar to Figure 21.4.3-1 Here the purple "duck beak" points at the external border (1000 m) of sectors 12-13-14 that add the maximal dose rate to the animals and plants due to Paks Nuclear Power Plant. From the emission points of the new units, this falls in sectors 14-15-16. Here the anticipated impact of Paks II was tested in the 1000-1500 m range, with the method detailed above, at Tier 3 in ERICA Program. Based on the statistical distribution of data resulting from modelling several decades of operation, the dose rates for the individual reference animals and plants are summarized in Table 21.4.3-4. Prognosticated incremental radiation exposure is in the tenth nGy/h magnitude for practically all the animals and plants. These data should be compared with the values given in Table 21.4.1-7 for the maximum impact of Paks Nuclear Power Plant. For simple comparability, this is also shown in Table 21.4.3-5 which summarizes joint impact. As the table suggests, practically speaking the same dose rate values were received for almost all the animals and plants, so after the commissioning of the two planned units the impact on animals and plants will be doubled here. However, owing to the gradual stoppage of the currently operating units, the "old" conditions will slowly be restored in this small area around the southern borderline of the site and the western half of Lake Kondor.

organism	**dose rate, µGy/h**			**max. risk quotient (RQ)**
	5%	**average**	**95%**	
amphibian	$5.76 \cdot 10^{-05}$	$1.96 \cdot 10^{-04}$	$5.20 \cdot 10^{-04}$	$5.20 \cdot 10^{-05}$
bird	$7.61 \cdot 10^{-05}$	$2.43 \cdot 10^{-04}$	$6.45 \cdot 10^{-04}$	$6.45 \cdot 10^{-05}$
bird's egg	$5.61 \cdot 10^{-05}$	$1.83 \cdot 10^{-04}$	$4.87 \cdot 10^{-04}$	$4.87 \cdot 10^{-05}$
saprophyte invertebrate	$2.44 \cdot 10^{-05}$	$8.32 \cdot 10^{-05}$	$2.05 \cdot 10^{-04}$	$2.05 \cdot 10^{-05}$
flying insect	$9.67 \cdot 10^{-05}$	$2.81 \cdot 10^{-04}$	$7.46 \cdot 10^{-04}$	$7.46 \cdot 10^{-05}$
snail	$1.06 \cdot 10^{-04}$	$3.06 \cdot 10^{-04}$	$8.15 \cdot 10^{-04}$	$8.15 \cdot 10^{-05}$
grasses and herbs	$6.57 \cdot 10^{-05}$	$2.11 \cdot 10^{-04}$	$5.63 \cdot 10^{-04}$	$5.63 \cdot 10^{-05}$
lichen/moss	$6.23 \cdot 10^{-05}$	$1.93 \cdot 10^{-04}$	$5.04 \cdot 10^{-04}$	$5.04 \cdot 10^{-05}$
big mammal	$3.20 \cdot 10^{-05}$	$1.33 \cdot 10^{-04}$	$3.36 \cdot 10^{-04}$	$3.36 \cdot 10^{-05}$
small mammal	$2.39 \cdot 10^{-05}$	$1.00 \cdot 10^{-04}$	$2.56 \cdot 10^{-04}$	$2.56 \cdot 10^{-05}$
reptilian	$4.23 \cdot 10^{-05}$	$1.53 \cdot 10^{-04}$	$3.79 \cdot 10^{-04}$	$3.79 \cdot 10^{-05}$
bush	$6.71 \cdot 10^{-05}$	$2.11 \cdot 10^{-04}$	$5.53 \cdot 10^{-04}$	$5.53 \cdot 10^{-05}$
soil invertebrate (worm)	$8.95 \cdot 10^{-06}$	$4.06 \cdot 10^{-05}$	$9.93 \cdot 10^{-05}$	$9.93 \cdot 10^{-06}$
tree	$6.79 \cdot 10^{-05}$	$2.36 \cdot 10^{-04}$	$6.42 \cdot 10^{-04}$	$6.42 \cdot 10^{-05}$

Table 21.4.3-4: Statistical distribution of the total dose rate increment of Paks II, and maximum risk quotient values.

organism	**dose rate, µGy/h**			**joint risk quotient (RQ)**	**Paks Nuclear Power Plant / Paks II**
	Paks Nuclear Power Plant	**Paks II**	**jointly**		
amphibian	$1.95 \cdot 10^{-04}$	$1.96 \cdot 10^{-04}$	$3.91 \cdot 10^{-04}$	$3.91 \cdot 10^{-05}$	0.99
bird	$2.44 \cdot 10^{-04}$	$2.43 \cdot 10^{-04}$	$4.87 \cdot 10^{-04}$	$4.87 \cdot 10^{-05}$	1.00
bird's egg	$1.79 \cdot 10^{-04}$	$1.83 \cdot 10^{-04}$	$3.62 \cdot 10^{-04}$	$3.62 \cdot 10^{-05}$	0.98
saprophyte invertebrate	$7.51 \cdot 10^{-05}$	$8.32 \cdot 10^{-05}$	$1.58 \cdot 10^{-04}$	$1.58 \cdot 10^{-05}$	0.90
flying insect	$2.82 \cdot 10^{-04}$	$2.81 \cdot 10^{-04}$	$5.63 \cdot 10^{-04}$	$5.63 \cdot 10^{-05}$	1.00
snail	$3.05 \cdot 10^{-04}$	$3.06 \cdot 10^{-04}$	$6.11 \cdot 10^{-04}$	$6.11 \cdot 10^{-05}$	1.00
grasses and herbs	$2.05 \cdot 10^{-04}$	$2.11 \cdot 10^{-04}$	$4.16 \cdot 10^{-04}$	$4.16 \cdot 10^{-05}$	0.97
lichen/moss	$1.90 \cdot 10^{-04}$	$1.93 \cdot 10^{-04}$	$3.82 \cdot 10^{-04}$	$3.82 \cdot 10^{-05}$	0.98
big mammal	$1.30 \cdot 10^{-04}$	$1.33 \cdot 10^{-04}$	$2.63 \cdot 10^{-04}$	$2.63 \cdot 10^{-05}$	0.98
small mammal	$9.60 \cdot 10^{-05}$	$1.00 \cdot 10^{-04}$	$1.96 \cdot 10^{-04}$	$1.96 \cdot 10^{-05}$	0.96
reptilian	$1.49 \cdot 10^{-04}$	$1.53 \cdot 10^{-04}$	$3.03 \cdot 10^{-04}$	$3.03 \cdot 10^{-05}$	0.98
bush	$2.05 \cdot 10^{-04}$	$2.11 \cdot 10^{-04}$	$4.15 \cdot 10^{-04}$	$4.15 \cdot 10^{-05}$	0.97
soil invertebrate	$3.18 \cdot 10^{-05}$	$4.06 \cdot 10^{-05}$	$7.25 \cdot 10^{-05}$	$7.25 \cdot 10^{-06}$	0.78
tree	$2.35 \cdot 10^{-04}$	$2.36 \cdot 10^{-04}$	$4.71 \cdot 10^{-04}$	$4.71 \cdot 10^{-05}$	0.99

Table 21.4.3-5: Comparison of total average dose rate increments in the joint receptor area.

In summary, concerning the impact of joint operation of the old and planned units: the maximal anticipated dose rates affecting animals and plants will apply in the area of the site, and the currently operating and future units will have a roughly 1:3 share. A mere approx. 75% of the above maximum, i.e. typically 0.3-0.4 nGy/h is anticipated in the direct southern vicinity of the site, which is just a few thousandths of the estimated natural radiation exposure.

The joint impact of fluid emissions from the two power plants was tested in V2 habitat around the outlet of the Hot Water Canal. Incremental radiation exposure originating from the planned two new units was compared with incremental radiation exposure from the existing 4 units of Paks Nuclear Power Plant and the global artificial isotopes, relevant to planned launch by 2025. To model the impact of these two latter units, we used the activity concentrations stated in the specific test underlying this EIS for the Hot Water Canal and typical of power plant isotopes and the data characterizing global artificial isotopes under 2013 conditions, but with the below corrections:

- Since average water flow in the Hot Water Canal will increase from the current ~100 m^3/s to 232 m^3/s, the activity concentrations generated in V2 habitat from the fluid emission of Paks Nuclear Power Plant will decrease with over a factor of two.
- The activity concentrations of global artificial ^{137}Cs and ^{90}Sr will decrease by ~0.4 half-time radioactive disintegration in 12 years (by 2025).

The corrected activity concentrations and the results from model calculation are summarized in Table 21.4.3-6 and Table 21.4.3-7, respectively.

	Paks Nuclear Power Plant		**global artificial**	
	sludge	**water**	**sludge**	**water**
	Bq/kg	**mBq/l**	**Bq/kg**	**mBq/l**
^{137}Cs	4.3	0.3	15	0.4
^{90}Sr	0.1	0.2	0.3	0.7
^{60}Co	0.9	3.1	0	0
T	-	500	0	0
^{14}C	-	0.2	0	0

Table 21.4.3-6: Concentration of artificial isotopes in the Hot Water Canal.

organism	**total dose rate, µGy/h**				**Paks II increment to total power plant value, %**	**Paks II increment to total artificial, %**
	Paks II	**Paks Nuclear Power Plant**	**global**	**total**		
amphibian	$9.96\cdot10^{-05}$	$5.18\cdot10^{-04}$	$5.65\cdot10^{-04}$	$\mathbf{1.18\cdot10^{-03}}$	16.1	8.4
benthic fish	$5.13\cdot10^{-04}$	$1.89\cdot10^{-03}$	$2.59\cdot10^{-03}$	$\mathbf{5.00\cdot10^{-03}}$	21.3	10.3
bird	$6.10\cdot10^{-05}$	$5.49\cdot10^{-04}$	$2.36\cdot10^{-04}$	$\mathbf{8.45\cdot10^{-04}}$	10.0	7.2
shellfish	$4.90\cdot10^{-04}$	$1.61\cdot10^{-03}$	$2.48\cdot10^{-03}$	$\mathbf{4.57\cdot10^{-03}}$	23.4	10.7
crab	$5.89\cdot10^{-04}$	$2.04\cdot10^{-03}$	$3.27\cdot10^{-03}$	$\mathbf{5.90\cdot10^{-03}}$	22.4	10.0
snail	$5.26\cdot10^{-04}$	$2.32\cdot10^{-03}$	$2.75\cdot10^{-03}$	$\mathbf{5.60\cdot10^{-03}}$	18.5	9.4
insect larva	$1.10\cdot10^{-03}$	$4.87\cdot10^{-03}$	$6.12\cdot10^{-03}$	$\mathbf{1.21\cdot10^{-02}}$	18.5	9.1
mammal	$1.49\cdot10^{-04}$	$1.09\cdot10^{-03}$	$7.89\cdot10^{-04}$	$\mathbf{2.02\cdot10^{-03}}$	12.1	7.4
pelagic fish	$1.00\cdot10^{-04}$	$7.05\cdot10^{-04}$	$5.19\cdot10^{-04}$	$\mathbf{1.32\cdot10^{-03}}$	12.4	7.6
phytoplankton	$8.58\cdot10^{-05}$	$4.91\cdot10^{-04}$	$2.37\cdot10^{-04}$	$\mathbf{8.13\cdot10^{-04}}$	14.9	10.6
vascular plant	$3.89\cdot10^{-04}$	$1.61\cdot10^{-03}$	$2.08\cdot10^{-03}$	$\mathbf{4.07\cdot10^{-03}}$	19.5	9.6
zooplankton	$3.16\cdot10^{-05}$	$1.72\cdot10^{-04}$	$5.38\cdot10^{-05}$	$\mathbf{2.58\cdot10^{-04}}$	15.5	12.3

Table 21.4.3-7: Increments from Paks II and existing artificial sources to the radiation exposure of aquatic animals and plants in the Danube, in 2025.

The above table shows that at the time of launch in 2025, Paks II will make up 12-24% of total power plant incremental dose rate and 8-10% of the total dose rate from artificial isotopes, based on model calculations. Still, both ratios are expected to rise by time: partly due to the phased stoppage of Paks Nuclear Power Plant and partly to the continued radioactive disintegration of global ^{137}Cs and ^{90}Sr. The total incremental radiation exposure of insect larvae will be ~0.01 µGy/h in absolute value, which equals a 0.001 risk quotient. Relative to the natural background, fishes living near the river bed will further on suffer the biggest relative dose rate increment, reaching approx. 3% for all the sources. Naturally, these values will decrease in the future, for the reasons above.

21.4.3.1 Direct impacts

The incremental radiation exposure of animals and plants was estimated for the V2 estuary area of the Danube, with the joint operation of the two power plants, and the residual impact of global fall-outs was also taken into consideration. Relying on the terminology in the legal regulation, we stated that there is no direct impact on animals and plants under ordinary operating conditions because although emission can be observed in the tested area (owing to the immensely sensitive nuclear measurement techniques), it does not make any change in the condition of the affected environmental element (which in this case means animals and plants).

21.4.3.2 Indirect impacts

Although the impact of the radioactive material that disperses with the mediation of water can be considered indirect impact, the huge water flow of the river Danube implies considerable thinning, so if it did not have any direct detectable impact on animals and plants in the V2 estuary area, it will not have such an impact further on, either, so aquatic emissions will have no indirect impact.

21.4.3.3 Cross-border environmental effects

The two above statements clearly conclude that no impact crossing the country border with the Danube should be anticipated with regard to animals and plants.

21.4.4 Impact areas of the joint operation of Paks II and Paks Nuclear Power Plant

21.4.4.1 Area of direct impacts

Since no direct impact could be identified, no direct impact area can be delimited, either, regarding the radiation exposure of aquatic animals and plants.

21.4.4.2 Area of indirect impacts

Since no direct impact area can be delimited under ordinary operating conditions, no indirect impact area can be delimited, either, because the size of presumed load in the tested area fails to reach the level whereby, even if proceeding through any known impact process, it could cause bigger radiation exposure to animals and plants in other areas.

21.4.4.3 Area of cross-border environmental effects

The size of the incremental radiation exposure of aquatic animals and plants does not influence the condition of animals and plants in the environment where the Hot Water Canal joins the Danube, not even in the most exposed habitat, so, under ordinary operating conditions, we do not have to count with any impacts in the radiation exposure of animals and plants that could potentially cross the country border with the Danube.

21.4.5 Incidents in the design basis

Although the design, construction and operation of high-performance nuclear power plants intended for energetics purposes is all characterized by outstanding security, one should not in theory exclude certain situations that derive from material defect, natural disaster, perhaps human mistake or error and situations when the immense volume of energy released in the reactor vessel cannot be duly led away in ordinary operation. Although the chance of all this to occur is rather scarce, most of the imaginable scenarios are already taken into consideration in the design phase, so the technologies supporting their management are built in in the course of power plant investment.

With regard to the planned 3^+ generation power plant, the designer made the security analyses proposed in the EUR recommendation, specified the probabilities of occurrence of certain breakdown conditions and accident situations and set the radioactive emissions anticipated in those cases. The data supplied by the Russian party contained several such cases in detail, including a specific scenario of DBC4-category design breakdowns (frequency: 10^{-4}-10^{-6}/year) that we estimated the impact of, on animals and plants. One of the characteristics of this tested *very small frequency design breakdown* is that it implies atmospheric emission only, moreover, in controlled circumstances. This can happen in two places: the 100 m high chimney functionally used for ordinary operating atmospheric emissions, on the one hand, and in the place of the 4 security blow-offs that belong to the secondary circuit, which means emission at 35 m height, on the other. The cumulative emission data are summarized in Table 21.4.5-1.

radioisotope	emitted activity in 100 m, Bq			emitted activity in 35 m, Bq		
	1st day	in 10 days	in 1 month	1st day	in 10 days	in 1 month
^{131}I elementary	$5.5 \cdot 10^{07}$	$2.9 \cdot 10^{08}$	$4.3 \cdot 10^{08}$	$3.8 \cdot 10^{08}$	$2.1 \cdot 10^{09}$	$3.0 \cdot 10^{09}$
^{132}I elementary	$1.5 \cdot 10^{07}$	$1.5 \cdot 10^{07}$	$1.5 \cdot 10^{07}$	$1.0 \cdot 10^{08}$	$1.0 \cdot 10^{08}$	$1.0 \cdot 10^{08}$
^{133}I elementary	$3.6 \cdot 10^{07}$	$5.8 \cdot 10^{07}$	$5.8 \cdot 10^{07}$	$2.5 \cdot 10^{08}$	$4.0 \cdot 10^{08}$	$4.0 \cdot 10^{08}$
^{134}I elementary	$3.2 \cdot 10^{06}$	$3.2 \cdot 10^{06}$	$3.2 \cdot 10^{06}$	$2.3 \cdot 10^{07}$	$2.3 \cdot 10^{07}$	$2.3 \cdot 10^{07}$
^{135}I elementary	$9.6 \cdot 10^{06}$	$1.0 \cdot 10^{07}$	$1.0 \cdot 10^{07}$	$6.7 \cdot 10^{07}$	$7.1 \cdot 10^{07}$	$7.1 \cdot 10^{07}$
^{131}I organic	$1.2 \cdot 10^{09}$	$8.7 \cdot 10^{09}$	$1.4 \cdot 10^{10}$	$8.7 \cdot 10^{08}$	$6.1 \cdot 10^{09}$	$9.8 \cdot 10^{09}$
^{132}I organic	$1.7 \cdot 10^{08}$	$1.7 \cdot 10^{08}$	$1.7 \cdot 10^{08}$	$1.2 \cdot 10^{08}$	$1.2 \cdot 10^{08}$	$1.2 \cdot 10^{08}$
^{133}I organic	$7.6 \cdot 10^{08}$	$1.4 \cdot 10^{09}$	$1.4 \cdot 10^{09}$	$5.4 \cdot 10^{08}$	$9.8 \cdot 10^{08}$	$9.8 \cdot 10^{08}$
^{134}I organic	$2.0 \cdot 10^{07}$	$2.0 \cdot 10^{07}$	$2.0 \cdot 10^{07}$	$1.4 \cdot 10^{07}$	$1.4 \cdot 10^{07}$	$1.4 \cdot 10^{07}$
^{135}I organic	$1.7 \cdot 10^{08}$	$1.9 \cdot 10^{08}$	$1.9 \cdot 10^{08}$	$1.2 \cdot 10^{08}$	$1.3 \cdot 10^{08}$	$1.3 \cdot 10^{08}$
^{85m}Kr	$9.4 \cdot 10^{10}$	$9.6 \cdot 10^{10}$	$9.6 \cdot 10^{10}$	$6.5 \cdot 10^{08}$	$6.7 \cdot 10^{08}$	$6.7 \cdot 10^{08}$
^{87}Kr	$4.4 \cdot 10^{10}$	$4.4 \cdot 10^{10}$	$4.4 \cdot 10^{10}$	$3.1 \cdot 10^{08}$	$3.1 \cdot 10^{08}$	$3.1 \cdot 10^{08}$
^{88}Kr	$1.8 \cdot 10^{11}$	$1.8 \cdot 10^{11}$	$1.8 \cdot 10^{11}$	$1.2 \cdot 10^{09}$	$1.2 \cdot 10^{09}$	$1.2 \cdot 10^{09}$
^{133}Xe	$1.6 \cdot 10^{13}$	$9.7 \cdot 10^{13}$	$1.3 \cdot 10^{14}$	$1.1 \cdot 10^{11}$	$6.8 \cdot 10^{11}$	$9.2 \cdot 10^{11}$
^{135}Xe	$2.8 \cdot 10^{11}$	$3.3 \cdot 10^{11}$	$3.3 \cdot 10^{11}$	$1.9 \cdot 10^{09}$	$2.3 \cdot 10^{09}$	$2.3 \cdot 10^{09}$
^{138}Xe	$7.0 \cdot 10^{09}$	$7.0 \cdot 10^{09}$	$7.0 \cdot 10^{09}$	$4.9 \cdot 10^{07}$	$4.9 \cdot 10^{07}$	$4.9 \cdot 10^{07}$
^{134}Cs	$6.2 \cdot 10^{05}$	$6.2 \cdot 10^{05}$	$6.2 \cdot 10^{05}$	$4.3 \cdot 10^{07}$	$4.3 \cdot 10^{07}$	$4.3 \cdot 10^{07}$
^{137}Cs	$2.2 \cdot 10^{05}$	$2.2 \cdot 10^{05}$	$2.2 \cdot 10^{05}$	$1.6 \cdot 10^{07}$	$1.6 \cdot 10^{07}$	$1.6 \cdot 10^{07}$

Table 21.4.5-1: Atmospheric emission in case of DBC4-category breakdown [21-13]

For a specific isotope, the comparison among activities for individual time periods concludes that short half-time isotopes ($t_{1/2}$ ~a few hours) are practically emitted on the first day only. The other conclusion is that the installed and presumably automatically starting failure event management technology is rather efficient in keeping back relatively long half-time iodine isotopes in their elementary condition, as well as e.g. Cs isotopes.

The role of the two emission points significantly differs. Directly after the occurrence of breakdown (1st day), ~17 TBq activity (including 16 TBq for ^{133}Xe) leaves through the air chimney; less than 1% thereof at the 35 m emission point. This is the determinative emission route for rare gases during the entire course of the breakdown, however, 99% of caesium isotopes and about half of iodine isotopes leaves at 35 m height. 99.5% of total accident emission comes from ^{133}Xe activity, totalling 131 TBq. The emission speed for this determinant radioisotope decreases only in line with half-time during the breakdown, and ~10^8 Bq/m^3 activity concentration can be estimated at the emission point, based on the given data. This can obviously cause a significant dose rate for the animals and plants that stay on the soil surface in the direction of the plume. Size and area coverage evidently depend on actual meteorological conditions.

To estimate the impact on terrestrial animals and plants, we modelled the route of the radioactive cloud leaving through the emission points, its volume and the fall-out from it, for the environment of Paks, for the weather conditions used in similar analyses on the currently operating units. This means Pasquill D category condition (height of inversion layer: 560 m); 5 m/s wind at 120 m height; rainy weather (1 mm/h). Since no property is specifically given for wind direction, the direction of emission was chosen to be the most frequent direction (SE, sector 13), based on 8 years' data used for ordinary operation tests, in the model calculations.

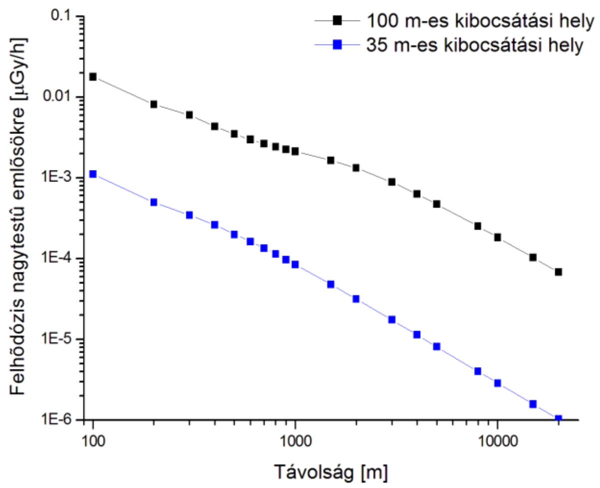
During breakdown, the part of the radioactive material (emitted into the atmosphere) that determines its long-term effect leaves at a 35 m high emission point, which was taken into consideration in modelling. Accordingly, the receptor points were chosen to be in every 100 m (from 100 m to 1000 m), then in 1500 m, 2000 m, 3000 m, 5000 m, 8000 m, 10000 m, 15000 m and 20000 m distance from the emission point. Any distance up to 500 m falls within the industrial area of the Power Plant with any wind direction; the 1000 m distance is within the industrial area with the most frequent NW winds but with NE, E and SE winds it is partly in the environment of the Power Plant. With the most frequent wind direction, the borderline of the industrial area is 1500 m from the atmospheric emission points of the planned new power plant units.

For the sake of assessing early impact, the radioactive material emitted in the first 10 days was separately managed and, as mentioned above, the wind was calculated to be constantly blowing in a single direction. According to the PC-CREAM calculation with the Gaussian plume model, the activity concentration of some radioisotopes in near-surface air in the directions that were considered the most important as regards environmental impact and soil pollution due to fall-out reached the figures listed in Table 21.4.5-2. Relative to the 100 m emission point, air activity concentration in 1500 m distance reaches the maximum in the specific circumstances, whereas the distance is 5-600 m (i.e. by far within the site) with a 35 m place of emission. The two plumes proceed in only approx. 100 m distance from each other, however, in near-surface activity concentration, the 35 m emission is determinative to up to 600 m (practically, within the site) and from 1000 m the radioactive material leaving through the air chimney determines the activity concentration of air. Naturally, all this will only be true if the wind does not blow strictly along the line determined by the two places of emission (S-SW, N-NE). Due to the relatively high inversion layer, the z-direction dispersion of the plume is significant, so no major activity can be expected in near-soil air outside the site. The radioactivity of the air in the early phase is determined by ~5-day half-time ^{133}Xe, however, its activity concentration is not significant outside the site. According to the model calculation, soil contamination is determined by the material that leaves at a 35 m place of emission, this, however, mainly means the site itself.

isotope	average activity concentration from 100 m emission point			average activity concentration from 35 m emission point		
	100 m	500 m	1500 m	100 m	500 m	1500 m
	air, Bq/m³					
^{85m}Kr	$3.74{\cdot}10^{-40}$	$3.50{\cdot}10^{-03}$	$1.46{\cdot}10^{-01}$	$3.30{\cdot}10^{-03}$	$2.66{\cdot}10^{-02}$	$5.62{\cdot}10^{-03}$
^{87}Kr	$1.72{\cdot}10^{-40}$	$1.60{\cdot}10^{-03}$	$6.62{\cdot}10^{-02}$	$1.52{\cdot}10^{-03}$	$1.21{\cdot}10^{-02}$	$2.49{\cdot}10^{-03}$
^{88}Kr	$7.06{\cdot}10^{-40}$	$6.79{\cdot}10^{-03}$	$3.02{\cdot}10^{-01}$	$5.98{\cdot}10^{-03}$	$5.10{\cdot}10^{-02}$	$1.21{\cdot}10^{-02}$
^{131}I	$3.50{\cdot}10^{-41}$	$3.29{\cdot}10^{-04}$	$1.37{\cdot}10^{-02}$	$4.03{\cdot}10^{-02}$	$3.24{\cdot}10^{-01}$	$6.79{\cdot}10^{-02}$
^{132}I	$7.20{\cdot}10^{-43}$	$6.73{\cdot}10^{-06}$	$2.79{\cdot}10^{-04}$	$1.08{\cdot}10^{-03}$	$8.58{\cdot}10^{-03}$	$1.75{\cdot}10^{-03}$
^{133}I	$5.69{\cdot}10^{-42}$	$5.31{\cdot}10^{-05}$	$2.22{\cdot}10^{-03}$	$6.78{\cdot}10^{-03}$	$5.45{\cdot}10^{-02}$	$1.14{\cdot}10^{-02}$
^{133}Xe	$3.78{\cdot}10^{-37}$	$3.55{\cdot}10^{00}$	$1.49{\cdot}10^{02}$	$3.34{\cdot}10^{00}$	$2.71{\cdot}10^{01}$	$5.77{\cdot}10^{00}$
^{134}Cs	$2.41{\cdot}10^{-45}$	$2.26{\cdot}10^{-08}$	$9.44{\cdot}10^{-07}$	$2.11{\cdot}10^{-04}$	$1.70{\cdot}10^{-03}$	$3.58{\cdot}10^{-04}$
^{134}I	$9.02{\cdot}10^{-44}$	$8.35{\cdot}10^{-07}$	$3.41{\cdot}10^{-05}$	$1.80{\cdot}10^{-04}$	$1.42{\cdot}10^{-03}$	$2.79{\cdot}10^{-04}$
^{135}I	$7.80{\cdot}10^{-43}$	$7.28{\cdot}10^{-06}$	$3.03{\cdot}10^{-04}$	$9.87{\cdot}10^{-04}$	$7.90{\cdot}10^{-03}$	$1.64{\cdot}10^{-03}$
^{135}Xe	$1.28{\cdot}10^{-39}$	$1.20{\cdot}10^{-02}$	$5.04{\cdot}10^{-01}$	$1.13{\cdot}10^{-02}$	$9.17{\cdot}10^{-02}$	$1.95{\cdot}10^{-02}$
^{137}Cs	$8.99{\cdot}10^{-46}$	$9.80{\cdot}10^{-09}$	$5.13{\cdot}10^{-07}$	$8.69{\cdot}10^{-05}$	$9.03{\cdot}10^{-04}$	$2.41{\cdot}10^{-04}$
^{138}Xe	$2.82{\cdot}10^{-41}$	$2.59{\cdot}10^{-04}$	$1.03{\cdot}10^{-02}$	$2.38{\cdot}10^{-04}$	$1.85{\cdot}10^{-03}$	$3.53{\cdot}10^{-04}$
	soil, Bq/kg					
^{131}I	$3.41{\cdot}10^{01}$	$6.80{\cdot}10^{00}$	$2.29{\cdot}10^{00}$	$6.98{\cdot}10^{01}$	$2.31{\cdot}10^{01}$	$6.33{\cdot}10^{00}$
^{132}I	$1.45{\cdot}10^{-02}$	$2.87{\cdot}10^{-03}$	$9.89{\cdot}10^{-04}$	$3.90{\cdot}10^{-02}$	$1.67{\cdot}10^{-02}$	$4.19{\cdot}10^{-03}$
^{133}I	$1.03{\cdot}10^{00}$	$2.05{\cdot}10^{-01}$	$6.92{\cdot}10^{-02}$	$2.19{\cdot}10^{00}$	$7.62{\cdot}10^{-01}$	$2.06{\cdot}10^{-01}$
^{134}Cs	$3.49{\cdot}10^{-03}$	$6.95{\cdot}10^{-04}$	$2.43{\cdot}10^{-04}$	$5.37{\cdot}10^{-01}$	$1.29{\cdot}10^{-01}$	$3.92{\cdot}10^{-02}$
^{134}I	$6.89{\cdot}10^{-04}$	$1.36{\cdot}10^{-04}$	$4.78{\cdot}10^{-05}$	$2.51{\cdot}10^{-03}$	$1.27{\cdot}10^{-03}$	$2.96{\cdot}10^{-04}$
^{135}I	$4.51{\cdot}10^{-02}$	$8.94{\cdot}10^{-03}$	$3.03{\cdot}10^{-03}$	$1.02{\cdot}10^{-01}$	$3.87{\cdot}10^{-02}$	$1.02{\cdot}10^{-02}$
^{137}Cs	$1.30{\cdot}10^{-03}$	$3.02{\cdot}10^{-04}$	$1.32{\cdot}10^{-04}$	$2.21{\cdot}10^{-01}$	$6.88{\cdot}10^{-02}$	$2.66{\cdot}10^{-02}$

Table 21.4.5-2: Surface and near-surface activity concentrations from 10-day emission, in the function of distance.

The early dose from the radioactive cloud is shown on the basis of data calculated for big mammals, illustrated in Figure 21.4.5-1 for both emission points. As the figure suggests and contrary to the above statement regarding emission points, radiation exposure is decisively determined by the radioactive materials emitted at 100 m, in any distance. The underlying reason, as explained earlier at the beginning of this section, is that ^{133}Xe, 99% of total emission, leaves from this point. As regards the dose rate values estimated with ERICA Program, the values are by far below the natural background load even in the direct environment of the emission point. Outside the site, just ~nGy/h dose rate is expectable.



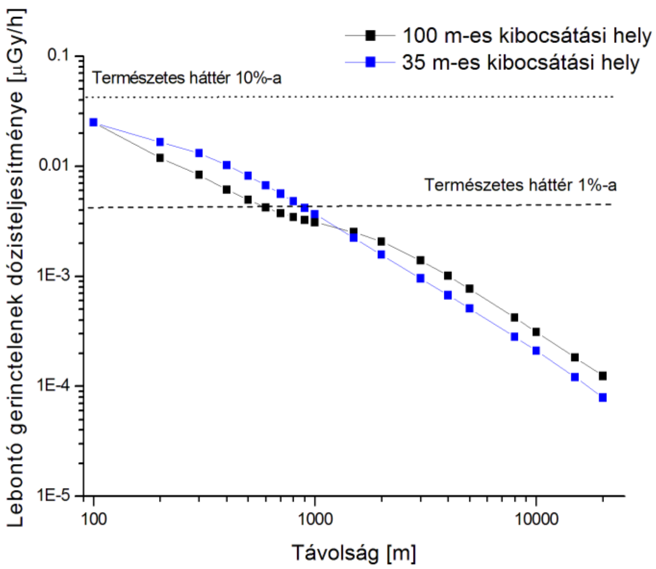
100 m-es kibocsátási hely - 100 m place of emission
35 m-es kibocsátási hely - 35 m place of emission
Felhődózis nagytestű emlősökre (µGy/h) - Cloud dose for big-bodied mammals (µGy/h)
Távolság (m) - Distance (m)

Figure 21.4.5-1: Cloud dose rate of big-bodied mammals, in the function of distance, in the early phase.

In the key distances mentioned above, the cumulated dose rate from the radioactive cloud, from air and soil radioactivity, typical of external radiation exposure and relevant to all the terrestrial reference animals and plants is summarized in Table 21.4.5-3. The maximum values are at 100 m for both places of emission, but as seen in the table, just in a few cases do they reach 10% of natural background radiation exposure. Outside the site, early radiation exposure is expected to be below this value for all the animals and plants. The expected early dose rate is graphically illustrated hereinafter for some creatures, in the function of distance from the emission point.

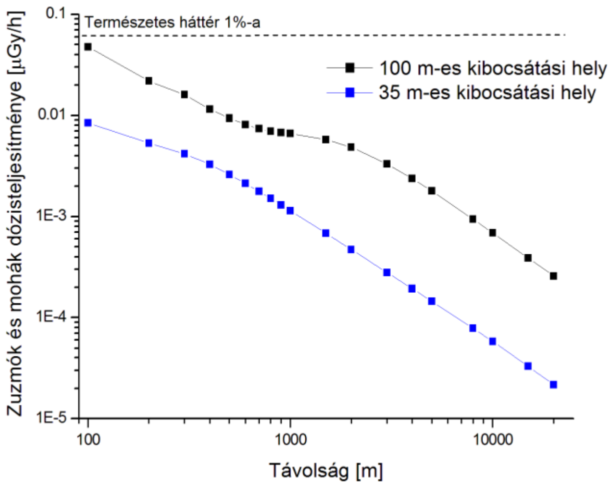
organism	average dose rate from 100 m emission point, µGy/h			average dose rate from 35 m emission point, µGy/h		
	100 m	500 m	1500 m	100 m	500 m	1500 m
amphibian	$4.65\cdot10^{-02}$	$9.13\cdot10^{-03}$	$4.57\cdot10^{-03}$	$1.43\cdot10^{-02}$	$4.41\cdot10^{-03}$	$1.19\cdot10^{-03}$
bird	$6.08\cdot10^{-02}$	$1.19\cdot10^{-02}$	$5.79\cdot10^{-03}$	$1.49\cdot10^{-02}$	$4.45\cdot10^{-03}$	$1.20\cdot10^{-03}$
bird's egg	$4.65\cdot10^{-02}$	$9.13\cdot10^{-03}$	$4.57\cdot10^{-03}$	$1.43\cdot10^{-02}$	$4.41\cdot10^{-03}$	$1.19\cdot10^{-03}$
saprophyte invertebrate	$2.50\cdot10^{-02}$	$4.94\cdot10^{-03}$	$2.51\cdot10^{-03}$	$2.49\cdot10^{-02}$	$8.16\cdot10^{-03}$	$2.23\cdot10^{-03}$
flying insect	$8.62\cdot10^{-02}$	$1.69\cdot10^{-02}$	$9.03\cdot10^{-03}$	$1.69\cdot10^{-02}$	$5.05\cdot10^{-03}$	$1.34\cdot10^{-03}$
snail	$9.32\cdot10^{-02}$	$1.83\cdot10^{-02}$	$1.05\cdot10^{-02}$	$1.74\cdot10^{-02}$	$5.27\cdot10^{-03}$	$1.39\cdot10^{-03}$
grasses and herbs	$5.47\cdot10^{-02}$	$1.08\cdot10^{-02}$	$7.92\cdot10^{-03}$	$1.49\cdot10^{-02}$	$4.97\cdot10^{-03}$	$1.31\cdot10^{-03}$
lichens and mosses	$4.77\cdot10^{-02}$	$9.38\cdot10^{-03}$	$5.76\cdot10^{-03}$	$8.41\cdot10^{-03}$	$2.60\cdot10^{-03}$	$6.82\cdot10^{-04}$
big mammal	$2.05\cdot10^{-02}$	$4.03\cdot10^{-03}$	$1.93\cdot10^{-03}$	$6.80\cdot10^{-03}$	$2.09\cdot10^{-03}$	$5.67\cdot10^{-04}$
small mammal	$1.57\cdot10^{-02}$	$3.11\cdot10^{-03}$	$1.23\cdot10^{-03}$	$2.31\cdot10^{-02}$	$7.58\cdot10^{-03}$	$2.08\cdot10^{-03}$
reptilian	$2.80\cdot10^{-02}$	$5.51\cdot10^{-03}$	$2.61\cdot10^{-03}$	$1.26\cdot10^{-02}$	$3.97\cdot10^{-03}$	$1.08\cdot10^{-03}$
bush	$5.43\cdot10^{-02}$	$1.07\cdot10^{-02}$	$7.90\cdot10^{-03}$	$1.42\cdot10^{-02}$	$4.74\cdot10^{-03}$	$1.25\cdot10^{-03}$
soil invertebrate	$1.37\cdot10^{-02}$	$2.74\cdot10^{-03}$	$9.23\cdot10^{-04}$	$2.92\cdot10^{-02}$	$9.63\cdot10^{-03}$	$2.65\cdot10^{-03}$
tree	$5.35\cdot10^{-02}$	$1.06\cdot10^{-02}$	$7.85\cdot10^{-03}$	$1.25\cdot10^{-02}$	$4.18\cdot10^{-03}$	$1.10\cdot10^{-03}$

Table 21.4.5-3: Cumulated maximum of external dose rate in three distances, separate for the two places of emission.



100 m-es kibocsátási hely - 100 m place of emission
35 m-es kibocsátási hely - 35 m place of emission
Természetes háttér 10%-a / 1%-a - 10% / 1% of natural background
Lebontó gerinctelenek dózisteljesítménye (µGy/h) - Dose rate of saprophyte invertebrates (µGy/h)
Távolság (m) - Distance (m)

Figure 21.4.5-2: Trends in the external dose rate of saprophyte invertebrate in the early phase, in the function of distance.

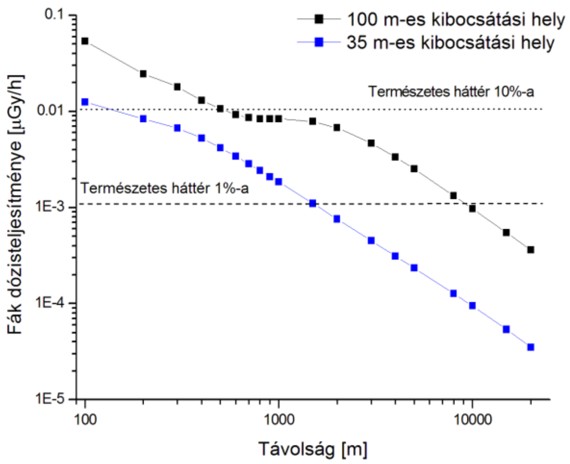


100 m-es kibocsátási hely - 100 m place of emission
35 m-es kibocsátási hely - 35 m place of emission
Természetes háttér 1%-a - 1% of natural background
Zuzmók és mohák dózisteljesítménye (µGy/h) - Dose rate of lichens and mosses (µGy/h)
Távolság (m) - Distance (m)

Figure 21.4.5-3: Trends in the external dose rate of lichens and mosses in the early phase, in the function of distance.

The radioactive material spilt on the soil plays a fairly big role in the case of saprophyte invertebrates (Figure 21.4.5-2), so the two emission points here add nearly identical dose increment to total external radiation exposure. Outside the site, the early impact of breakdown is practically insignificant in the case of these creatures. As regards lichens and mosses (Figure 21.4.5-3), radiation exposure from the radioactive cloud at 120 m height dominates within the site, moreover, the immersion dose also adds quite a significant increment near the borderline of the site, so total external radiation exposure hardly depends on distance here, within a band. All in all, however, the load relative to the natural background is negligible even in the test distance closest to the emission point. As regards trees (Figure 21.4.5-4), the distance dependence of total dose rate from the two sources is similar to that of mosses, moreover, the size is also quite similar, but due to their relatively low background radiation exposure, the estimated dose rate within the site exceeds 10% thereof. However, regarding any small forest around the Power Plant, just 10 nGy/h external radiation exposure is expected, due to early emission.

In summary, concluding from the data above, the DBC4 category operational incident at issue has neutral impact on nearby animals and plants, even under unfavourable meteorological conditions. This also means that emission due to breakdown does not lead to the creation of an impact area.



100 m-es kibocsátási hely - 100 m place of emission
35 m-es kibocsátási hely - 35 m place of emission
Természetes háttér 10%-a / 1%-a - 10% / 1% of natural background
Fák dózisteljesítménye (µGy/h) - Dose rate of trees (µGy/h)
Távolság (m) - Distance (m)

Figure 21.4.5-4: Trends in the external dose rate of trees in the early phase, in the function of distance.

The late impacts of the tested breakdown were assessed on the basis of the 30-day emission data, under the meteorological conditions described above. So the wind still blows in the direction observed at the start of the breakdown and it is invariably raining. These conditions lead to a rather conservative estimation because the total emitted radioactive material moves into a specific direction and it is expected to have an impact in a narrow band only. With PC-CREAM and ERICA programs, the anticipated trends in late impact were modelled fully similar to estimating early impact, and the results are hereinafter shown in the sequence and breakdown as above.

The activity concentration of some radioisotopes in near-surface air and soil pollution from fall-out are detailed in Table 21.4.5-4.

isotope	average activity concentration from 100 m emission point			average activity concentration from 35 m emission point		
	100 m	500 m	1500 m	100 m	500 m	1500 m
	air, Bq/m³					
^{85m}Kr	$1.25 \cdot 10^{-40}$	$1.17 \cdot 10^{-03}$	$4.89 \cdot 10^{-02}$	$1.10 \cdot 10^{-03}$	$8.85 \cdot 10^{-03}$	$1.87 \cdot 10^{-03}$
^{87}Kr	$5.70 \cdot 10^{-41}$	$5.31 \cdot 10^{-04}$	$2.20 \cdot 10^{-02}$	$5.06 \cdot 10^{-04}$	$4.04 \cdot 10^{-03}$	$8.30 \cdot 10^{-04}$
^{88}Kr	$2.36 \cdot 10^{-40}$	$2.27 \cdot 10^{-03}$	$1.01 \cdot 10^{-01}$	$1.99 \cdot 10^{-03}$	$1.70 \cdot 10^{-02}$	$4.03 \cdot 10^{-03}$
^{131}I	$1.87 \cdot 10^{-41}$	$1.75 \cdot 10^{-04}$	$7.32 \cdot 10^{-03}$	$2.09 \cdot 10^{-02}$	$1.68 \cdot 10^{-01}$	$3.52 \cdot 10^{-02}$
^{132}I	$2.41 \cdot 10^{-43}$	$2.24 \cdot 10^{-06}$	$9.28 \cdot 10^{-05}$	$3.60 \cdot 10^{-04}$	$2.87 \cdot 10^{-03}$	$5.85 \cdot 10^{-04}$
^{133}I	$1.89 \cdot 10^{-42}$	$1.77 \cdot 10^{-05}$	$7.38 \cdot 10^{-04}$	$2.26 \cdot 10^{-03}$	$1.81 \cdot 10^{-02}$	$3.78 \cdot 10^{-03}$
^{133}Xe	$1.69 \cdot 10^{-37}$	$1.58 \cdot 10^{+00}$	$6.65 \cdot 10^{01}$	$1.51 \cdot 10^{00}$	$1.22 \cdot 10^{01}$	$2.61 \cdot 10^{00}$
^{134}Cs	$8.05 \cdot 10^{-46}$	$7.53 \cdot 10^{-09}$	$3.15 \cdot 10^{-07}$	$7.04 \cdot 10^{-05}$	$5.67 \cdot 10^{-04}$	$1.19 \cdot 10^{-04}$
^{134}I	$3.00 \cdot 10^{-44}$	$2.78 \cdot 10^{-07}$	$1.14 \cdot 10^{-05}$	$6.03 \cdot 10^{-05}$	$4.73 \cdot 10^{-04}$	$9.28 \cdot 10^{-05}$
^{135}I	$2.60 \cdot 10^{-43}$	$2.42 \cdot 10^{-06}$	$1.01 \cdot 10^{-04}$	$3.28 \cdot 10^{-04}$	$2.64 \cdot 10^{-03}$	$5.46 \cdot 10^{-04}$
^{135}Xe	$4.29 \cdot 10^{-40}$	$4.02 \cdot 10^{-03}$	$1.69 \cdot 10^{-01}$	$3.77 \cdot 10^{-03}$	$3.06 \cdot 10^{-02}$	$6.52 \cdot 10^{-03}$
^{137}Cs	$3.00 \cdot 10^{-46}$	$3.28 \cdot 10^{-09}$	$1.71 \cdot 10^{-07}$	$2.90 \cdot 10^{-05}$	$3.01 \cdot 10^{-04}$	$8.06 \cdot 10^{-05}$
^{138}Xe	$9.06 \cdot 10^{-42}$	$8.33 \cdot 10^{-05}$	$3.32 \cdot 10^{-03}$	$7.94 \cdot 10^{-05}$	$6.16 \cdot 10^{-04}$	$1.18 \cdot 10^{-04}$
	soil, Bq/kg					
^{131}I	$2.90 \cdot 10^{01}$	$5.81 \cdot 10^{00}$	$1.95 \cdot 10^{00}$	$5.78 \cdot 10^{01}$	$1.85 \cdot 10^{01}$	$5.13 \cdot 10^{00}$
^{132}I	$4.81 \cdot 10^{-03}$	$9.57 \cdot 10^{-04}$	$3.30 \cdot 10^{-04}$	$1.30 \cdot 10^{-02}$	$5.58 \cdot 10^{-03}$	$1.40 \cdot 10^{-03}$
^{133}I	$3.42 \cdot 10^{-01}$	$6.82 \cdot 10^{-02}$	$2.31 \cdot 10^{-02}$	$7.30 \cdot 10^{-01}$	$2.54 \cdot 10^{-01}$	$6.87 \cdot 10^{-02}$
^{134}Cs	$3.46 \cdot 10^{-03}$	$6.90 \cdot 10^{-04}$	$2.40 \cdot 10^{-04}$	$5.32 \cdot 10^{-01}$	$1.28 \cdot 10^{-01}$	$3.88 \cdot 10^{-02}$
^{134}I	$2.29 \cdot 10^{-04}$	$4.52 \cdot 10^{-05}$	$1.60 \cdot 10^{-05}$	$8.38 \cdot 10^{-04}$	$4.21 \cdot 10^{-04}$	$9.87 \cdot 10^{-05}$
^{135}I	$1.50 \cdot 10^{-02}$	$2.98 \cdot 10^{-03}$	$1.01 \cdot 10^{-03}$	$3.40 \cdot 10^{-02}$	$1.29 \cdot 10^{-02}$	$3.38 \cdot 10^{-03}$
^{137}Cs	$1.31 \cdot 10^{-03}$	$3.03 \cdot 10^{-04}$	$1.32 \cdot 10^{-04}$	$2.22 \cdot 10^{-01}$	$6.89 \cdot 10^{-02}$	$2.66 \cdot 10^{-02}$

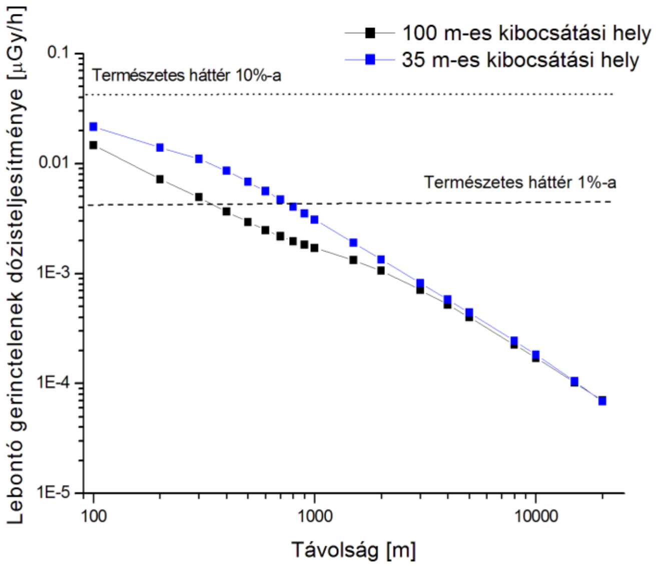
Table 21.4.5-4: Surface and near-surface activity concentrations from 30-day emission, in the function of distance.

The same applies to the movement of the radioactive plume leaving the individual places of emission and the maximum places as in the 10-day case. In the distances prioritized for the reasons above, the expected dose rates (incl. internal radiation exposure) from the two emission points for the reference animals and plants are summarized in Table 21.4.5-5.

organism	average dose rate from 100 m emission point, µGy/h			average dose rate from 35 m emission point, µGy/h		
	100 m	500 m	1500 m	100 m	500 m	1500 m
amphibian	$1.95 \cdot 10^{-02}$	$3.88 \cdot 10^{-03}$	$1.84 \cdot 10^{-03}$	$1.35 \cdot 10^{-02}$	$4.19 \cdot 10^{-03}$	$1.16 \cdot 10^{-03}$
bird	$2.44 \cdot 10^{-02}$	$4.84 \cdot 10^{-03}$	$2.24 \cdot 10^{-03}$	$1.42 \cdot 10^{-02}$	$4.34 \cdot 10^{-03}$	$1.19 \cdot 10^{-03}$
bird's egg	$1.95 \cdot 10^{-02}$	$3.88 \cdot 10^{-03}$	$1.84 \cdot 10^{-03}$	$1.35 \cdot 10^{-02}$	$4.18 \cdot 10^{-03}$	$1.15 \cdot 10^{-03}$
saprophyte invertebrate	$1.47 \cdot 10^{-02}$	$2.94 \cdot 10^{-03}$	$1.32 \cdot 10^{-03}$	$2.16 \cdot 10^{-02}$	$6.85 \cdot 10^{-03}$	$1.90 \cdot 10^{-03}$
flying insect	$3.21 \cdot 10^{-02}$	$6.37 \cdot 10^{-03}$	$3.37 \cdot 10^{-03}$	$1.36 \cdot 10^{-02}$	$4.13 \cdot 10^{-03}$	$1.13 \cdot 10^{-03}$
snail	$3.42 \cdot 10^{-02}$	$6.78 \cdot 10^{-03}$	$3.91 \cdot 10^{-03}$	$1.32 \cdot 10^{-02}$	$4.04 \cdot 10^{-03}$	$1.10 \cdot 10^{-03}$
grasses and herbs	$2.13 \cdot 10^{-02}$	$4.24 \cdot 10^{-03}$	$3.18 \cdot 10^{-03}$	$1.18 \cdot 10^{-02}$	$3.80 \cdot 10^{-03}$	$1.03 \cdot 10^{-03}$
lichens and mosses	$1.81 \cdot 10^{-02}$	$3.59 \cdot 10^{-03}$	$2.22 \cdot 10^{-03}$	$7.88 \cdot 10^{-03}$	$2.44 \cdot 10^{-03}$	$6.65 \cdot 10^{-04}$
big mammal	$1.11 \cdot 10^{-02}$	$2.20 \cdot 10^{-03}$	$9.37 \cdot 10^{-04}$	$1.10 \cdot 10^{-02}$	$3.46 \cdot 10^{-03}$	$9.56 \cdot 10^{-04}$
small mammal	$1.20 \cdot 10^{-02}$	$2.40 \cdot 10^{-03}$	$8.72 \cdot 10^{-04}$	$2.20 \cdot 10^{-02}$	$6.97 \cdot 10^{-03}$	$1.94 \cdot 10^{-03}$
reptilian	$1.34 \cdot 10^{-02}$	$2.66 \cdot 10^{-03}$	$1.16 \cdot 10^{-03}$	$1.32 \cdot 10^{-02}$	$4.10 \cdot 10^{-03}$	$1.14 \cdot 10^{-03}$
bush	$2.10 \cdot 10^{-02}$	$4.18 \cdot 10^{-03}$	$3.16 \cdot 10^{-03}$	$1.15 \cdot 10^{-02}$	$3.70 \cdot 10^{-03}$	$1.01 \cdot 10^{-03}$
soil invertebrate	$1.18 \cdot 10^{-02}$	$2.36 \cdot 10^{-03}$	$7.94 \cdot 10^{-04}$	$2.46 \cdot 10^{-02}$	$7.82 \cdot 10^{-03}$	$2.18 \cdot 10^{-03}$
tree	$2.09 \cdot 10^{-02}$	$4.17 \cdot 10^{-03}$	$3.15 \cdot 10^{-03}$	$1.10 \cdot 10^{-02}$	$3.55 \cdot 10^{-03}$	$9.62 \cdot 10^{-04}$

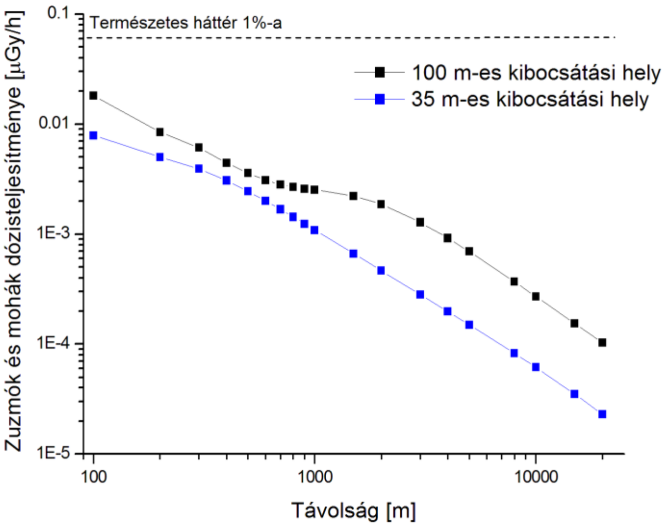
Table 21.4.5-5: Total late dose rate in three distances, separate for the two places of emission.

The expected late dose rate is graphically shown for some creatures, in the function of distance from the emission point. With short distances, external radiation exposure from the radioactive cloud is also determinative, however, outside the site, the dose rate from the radioactive material getting on the soil will be determinative and in this regard the majority of the increment comes from the fall-out from 35 m emission outside the site. The estimated dose rate values are typically small in this case again: they fail to reach 10% of relevant natural background radiation exposure in the environment of the Power Plant, with regard to any of the animals and plants.



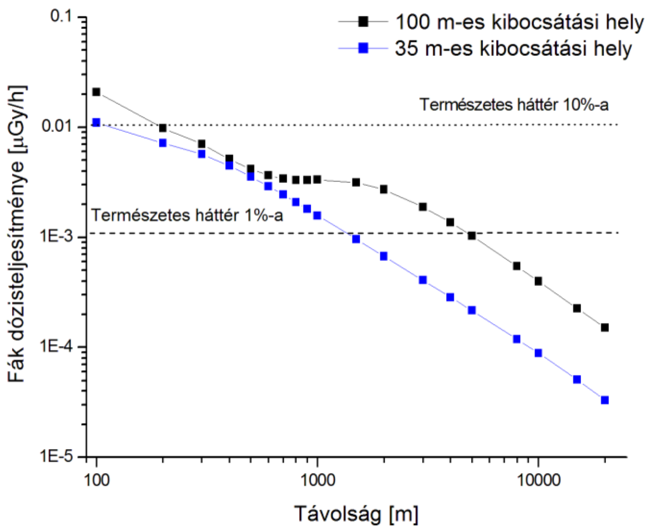
100 m-es kibocsátási hely - 100 m place of emission
35 m-es kibocsátási hely - 35 m place of emission
Természetes háttér 10%-a / 1%-a - 10% / 1% of natural background
Lebontó gerinctelenek dózisteljesítménye (μGy/h) - Dose rate of saprophyte invertebrates (μGy/h)
Távolság (m) - Distance (m)

Figure 21.4.5-5: Trends in the late dose rate of saprophyte invertebrates, in the function of distance.



100 m-es kibocsátási hely - 100 m place of emission
35 m-es kibocsátási hely - 35 m place of emission
Természetes háttér 1%-a - 1% of natural background
Zuzmók és mohák dózisteljesítménye (μGy/h) - Dose rate of lichens and mosses (μGy/h)
Távolság (m) - Distance (m)

Figure 21.4.5-6: Late dose rate of lichens and mosses, in the function of distance.



100 m-es kibocsátási hely - 100 m place of emission
35 m-es kibocsátási hely - 35 m place of emission
Természetes háttér 10%-a / 1%-a - 10% / 1% of natural background
Fák dózisteljesítménye (µGy/h) - Dose rate of trees (µGy/h)
Távolság (m) - Distance (m)

Figure 21.4.5-7: Distance dependence of the late dose rate of trees.

So, regarding late impact, the above data similarly conclude that the DBC4 category operational incident at issue has neutral impact on nearby animals and plants. Here we should particularly emphasize that the weather conditions, which were considered to be invariable all through the incident, resulted in the by far biggest impact from emissions since total emitted radioactivity was restricted to a relatively narrow zone. If this conservatism is further reinforced by considering the sum of the dose rates (estimated as the impact of the two emission points) as load on animals and plants, the expected impact will be doubled with some creatures at the most, still, this is by far within 10% of the natural level. This means that emission due to breakdown does not result in evincible impact and, consequently, any impact area.

The fact of using the recorded conditions for the above presented impact assessment is presumed to be motivated by the need to manage nuclear emergency situations with an identical methodology compliant with that used in former impact studies. However, the to-be-built units share the 3+ generation family features of nuclear power plants which implies, among others, the application of efficient technologies for the management of industrial incidents. This actually follows from the emission data supplied by the Russian party. Namely, the emitted activities stated for the individual periods and their locations prove that they can contribute to significant retention with regard to long-term impact isotopes. This is particularly conspicuous on the basis of data on caesium isotopes as they practically appear in the environment on the first day of the industrial incident only. The data in Table 21.4.5-1 suggest that in the case of iodine isotopes the emission speed is more significant on the first day than afterwards. Moreover, regarding animals and plants, the tool for testing impact is at present expressly the dose rate (µGy/h), so the above estimation should reasonably be studied with finer time resolution and the accumulation in emission data should be avoided. The early impact of the tested industrial incident will hereinafter be monitored with regard to these factors as well.

The radiation conditions along the direction of the plume were modelled with, among others, the emission data supplied for the first day by the Russian party, with the presumption of the above detailed meteorological situation. The total external radiation exposure of the reference animals and plants was estimated with the resulting activity concentrations at Tier 2 in ERICA Program. The result is summarized in Table 21.4.5-6.

organism	dose rate from 100 m emission point, µGy/h			dose rate from 35 m emission point, µGy/h		
	500 m	1500 m	5000 m	500 m	1500 m	5000 m
amphibian	$2.37\cdot10^{-02}$	$1.20\cdot10^{-02}$	$3.62\cdot10^{-03}$	$3.39\cdot10^{-03}$	$8.65\cdot10^{-04}$	$1.75\cdot10^{-04}$
bird	$3.19\cdot10^{-02}$	$1.57\cdot10^{-02}$	$4.72\cdot10^{-03}$	$3.78\cdot10^{-03}$	$9.58\cdot10^{-04}$	$1.91\cdot10^{-04}$
bird's egg	$2.37\cdot10^{-02}$	$1.20\cdot10^{-02}$	$3.62\cdot10^{-03}$	$3.39\cdot10^{-03}$	$8.64\cdot10^{-04}$	$1.75\cdot10^{-04}$
saprophyte invertebrate	$8.71\cdot10^{-03}$	$4.85\cdot10^{-03}$	$1.50\cdot10^{-03}$	$4.63\cdot10^{-03}$	$1.22\cdot10^{-03}$	$2.63\cdot10^{-04}$
flying insect	$4.63\cdot10^{-02}$	$2.41\cdot10^{-02}$	$7.32\cdot10^{-03}$	$4.91\cdot10^{-03}$	$1.22\cdot10^{-03}$	$2.36\cdot10^{-04}$
snail	$5.03\cdot10^{-02}$	$2.73\cdot10^{-02}$	$8.39\cdot10^{-03}$	$5.42\cdot10^{-03}$	$1.34\cdot10^{-03}$	$2.56\cdot10^{-04}$
grasses and herbs	$2.85\cdot10^{-02}$	$1.86\cdot10^{-02}$	$5.91\cdot10^{-03}$	$4.43\cdot10^{-03}$	$1.09\cdot10^{-03}$	$2.10\cdot10^{-04}$
lichens and mosses	$2.59\cdot10^{-02}$	$1.47\cdot10^{-02}$	$4.56\cdot10^{-03}$	$2.88\cdot10^{-03}$	$7.08\cdot10^{-04}$	$1.34\cdot10^{-04}$
big mammal	$1.04\cdot10^{-02}$	$5.09\cdot10^{-03}$	$1.53\cdot10^{-03}$	$1.57\cdot10^{-03}$	$4.04\cdot10^{-04}$	$8.25\cdot10^{-05}$
small mammal	$3.67\cdot10^{-03}$	$1.72\cdot10^{-03}$	$5.18\cdot10^{-04}$	$3.99\cdot10^{-03}$	$1.06\cdot10^{-03}$	$2.34\cdot10^{-04}$
reptilian	$1.34\cdot10^{-02}$	$6.58\cdot10^{-03}$	$1.98\cdot10^{-03}$	$2.65\cdot10^{-03}$	$6.87\cdot10^{-04}$	$1.43\cdot10^{-04}$
bush	$2.85\cdot10^{-02}$	$1.85\cdot10^{-02}$	$5.90\cdot10^{-03}$	$4.35\cdot10^{-03}$	$1.07\cdot10^{-03}$	$2.06\cdot10^{-04}$
soil invertebrate	$1.11\cdot10^{-03}$	$3.81\cdot10^{-04}$	$1.10\cdot10^{-04}$	$4.92\cdot10^{-03}$	$1.32\cdot10^{-03}$	$2.93\cdot10^{-04}$
tree	$2.84\cdot10^{-02}$	$1.85\cdot10^{-02}$	$5.90\cdot10^{-03}$	$4.06\cdot10^{-03}$	$9.92\cdot10^{-04}$	$1.88\cdot10^{-04}$

Table 21.4.5-6: External dose rate in three distances from the 1st day emission, separate for the two places of emission.

Here, instead of dose rates in 100 m distance, the results apply to 5000 m which is more relevant regarding the impact assessment. The 500 m and 1500 m data should be compared with the data in Table 21.4.5-3 for both emission points. This concludes that emission through the air chimney reached somewhat bigger values in this case, aligned to the higher emission speed. To the contrary, the dose rate values are less with the radioactive material emitted at 35 m.

The activity of the radioactive material emitted in 2-10 days can be calculated from the emission data supplied for the 1st and 10 days. The environmental conditions remain unchanged but emission speeds somewhat decrease and emission from the two caesium isotopes stops. In model calculations, the ^{131}I, ^{133}I, ^{135}I, ^{134}Cs and ^{137}Cs soil activity concentrations from 1-day emission are handed down with due ageing. The external dose rate data for stage 2 of the early phase are summarized in Table 21.4.5-7. The values for the individual animals and plants are recommended to be compared with the 1st day dose rate data calculated for the same receptor distance. This shows that the dose rate from the radioactive material leaving through the air chimney at the borderline of the site is e.g. just half or third of that on the first day. The 35 m emission point became subordinated with regard to the impact because, almost unexceptionally, the dose rate is for each creature just a third or fourth of that from 100 m emission. This at the same time facilitates the easier assessment of the impact. We should also note in connection with early impact that the snail suffers the biggest external dose rate, probably due to staying on the surface of the soil, given that the three sources causing external radiation exposure (cloud dose, immersion dose, soil gamma radiation) can affect it with equally no obstacle.

organism	dose rate from 100 m emission point, µGy/h			dose rate from 35 m emission point, µGy/h		
	500 m	1500 m	5000 m	500 m	1500 m	5000 m
amphibian	$7.46\cdot10^{-03}$	$3.74\cdot10^{-03}$	$1.10\cdot10^{-03}$	$4.39\cdot10^{-03}$	$1.19\cdot10^{-03}$	$2.67\cdot10^{-04}$
bird	$9.66\cdot10^{-03}$	$4.68\cdot10^{-03}$	$1.36\cdot10^{-03}$	$4.39\cdot10^{-03}$	$1.19\cdot10^{-03}$	$2.65\cdot10^{-04}$
bird's egg	$7.46\cdot10^{-03}$	$3.74\cdot10^{-03}$	$1.10\cdot10^{-03}$	$4.39\cdot10^{-03}$	$1.19\cdot10^{-03}$	$2.67\cdot10^{-04}$
saprophyte invertebrate	$4.43\cdot10^{-03}$	$2.22\cdot10^{-03}$	$6.77\cdot10^{-04}$	$8.28\cdot10^{-03}$	$2.27\cdot10^{-03}$	$5.19\cdot10^{-04}$
flying insect	$1.36\cdot10^{-02}$	$7.36\cdot10^{-03}$	$2.20\cdot10^{-03}$	$4.92\cdot10^{-03}$	$1.32\cdot10^{-03}$	$2.89\cdot10^{-04}$
snail	$1.47\cdot10^{-02}$	$8.60\cdot10^{-03}$	$2.62\cdot10^{-03}$	$5.12\cdot10^{-03}$	$1.36\cdot10^{-03}$	$2.96\cdot10^{-04}$
grasses and herbs	$8.78\cdot10^{-03}$	$6.75\cdot10^{-03}$	$2.17\cdot10^{-03}$	$4.90\cdot10^{-03}$	$1.30\cdot10^{-03}$	$2.84\cdot10^{-04}$
lichens and mosses	$7.52\cdot10^{-03}$	$4.77\cdot10^{-03}$	$1.47\cdot10^{-03}$	$2.50\cdot10^{-03}$	$6.60\cdot10^{-04}$	$1.42\cdot10^{-04}$

organism	dose rate from 100 m emission point, μGy/h			dose rate from 35 m emission point, μGy/h		
	500 m	1500 m	5000 m	500 m	1500 m	5000 m
big mammal	$3.30\cdot10^{-03}$	$1.57\cdot10^{-03}$	$4.59\cdot10^{-04}$	$2.08\cdot10^{-03}$	$5.66\cdot10^{-04}$	$1.28\cdot10^{-04}$
small mammal	$2.95\cdot10^{-03}$	$1.15\cdot10^{-03}$	$3.35\cdot10^{-04}$	$7.71\cdot10^{-03}$	$2.12\cdot10^{-03}$	$4.87\cdot10^{-04}$
reptilian	$4.59\cdot10^{-03}$	$2.16\cdot10^{-03}$	$6.30\cdot10^{-04}$	$3.99\cdot10^{-03}$	$1.09\cdot10^{-03}$	$2.47\cdot10^{-04}$
bush	$8.71\cdot10^{-03}$	$6.72\cdot10^{-03}$	$2.16\cdot10^{-03}$	$4.65\cdot10^{-03}$	$1.23\cdot10^{-03}$	$2.68\cdot10^{-04}$
soil invertebrate	$2.80\cdot10^{-03}$	$9.45\cdot10^{-04}$	$2.74\cdot10^{-04}$	$9.81\cdot10^{-03}$	$2.70\cdot10^{-03}$	$6.22\cdot10^{-04}$
tree	$8.54\cdot10^{-03}$	$6.67\cdot10^{-03}$	$2.15\cdot10^{-03}$	$4.08\cdot10^{-03}$	$1.08\cdot10^{-03}$	$2.32\cdot10^{-04}$

Table 21.4.5-7: External dose rate in three distances from the 10th day emission, separate for the two places of emission

In modelling 11-30-day emission we no more presumed invariable wind direction as this condition is highly improbable in the environment of Paks. Instead, relying on the past 8 years' meteorological data several times used here, we determined the frequency distribution of wind direction in Pasquill D category incidents and this was used, in 32-sector resolution, to follow the movement of the material emitted in the last 19 days. As regards precipitation, the data were left unchanged, so rainy weather was presumed for the entire duration of the industrial incident. Here again we naturally counted with the impact of isotopes earlier falling on the soil, though this was taken into consideration for each sector. Although this results in overestimating late impact for all the sectors excluding one, still, it is more realistic in reflecting the impact of most recent fall-out and air radioactivity. The prognosticated impact includes internal radiation exposure.

According to the results from the runs, the biggest impact from 100 m and 35 m emission is felt at the 15th and the 16th sectors, respectively. Table 21.4.5-8 summarizes the dose rate in these sectors, for reference animals and plants.

organism	dose rate from 100 m emission point, μGy/h			dose rate from 35 m emission point, μGy/h		
	500 m	1500 m	5000 m	500 m	1500 m	5000 m
amphibian	$5.97\cdot10^{-04}$	$2.17\cdot10^{-04}$	$6.33\cdot10^{-05}$	$1.90\cdot10^{-03}$	$5.24\cdot10^{-04}$	$1.21\cdot10^{-04}$
bird	$6.35\cdot10^{-04}$	$2.33\cdot10^{-04}$	$6.77\cdot10^{-05}$	$1.95\cdot10^{-03}$	$5.37\cdot10^{-04}$	$1.24\cdot10^{-04}$
bird's egg	$5.96\cdot10^{-04}$	$2.17\cdot10^{-04}$	$6.33\cdot10^{-05}$	$1.89\cdot10^{-03}$	$5.18\cdot10^{-04}$	$1.19\cdot10^{-04}$
saprophyte invertebrate	$9.00\cdot10^{-04}$	$3.13\cdot10^{-04}$	$9.13\cdot10^{-05}$	$3.25\cdot10^{-03}$	$8.94\cdot10^{-04}$	$2.06\cdot10^{-04}$
flying insect	$6.37\cdot10^{-04}$	$2.51\cdot10^{-04}$	$7.38\cdot10^{-05}$	$1.76\cdot10^{-03}$	$4.83\cdot10^{-04}$	$1.11\cdot10^{-04}$
snail	$6.25\cdot10^{-04}$	$2.59\cdot10^{-04}$	$7.67\cdot10^{-05}$	$1.67\cdot10^{-03}$	$4.58\cdot10^{-04}$	$1.05\cdot10^{-04}$
grasses and herbs	$5.31\cdot10^{-04}$	$2.29\cdot10^{-04}$	$6.92\cdot10^{-05}$	$1.60\cdot10^{-03}$	$4.40\cdot10^{-04}$	$1.01\cdot10^{-04}$
lichens and mosses	$3.62\cdot10^{-04}$	$1.51\cdot10^{-04}$	$4.51\cdot10^{-05}$	$1.03\cdot10^{-03}$	$2.84\cdot10^{-04}$	$6.57\cdot10^{-05}$
big mammal	$4.78\cdot10^{-04}$	$1.67\cdot10^{-04}$	$4.86\cdot10^{-05}$	$1.59\cdot10^{-03}$	$4.35\cdot10^{-04}$	$9.98\cdot10^{-05}$
small mammal	$8.98\cdot10^{-04}$	$3.05\cdot10^{-04}$	$8.85\cdot10^{-05}$	$3.38\cdot10^{-03}$	$9.35\cdot10^{-04}$	$2.17\cdot10^{-04}$
reptilian	$5.50\cdot10^{-04}$	$1.94\cdot10^{-04}$	$5.62\cdot10^{-05}$	$1.96\cdot10^{-03}$	$5.46\cdot10^{-04}$	$1.27\cdot10^{-04}$
bush	$5.06\cdot10^{-04}$	$2.21\cdot10^{-04}$	$6.68\cdot10^{-05}$	$1.60\cdot10^{-03}$	$4.44\cdot10^{-04}$	$1.04\cdot10^{-04}$
soil invertebrate	$1.01\cdot10^{-03}$	$3.41\cdot10^{-04}$	$9.88\cdot10^{-05}$	$3.77\cdot10^{-03}$	$1.04\cdot10^{-03}$	$2.40\cdot10^{-04}$
tree	$4.99\cdot10^{-04}$	$2.18\cdot10^{-04}$	$6.61\cdot10^{-05}$	$1.47\cdot10^{-03}$	$4.04\cdot10^{-04}$	$9.30\cdot10^{-05}$

Table 21.4.5-8: Changes of late dose rate with distance, for the two places of emission.

If the wind was actually blowing toward sectors 15 and/or 16 in the early phase of emission, the dose rates in the above table characterize the actual radiation exposure of the specific animal/plant, including any late impact from radioactive materials earlier falling there. Moreover, these data can be directly compared by modelling late impact (as shown above) (Table 21.4.5-5). As a general statement for impacts from any emission point, the former data are approx. 1 magnitude bigger than those under more realistic conditions, which means that late impact was highly overestimated. The reasons include unvaried wind direction and the disregard of actual emission dynamics. This latter e.g. led to the fact that even after 25-30 days of the start of the incident some short half-time isotopes caused external radiation exposure, though just the impact of ^{131}I and ^{133}Xe isotopes should effectively be presumed for this period. Even from these, just insignificant activity concentration can be expected in the atmosphere, which is supported by the data in Table 21.4.5-9.

isotope	average activity concentration from 100 m emission point			average activity concentration from 35 m emission point		
	500 m	1500 m	5000 m	500 m	1500 m	5000 m
	air, Bq/m³					
^{131}I	$7.17 \cdot 10^{-06}$	$3.01 \cdot 10^{-04}$	$1.12 \cdot 10^{-04}$	$6.79 \cdot 10^{-03}$	$1.44 \cdot 10^{-03}$	$2.11 \cdot 10^{-04}$
^{133}Xe	$4.35 \cdot 10^{-02}$	$1.83 \cdot 10^{00}$	$6.80 \cdot 10^{-01}$	$3.55 \cdot 10^{-01}$	$7.57 \cdot 10^{-02}$	$1.13 \cdot 10^{-02}$
	soil, Bq/kg					
^{131}I	$2.54 \cdot 10^{00}$	$8.57 \cdot 10^{-01}$	$2.48 \cdot 10^{-01}$	$8.85 \cdot 10^{00}$	$2.41 \cdot 10^{00}$	$5.50 \cdot 10^{-01}$
^{134}Cs	$6.88 \cdot 10^{-04}$	$2.40 \cdot 10^{-04}$	$7.00 \cdot 10^{-05}$	$1.28 \cdot 10^{-01}$	$3.88 \cdot 10^{-02}$	$1.00 \cdot 10^{-02}$
^{137}Cs	$3.02 \cdot 10^{-04}$	$1.32 \cdot 10^{-04}$	$4.83 \cdot 10^{-05}$	$6.87 \cdot 10^{-02}$	$2.66 \cdot 10^{-02}$	$7.53 \cdot 10^{-03}$

Table 21.4.5-9: Average near-surface air and soil activity concentrations generated in 11-30-day emission.

The radiation exposure data calculated in relation to terrestrial animals and plants under these relatively realistic conditions confirm that no dose rate assessed, due to its size, as either direct or indirect impact can be expected in the environment of the Power Plant, due to the tested DBC4 category industrial incident. This is expressly shown in the dose rate maps below: the territorial distribution of the impact is shown here for snail (which is found to be the most exposed) and worm (the most sensitive to soil pollution). The colour scale of the maps is, for any case, identical: each colour represents the dose rate noted beside and expressed in μGy/h.

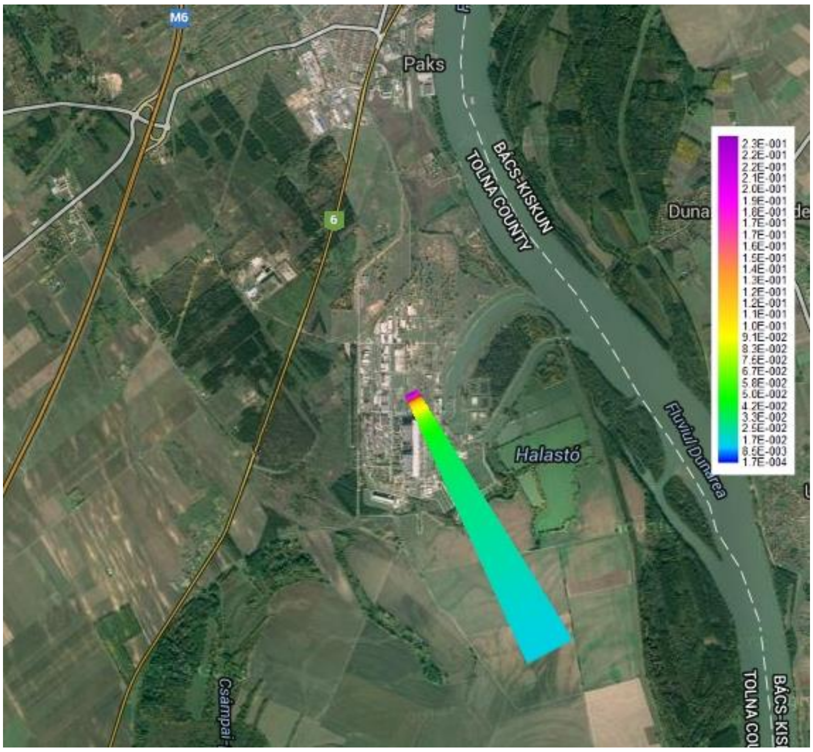


Figure 21.4.5-8: Dose rate of snail from 1-day emission (100 m).

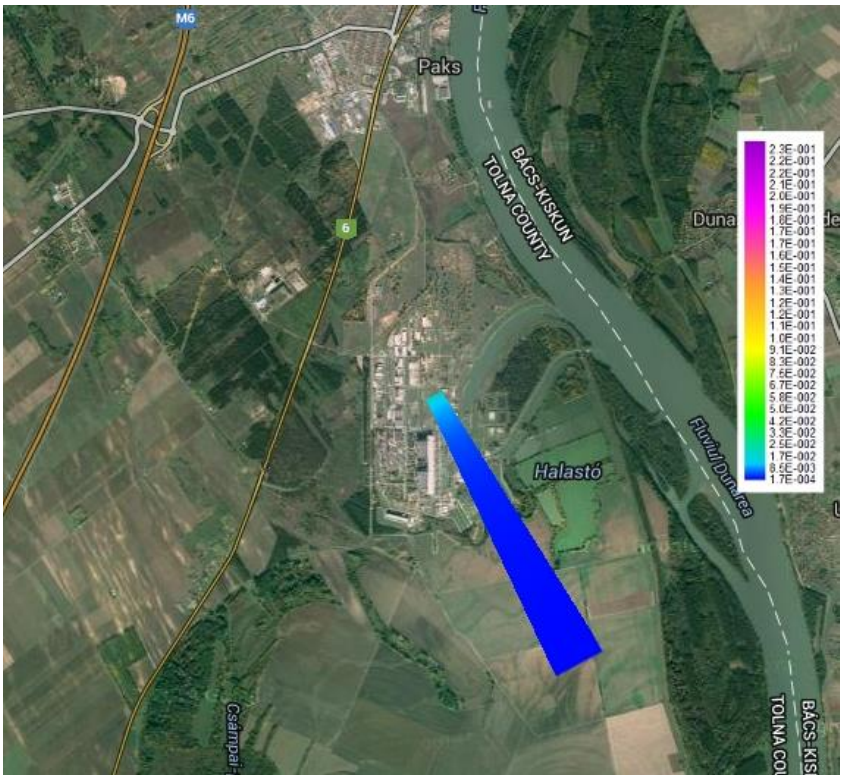


Figure 21.4.5-9: Dose rate of soil worm from 1-day emission (35 m).

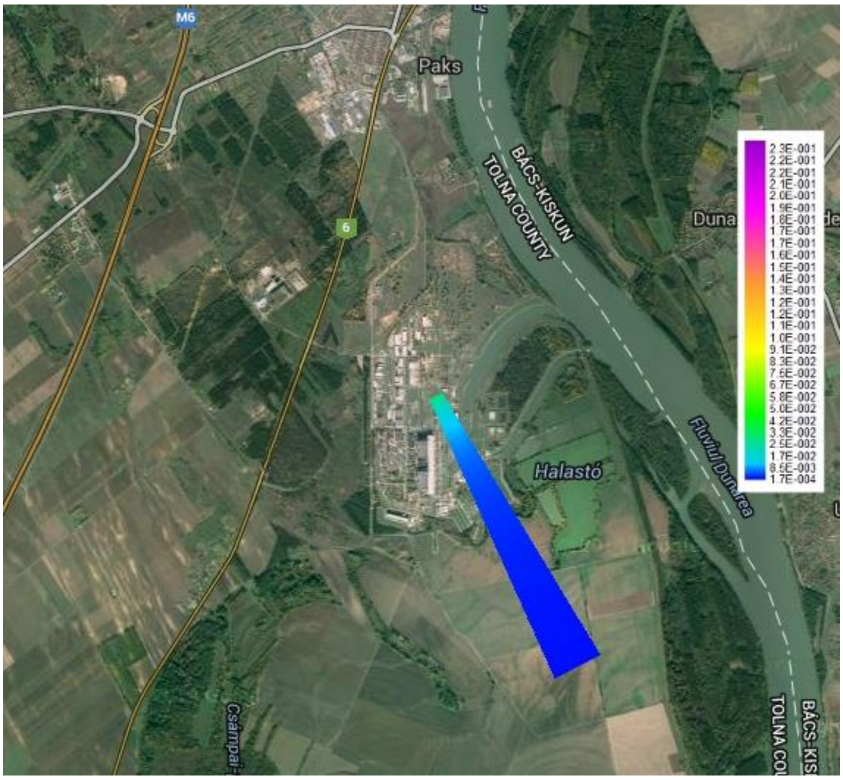


Figure 21.4.5-10: Dose rate of soil worm from 10-day emission (35 m).

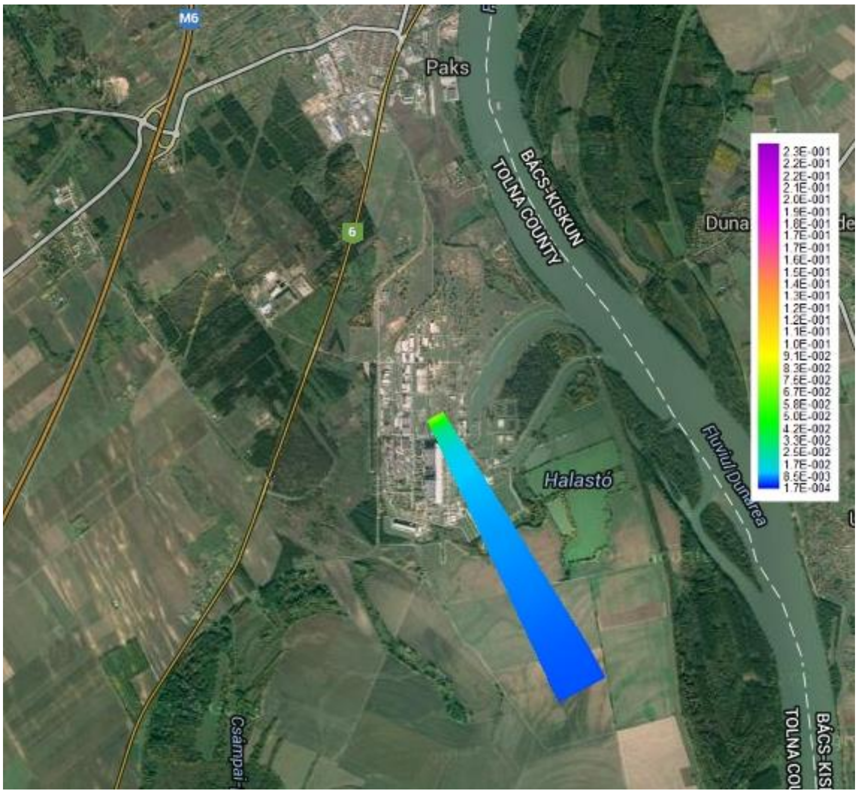


Figure 21.4.5-11: Dose rate of snail from 10-day emission (100 m).

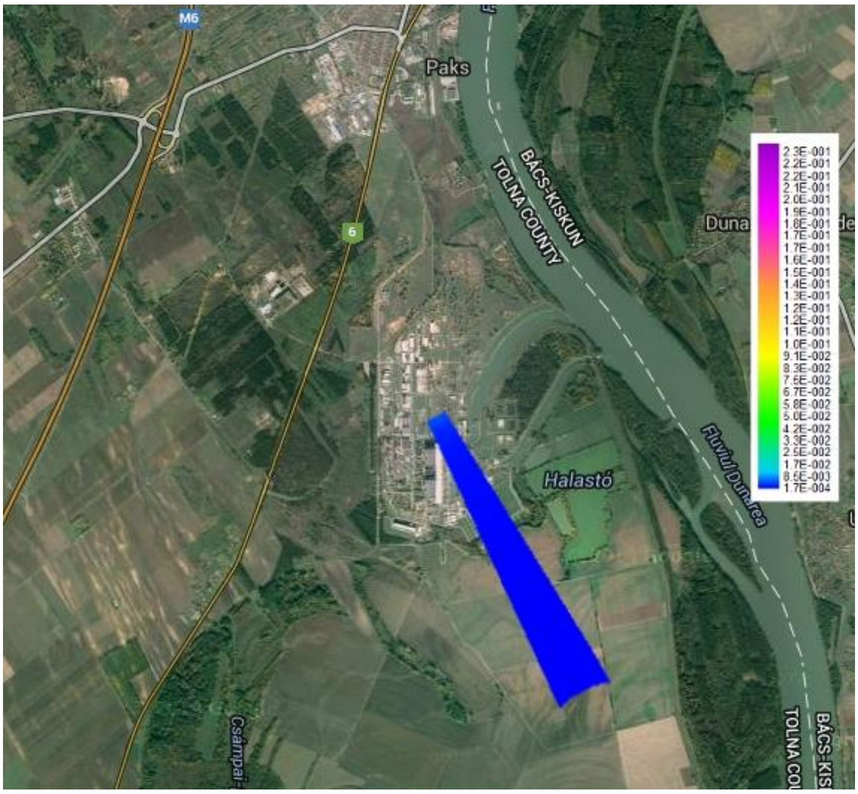


Figure 21.4.5-12: Dose rate of soil worm from 30-day emission (100 m).

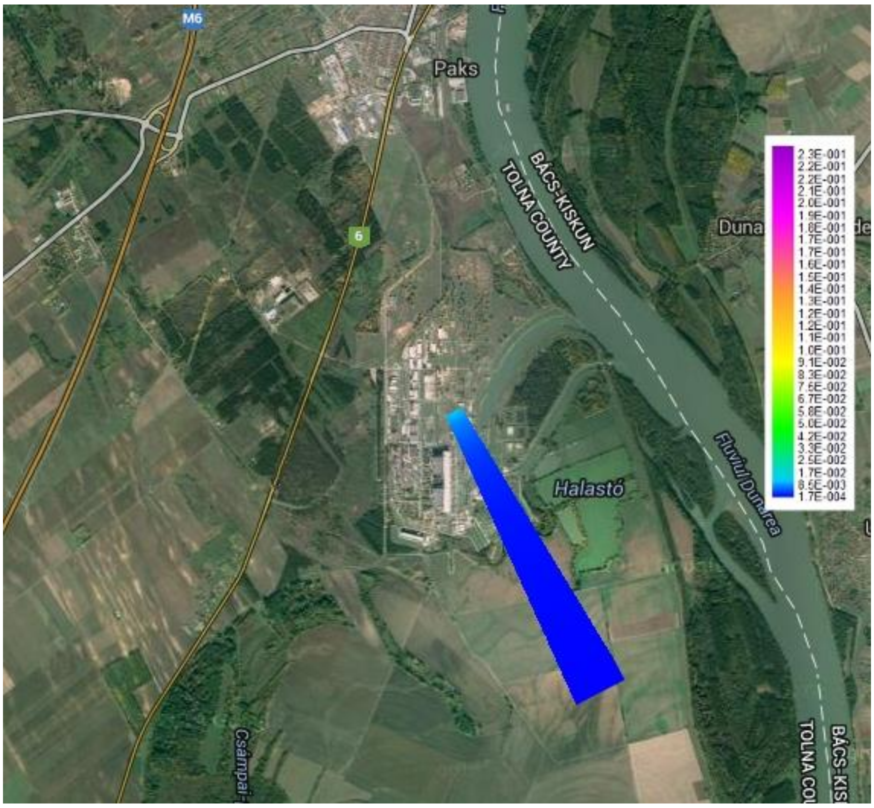


Figure 21.4.5-13: Dose rate of soil worm from 30-day emission (35 m).

Another "mitigating" circumstance should also be taken into account in assessing the impact of the incident. Namely, the radiological protection of animals and plants is not targeted at the specific protection of the individuals but the protection of the populations and of the entire ecosystem in the specific location. This in the environment of the Nuclear Power Plant means that e.g. with regard to trees the subject of protection is a small forest, i.e. an acacia or poplar forest covering in some cases a some thousand square meter area. A part (at most) of the population of hundreds of individuals will actually live in a place with maximum impact, so the average radiation exposure of the entire population can be significantly lower than the values in the above tables. Due to permanent motion, the animals moving in the area will also be exposed to less than estimated load on the average. If this factor is also taken into consideration in assessing the radiological protection of the incident, the incident can be rated to have no effect, at least regarding animals and plants and especially when considering its entire duration.

21.5 IMPACT OF DECOMMISSIONING PAKS II ON THE RADIATION EXPOSURE OF ANIMALS AND PLANTS IN THE ENVIRONMENT OF THE SITE

From among the decommissioning and dismantling scenarios, prompt dismantling can be considered to imply the biggest environmental risk because the activity stock is the highest at this time, given that short and medium-long half-time radionuclides still make up a major part of waste. The operational fluid radioactive emission of the facility is discontinued. The waste water used for decontaminating the various equipment and the elements of building, then collected and chemically treated can be emitted under control, provided the emission limits are complied with. The recipient will be the Danube. In terms of activity, this volume will be insignificant, relative to ordinary operation. Some radioactive material from structural elements can get in the groundwater (primarily by solution) when the substructure (slab foundation) is being demolished. In this case we should also anticipate short half-time radionuclides, but the migration of tritium between the main building and the Danube is 12-20 years, subject to location and water-level, which strongly restricts the impact of potential isotopes. But since the foundation of the current and the planned power plants is in the saturated zone (subject to Danube water-level), no surplus load considerably different from the operational condition can be presumed, which is detailed in the chapters above. In general, the mobility of radioactive materials (exc. tritium and radiocarbon) getting this way in the groundwater is minor. During dismantling, any local contamination can be controlled and liquidated in time, so it seems unreasonable to consider its impact in the current frames, considering that ordinary operation proved to have practically no effect on animals and plants.

The biggest risk may perhaps be connected with the aerosols generated during demolition and the radioactive materials dispersing with them. Naturally, their volume can be radically decreased with a relatively simple method (dust-laying the demolition area). Still, as seen above, in the case of emission both from chimneys and from the top of the containment, the fall-out maximum practically stays within the site under ordinary meteorological conditions. This will particularly apply at a lower emission point, which means that considerable activity cannot get out of the site with atmospheric dispersion, so the radiation exposure of animals and plants will not be significant from atmospheric emission, either.

Unintended spilling along the waste transport route, then inwash in the soil and dusting generate yet another risk, however, this impact can only be calculated in the knowledge of the specific dismantling plan and the transport routes.

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[21-11] MIR.1200 Preliminary data and information for safety and environmental licensing, Appendix 3

[21-12] MIR.1200 Preliminary data and information for safety and environmental licensing, Appendix 4

[21-13] Data for NPP environmental impact analysis (AES-2006); Table 13