IAEA/EMRAS, in collaboration with the IUR

Revision of the IAEA Technical Reports Series No. 364: Handbook of parameter values for the prediction of radionuclide transfer in temperate environments

Critical analysis: Arguments for revising the IAEA TRS No. 364

Contributions included: Pascal Santucci, Gabi Voigt, Sylvie Roussel-Debet, Shigeo Uchida, Tamara Yankovich, plus discussions from the November 2004 meeting. **WORKING DOCUMENT, FINAL DRAFT, April 2005**

1. Introduction

Most of the safety, performance, or radiological impact assessments concerning either actual or potential releases, when they comprise biosphere calculations, use parameters such as transfer or accumulation factors requiring their associated values. One international example is the IAEA SRS No. 19 (2001) on the assessment of routine releases. If future assessment purposes are currently considered, such as those linked to overall environmental impact assessments (Hunter, 2001), most of the current biosphere models still need such parameters and associated values.

In the literature, Whicker et al. (1999) reported that overall syntheses are not very numerous (e.g. the well known Coughtrey, Jackson and Thorne, 1985). One such important document is widely used by the scientific community: the IAEA Technical Reports Series No. 364, "Handbook of parameter values for the prediction of radionuclide transfer in temperate environments", published in collaboration with the International Union of Radioecology (IUR) in 1994. Its contents reflects radioecological results up to 1992. TRS 364 is widely used as a major source of information because it addresses numerous environmental transfer parameters and radionuclides. It is, therefore, quoted in numerous impact assessments, even if amended or completed by the scientific community (in the fields of radiation protection and radioecology). Moreover, many radiation protection models need to predict transfer of a large number of radionuclides. This requires information on the transfer of many less mobile radionuclides, which do not usually comprise an important component of discharges or dose. Such information is often sparse and difficult to collate and interpret. TRS 364 provides an important source of such information, and is one of the key cited sources for many models. It is thus essential that such information is kept up-to-date and that any relevant recent literature is included, especially considering the paucity of existing data sources.

Since 1992, new data have also been produced, such as post-Chernobyl information (Shaw, 2001), and new experimental results (e.g. lysimeter studies), potentially adding to the the existing data and syntheses, which are now more than 10 years old. In addition, a number of high quality critical reviews have been produced in recent years for some of the transfer parameter values, which merit consideration. International programmes have also been devoted to the construction and validation of radioecological models, including BIOMOVS, IAEA/VAMP, IAEA/BIOMASS, European Frameworks, etc. It is then assumed that there is sufficient new information available to warrant reconsideration of a significant proportion of the values given in TRS 364.

As a consequence, there are arguments for updating TRS 364 and extending it, in terms of the numbers and types of compartments, processes and radionuclides, which will likely improve its current contents, because a critical analysis can highlight some weaknesses, and additional data can confirm or enhance values previously cited in the document. As a result in 2003, the IAEA decided to include the revision of TRS 364, as a topic of the "Environmental Modelling for RAdiation Safety" programme (EMRAS).

2. Justification for the performance of an updated synthesis at the international level

Behind the necessity to take into account progress of science and knowledge, one question is to know to what extent it is useful or necessary to sustain an international work on a given field, rather than letting individuals manage the existing information.

During the IAEA/BIOMASS programme, a group was devoted to ensuring an appropriate data selection methodology for use in biosphere assessment models. The group showed that even if biosphere parameters cannot be considered as "constant" as the ICRP dose coefficients, they can be tabulated and subsequently applied: as default values when well characterised, for example this could be the case for IUR soil-to-plant transfer factors, according to broad crop groups; as example values or representative values, for use if the parameter is relatively unimportant in the assessment; or as a starting point if the parameter appears critical (as indicated by sensitivity and uncertainty analyses). Moreover, it was also shown during the BIOMASS programme, that even in the case for which regulation or methodology tend to favour the use of site-specific data, the availability of generic values is still important.

Compilation and tabulation of data is therefore useful; however, if the people responsible for such a work have a limited expertise (scope) and/or little resources, there is a risk of introducing biases during the process of data selection (see discussion about expert judgment, e.g. Thorne and Williams, 1992). Such biases could include:

- Poor representativeness of data, e.g.: individuals often are insensitive to sample size: the same weight, or level of confidence, can be attributed to parameter values for which there are much or little data (issue when the assessment addresses a broad spectrum of radionuclides); people are also over-sensitive to information, even when information is not related to data: this has been seen in the extensive discussions about the usefulness or necessity of site-specific data.
- Inadequate availability of data, e.g.: individuals often favour easily available and/or understandable information: it is a question of review management, but also of institutional culture; individuals can misinterpret the co-occurrence of naturally associated characteristics: the influence of potential co-factors could then be assumed rather than tested.
- Anchoring, e.g.: individuals often have difficulties to depart from initial values they know, even if the assessment context requires it; individuals have the tendency to underestimate the range of variation of a parameter.

Based on these arguments, it follows that review and syntheses that are performed by individuals or small groups will generally be limited in scope (considering few compartments and processes) for a given assessment context. The recourse to structured elicitation exercises appears interesting, but it is resource intensive and past experience has shown that it is difficult to systematically implement them (e.g. US/NRC&EU on COSYMA, BIOMASS on data selection). According to some participants in these exercises, their intrinsic value may even appear questionable because difficult to extrapolate. An intermediate approach is to try to build syntheses and databases at an international level. This will allow access to a large audience with various backgrounds and levels of expertise, optimisation of resources by the sharing of the overall effort (e.g. by ecological field) and consideration of already existing material (including reviews, bibliographic material, databases).

3. General features of the revision of IAEA TRS No. 364

Due to the large audience and use of TRS 364, there is a need to keep such a document as relevant, accurate and consistent as possible. The document should be relevant, because the purpose is to cover various assessment contexts, such as routine releases and accidental conditions, atmospheric and liquid releases, etc. It should be accurate to correct and/or avoid mistakes, and to incorporate up-to-date science although this could be difficult when data are scarce. Lastly, it should be consistent, where consistency between tables should be ensured, especially with regards to the list of radionuclides considered, all the more since integrated assessments require it.

An assessment of the quality of data obtained is of paramount importance to assure that the suggested best estimates of the environmental parameters can be used in generic predictive models. In an ideal world, a critical evaluation of data would include a statistical analysis of the data. However, because of the inadequate availability of resources, this was not attempted in TRS 364, and it may be difficult to carry it out in a revision.

In practice, the expected values and ranges given in TRS 364 are based on a variety of different approaches, which are not clearly specified for each value. They comprise statistical analysis, expert judgement or sometimes, only a single experiment. For some of the tables (e.g. animal transfers), the approach has been specified for each value. It is recommended to extend this approach to all other tables to the extent possible.

Uncertainty should be primarily addressed by giving ranges of variation. In some cases, probability density functions could be built through the performance of statistical analyses of databases (e.g. on some Kds and soil-to-plant transfer factors). The question should be raised about the extrapolation of their statistical results to other categories (e.g. confidence intervals extrapolated from one radionuclide to another). When data is scarce or missing, a discussion should be provided concerning the use of chemical analogues as a way of completing the tables. Variability could be reduced by revising classification systems (e.g. by crop groups) and introducing co-factors (e.g. with Kds and soil-to-plant TFs).

Steady state models are routinely used for dose assessment, for screening purposes and operational releases. Information in the TRS 364 is directly relevant for such models, when time dependency in transfers is neglected, assuming steady-state conditions. Many dynamic models are intended for dose assessment in emergency situations. For such models, often both empirical (based on classification of systems) and semi-mechanistic approaches are used. The availability and applicability of improved dynamic models based largely on mechanistic information is limited. In general, such models have only been developed for a small number of radionuclides (notably caesium and strontium), in particular types of systems, such as caesium behaviour in soils, forests or freshwaters, or metabolically-based models of animals. Such models have the additional advantage of being able to include the effect of countermeasures in a mechanistic way and complement other, more generalised models used for radiation protection purposes. It is therefore important to consider whether the continued use of empirical transfer values is always justified and appropriate.

For an accurate mathematical description of dynamic processes, a multi-compartment model, in which the material fluxes are described by mechanism-based rate equations, is essential. Such dynamic models apply to cycling of radionuclides in ecosystems with respect to retention and accumulation, migration and leaching. It is recognised that complex dynamic models, all the more because they often lack consensus and wide-scale validation, are outside of the scope of a revised TRS 364. An exception is made for dynamic, one-compartment models in which processes can be modelled by using a half-life concept. The dynamics of some of these processes are so important that neglecting them would be a serious shortcoming of the new TRS. A consideration of changes through time in terrestrial and aquatic systems, expressed as ecological half-lives in different environmental compartments and reflecting processes involved in the long-term transfers, provides an important improvement for modelling.

Nomenclature should be tested against official documents such as ICRU 65 (2001) "Quantities, Units and Terms in Radioecology". This document contains a list of units and quantities frequently used in the field of radioecology, and tries to harmonise these units, which have been derived from varying disciplines, such as ecology, chemistry, medicine and physics.

4. Analysis and completion of the existing TRS 364

4.1. Methodology

Starting with TRS364 (1994), section by section (based on ecological domains), the methodology for reviewing the current synthesis is as follows: list the processes of interest; review the modelling aspects in terms of compartments and processes, minimum model representation, alternative modelling and potential co-factors; analyse the radionuclides currently taken into account; consider the classification systems that could be used to reduce variability and/or to estimate values to fill existing gaps; highlight weaknesses and mistakes; and check the availability of new data for selection and inclusion in the new TRS.

When rewritten, the sections will be articulated according to a main text devoted to explaining the main processes involved, with the usual associated parameters, co-factors influencing some processes or the determination of parameters values, and key equations used for describing and assessing the transfers. The IAEA SRS 19 could be a basic reference for simple modelling. In addition, tables of transfer coefficients will be included, with values for species (or groups of species), environmental conditions, co-factors, and other relevant factors. In order to be able to complete calculations, element-independent information will be provided such as yields, moisture content, example animal diets, etc. The references used will of course be quoted.

4.2. Agricultural systems - Foliar interception, retention and translocation

Foliar interception is a prominent process after initial release from a nuclear facility. The section is not clear enough and not self-sufficient for building the intended model structure. It shows strong linkages with plant characteristics, at least because the plant stage of development, species specific attributes and plant density (biomass) are very important factors. For contamination of surfaces, two main deposition pathways are considered. These include direct dry or wet deposition.

The interception values for dry deposition refer to experimental work mostly performed in the early 1970s. Values relating to wet deposition refer mainly to two references published in 1965 and 1977. Meanwhile, much more data have become available which need to be included in the reprised TRS, such as those from experimental and post Chernobyl studies. Also, information on the seasonality of intercepted fractions relating to the biomass of different plant species could be greatly improved (in TRS 364 only one reference is given). Instead of providing individual experimental results, a critical compilation of values showing the dependence of intercepted fractions on the precipitation intensity, time period between precipitations and harvest, season and plant species should be tabulated. It has also been deemed useful to introduce deposition velocities. Since there is a requirement arising from the waste assessment field, irrigation processes, considered as a particular case of wet deposition, should also be introduced.

Under accidental conditions, parameter values should not be averaged over the year. Instead, parameter values should distinguish steady-state, pre-accident conditions from dynamic post-accident conditions. Under accident conditions, the physico-chemical features of the source term may be of importance (in terms of granularity, solubility). The amount of rainfall could also be specified.

In the revised TRS 364, the processes of foliar interception and translocation need to be clearly addressed, even if actually aggregated or not. In TRS 364, a collation of different translocation coefficients for crops with time dependencies before harvest are given; however, conclusions or recommendations on which values to use are not provided. The aim should be to derive generic parameter values from a review of revised data compilation. In addition, the conclusions and recommendations in IAEA/TECDOC 857 (1996) "Modelling of radionuclide interception and loss processes in vegetation and of transfer in semi-natural ecosystems" should also be considered.

New data can also be added on radionuclide transfer to fruit. Inclusion of time dependency in orchard trees including information about interception and retention in the canopy, and the subsequent translocation, might be useful, as their features are different from the other crop groups.

4.3. Agricultural systems - Soil retention and migration

The current classifications of soil systems used in TRS364 are rather simplistic and limited to only four categories, which include sand, loam, clay and peat. These categories are somewhat inadequate to account for the soil parameters that govern the behaviours of different radionuclides. The values were based on a relatively small number of experiments for a limited number of soils within each category. In recent years, the amount of data for each category have greatly increased, and analysis of the data distribution has shown a high variability and a high degree of overlap. Revised classification systems are currently being developed for addressing the determination of Kd, which are based on mechanistic information, including consideration of parameter values, such as pH, percent clay, exchangeable K and Ca in soil, moisture content of soil, organic matter content and the time that a radionuclide is present in a soil (ageing effect). Numerous multiregression analyses have been developed and give reasonable predictions on a local scale, but have not been proven on a world-wide scale. At least for some radionuclides (e.g. Cs, Sr, U, Tc) a semi-mechanistic approach should be used.

4.4. Agricultural systems - Uptake from soil to plant

At the time that TRS 364 was prepared, the IUR had already introduced “crop groups” as cereals, green vegetables, root crops, etc. It was, however, not yet then possible to use these crop groups to provide expected uptake parameters, so separate transfer values were provided for wheat, barley, rye, etc. These crop groups should now be introduced.

Currently, data on soil-to-plant transfer factors given in TRS 364 generally are not homogeneous:

For Cs and Sr, separate values are given for different soil categories (i.e. sand, loam, clay and peat) with a pH constraint. In recent years, the number of data for Cs and Sr has greatly increased, and analysis of the data distribution has shown a high variability and high degree of overlap. Revised classification systems are currently being developed which are based on mechanistic information including consideration of parameter values of co-factors with an objective to be consistent, if not similar, with those adopted for Kds (pH, soil type, etc.).

For Pu, Am and many other radionuclides, soil type is seldom considered. The data have largely been collated between 1980 and 1990, but for some of the elements (e.g. Pu, Am, Co, Mn, Tc, Zn), new data are now available. For others, it is doubtful that sufficient values for updating tables are available.

As a way to complete gaps, it is probably worthwhile to consider the uptake data of stable elements and their analogues of different nature. In particular, heavy metals have received considerable recent attention.

The contamination of plants by resuspension of contaminated soil particles should not be forgotten as an important indirect pathway, since the soil adhesion to vegetation may affect the ingestion dose. This process may be relevant when soil-to-plant transfer factors are low (representing slow transfers). However, soil adhesion should not be taken too seriously due to the interaction with food processing (e.g. washing, peeling, etc.).

4.5. Agricultural systems - Transfer from feed to animal products

This section could be improved with a review of recent literature, even if new data are more difficult to find than for plants. For many of the radionuclides, the tabulated data are based on a compilation originating from databases that are more than 20 years old. The intake rates of feedstuff by animals are based on European conditions only and should be supplemented by data for other areas of the world. Some FAO activities and results could be of use.

For ingestion doses, the application of equilibrium transfer coefficients for animal products is inappropriate for radionuclides with long biological half-lives. Therefore, in TRS 364, some transfer coefficients were modified to account for a known lack of non-equilibrium. This approach needs to be extended, possibly by providing half-life information, and evaluated. Furthermore, for strontium, iodine and caesium, information on biological half-lives is available and can be compiled.

A statistical analysis of the data is not possible for TRS 364 (1994) because many of the values came from reviews using extensive data and individual data sets which were not available. Supplementation of recent data with these reviews was attempted, but was only possible using expert judgement. For some selected radionuclides, a statistical analysis could be performed, since sufficient data and data sets are now available. However, this would be extremely time-consuming and is unrealistic. It is, therefore, recommended to use recently published reviews where statistical analysis have been attempted.

In the last decade, detailed and improved information on the influence of stable analogues for caesium, strontium and iodine has become available and should be considered for inclusion in revision of TRS 364.

4.6. Semi-natural ecosystems: forests and grasslands

It is important to include semi-natural ecosystems for caesium because the range of products harvested differs greatly from other ecosystems and the rate of transfer to food products is often much higher than for other ecosystems. Furthermore, the ecological half-lives of caesium in many products harvested from these ecosystems is much longer than in agricultural systems. For some human populations, consumption of semi-natural products is common; for others, it is confined to certain special groups. In both cases, such consumption can form a major proportion of ingestion dose in the mid-to-long term after deposition.

The section on semi-natural ecosystems in TRS 364 was largely based on simple, aggregated transfer coefficients, since the inherent variability and complexity of such systems make predictions using other approaches difficult. Recently, some dynamic models have been developed, which allow the estimation of transfer to certain forest products, but the number of products considered is limited. It is, therefore, recommended that the same parameter should be used in the revision to be able to include as wide a range of products as possible. The radionuclide spectrum considered in the revised TRS document should also be extended. Fortunately, data availability has greatly increased since 1992, largely from the considerable focus in both Europe and the CIS on caesium transfer to forest products.

Some game species and humans consume large quantities of mushrooms, which can take up large quantities of Cs. Mushroom consumption can, therefore, be a dominant pathway for the ingestion of caesium. Currently, much more data on mushroom transfer have now become available. In addition, for arctic systems, significant improvement of TRS 364 is now possible for quantifying transfer of caesium to reindeers and its time dependency, based on a review carried out under the Arctic Monitoring and Assessment Programme (AMAP).

Recent analysis of transfer to macrofungi suggested that it is not statistically valid to provide separate values for individual mushroom species, as done in TRS 364 (1994). Instead, tag values distinguishing mycorhizal, saprophitic and parasitic ecological categories are likely more appropriate. Nonetheless, some mushroom species with consistently higher transfer values than the mean for their ecological category could be identified (e.g. Rozites caparata). In addition, it may be possible to give some information on the dependency on soil type for a few mushroom species.

Reviews of tag values are now available for various product types and it should be possible to acquire or carry out statistical analysis of data for many of them. In addition, improved ecological half-life data are available for many products, notably reindeer, moose, roe deer and wild boar, and should now be reported. Descriptive text on the transfer processes for each food product could be substantially improved and extended.

4.7. Freshwater systems

This chapter should be rewritten and enhanced in terms of the compartments, processes and environmental conditions included, in consistency with the IAEA SRS 19. In particular, bottom sediments and suspended matters should be distinguished, as well as trophic levels for fish.

Concerning the suspended matter/water partition coefficient: The adsorption and desorption processes of radionuclides by suspended matter can strongly influence the behaviour of radionuclides in freshwater systems. Consequently, considerable research has been carried out on these processes. The most common and simple approach for modelling the adsorption/desorption processes at equilibrium is based on the particulate-to-water partition coefficient, Kd. The correlation between the partition coefficient and the chemical characteristics of the water body should be described. A variety of researchers have demonstrated that non-reversible adsorption processes are of importance for some radionuclides, notably caesium. A table of non-reversible fraction rates for caesium in different freshwater ecosystems should therefore be included.

Concerning other relevant migration processes and parameters: Among the various processes occurring in water bodies, the thermal stratification phenomena of deep lakes and river may strongly influence the concentration of any floating material in the water column. Stratification and de-stratification have a marked seasonal behaviour which can result, even for steady state releases, in significant seasonal variation in contamination levels in water and fish. Because of the peculiarity of these lake-related processes, it has been decided not to include lakes in the next revision of TRS364.

In TRS 364, the table concerning fish is based on a large database for a wide range of elements. However, the method of data selection for the expected values is not specified and appears to be inconsistent. However, the data are quite comprehensive and might be supplemented by a few recent literature reviews on concentration factors for the edible portion of fish in freshwater environments.

4.8. Food processing

There are currently numerous tables compiling information about the effect of food processing, but they are particularly useful in a context of accidental management. It is recommended to simplify them by focusing on the most efficient processes for radioactivity reduction. For instance, one could focus on the processing of dairy products and mushrooms.

5. Extension of TRS 364 in scope

5.1. Radioelements

At a methodological level, a discussion on chemical analogy should be introduced as a way to overcome the lack of data for some radionuclides, especially if consistency between the tables is to be reached.

There are so-called "special" radionuclides such as ^{3}H, ^{14}C, and this list may be extended to the isotopes of iodine and chlorine. If possible, it is suggested that their specificity be kept, provided that data could feed the tables. Specific models should also be included.

5.2. Climate conditions

TRS 364 was limited to temperate climatic zones because, at the time, few data from other climatic zones were available. Since 1992, new data on both arctic regions and tropical environments have become available. From these new data it appears that the climatic zone type itself seems to have little direct influence on radioecological transfer parameters, but that nevertheless, the impact of the zone type on other important parameters is large. Climate zone and parent rock material determine, to a large extent, the development of soil type.

In tropical areas, several soil types occur in which radionuclide uptake by crops consistently deviate from the expected values given in TRS 364. Under these hot and wet conditions, almost all organic material which reaches the soil surface decomposes rapidly; the accumulation of soil organic matter is therefore minimal, and there is rapid recycling making the nutrients available to the vegetation. In temperate zones, the decomposition of organic debris is slower and accumulation of soil organic matter can be larger than the rate of decomposition, resulting in highly organic soils.

Such examples show that if at least fundamental processes are well documented, their dependence on temperature could be taken into account.

5.3. Asian food-chains

Because agricultural products and food customs in Asian countries are different from those in temperate ones, it is expected that the critical foods differ as well. In European and North American countries, livestock products, including meat, eggs, and milk, make a big contribution to diet, while, in Asian countries, agricultural products, including cereals and vegetables, are the main components.

It has also been suggested to extend TRS 364 by introducing Asian food-chains. Such food-chains refer to several climate conditions, from temperate to tropical. Some crops are grown under particular conditions, as is the case for flooded rice.

The FAO/IAEA, in cooperation with the IUR, has established various programmes, which are of use for feeding a new TRS. These include "Transfer of radionuclides from air, soil, and freshwater to the foodchain of man in tropical and sub-tropical environments" (1993-1997), and "The Classification of Soil Systems on the Basis of Transfer Factors of Radionuclides from Soil to Reference Plants" (1999-2003).

5.4. Indirect pathways of contamination

Atmospheric resuspension and wash-off should be introduced as new processes because they are prominent secondary pathways of contamination.

Wash-off amounts to roughly less than 1%.y^{-1} for Cs and Sr. It is not important in terms of losses (in a short term period), but it is very important for the secondary contamination of rivers. It depends on amount of water, soil cover, slope or profile. Erosion is included in wash-off. There is a competition with vertical migration, which is an argument for time-dependency. In recent years, many attempts have been carried out to develop new approaches which allow modellers to predict radionuclide migration from catchments by using more simple, generic models, including half-lives and transfer factors. Due to the data available in the international literature following the Chernobyl accident, it is possible to produce a limited, but somewhat instructive list of half-lives and transfer factors, mainly for ^{90}Sr and ^{137}Cs. This list could be helpful for generic models applicable to both steady state and dynamic conditions.

In addition, resuspension of contaminated soil particles to the atmosphere can be an important contributor to the inhalation exposure pathway.

6. Revision of TRS 364 in practice ...*(on-going…)*

- The revision of TRS 364 is one of the main activities of the IAEA programme EMRAS (Environmental modelling for radiation safety), 2003-2006(7), and an IUR task group

- Collaboration with the International Union of Radioecology:
    - TRS 364 was issued in collaboration with the IUR
    - most of the IAEA/EMRAS participants belong to the IUR
    - the well known database on soil-to-plant TFs was managed by IUR; IUR was a co-sponsor of the European RadFlux database
    - there are IUR working groups of interest for the revision (radioecology of rice, radioecology and waste (special radionuclides), etc.), which explains that this revision is also an IUR activity
    - an agreement between IAEA and IUR was consequently reached, making this activity a joint-programme, as a way to benefit also from the IUR audience through a dedicated task group

- The overall work plan is the following:
    - Before EMRAS plenary 2004 : critical analysis nearly achieved, identification of responsible experts nearly complete, gathering of old and new references advanced, gathering of databases advanced ;
    - June 2005, WG meeting, Aix-en-Provence, with all interested participants : start of overall TRS drafting with specified contributions ;
    - End 2005, EMRAS plenary : final documents on the TRS critical analysis and on data availability, draft of TRS concerning already included parameters, draft on new parameters/ processes to be included, draft CD-rom with new data ;
    - April/May 2006, WG meeting, Aix-en-Provence, with all interested participants ;
    - End 2006, EMRAS plenary : draft of overall new TRS, draft 2 of CD-rom with source data
    - 2007 : finalisation and edition.

- Material:
    - nearly 90% of the TRS 364 references have been recovered (about 200)

- about 550 new references of interest have been found (later than 1992), including reviews and syntheses; the grey literature should not be discarded if valuable (institutional reports) which is the case with some overall syntheses

- some databases: IUR for soil-to-plant transfers, IAEA CRP on tropical systems, EU RadFlux multi-compartments too, national databases (NRPB, IRSN) on Kds, soil-to-plant TFs, animals, food processing

The proposed structure of the new TRS could be as follows:

Section	Title
1.	**INTRODUCTION**
1.1.	**Purpose**
1.2.	**Radioecology for safety assessment**
2.	**BASIC CONCEPTS**
2.1.	**Main components of the biosphere**
2.2.	**Definitions and units**
2.3.	**Issues related to the management of data**
2.4.	**The use of analogues for deriving quantities**
3.	**AGRICULTURAL ECOSYSTEMS**
3.1.	**Exchanges between atmosphere, plants and soil**
3.1.1.	***Interception by vegetation, weathering and translocation***
3.1.1.1.	Foliar contamination by dry deposition
3.1.1.2.	Foliar contamination by wet deposition
3.1.1.3.	Losses from leaves by weathering
3.1.1.4.	Translocation of contamination through plant to edible organs
3.1.2.	***Assessment of available contamination in soil***
3.1.2.1.	Partition of contamination between solid and liquid phases
3.1.2.2.	Evolution of bioavailability with time
3.1.3.	***Vertical migration through top-soil***

3.1.4.	***Plant uptake from soil***
3.1.4.1.	Root uptake
3.1.4.2.	Contamination of plants by resuspension and soil adhesion
3.1.4.3.	Inundated systems
3.1.5.	***Evolution of plant contamination with time***
3.1.6.	***Secondary contamination by resuspension***
3.2.	**Transfer to animals and animal products**
3.2.1.	***Modelling assumptions***
3.2.2.	***Transfer from feed to milk***
3.2.2.1.	Reference values for steady state conditions
3.2.2.2.	Biological half-lives
3.2.3.	***Transfer from feed to meat and eggs***
3.2.3.1.	Reference values for steady state conditions
3.2.3.2.	Biological half-lives
4.	**RADIONUCLIDES TRANSFER IN SEMI-NATURAL ECOSYSTEMS**
4.1.	**Introduction**
4.2.	**Radionuclide transfer in forests**
4.2.1.	***Compartments and processes in forests***
4.2.2.	***Modelling assumptions***
4.2.3.	***Aggregated transfer coefficients***
4.2.3.1.	mushrooms
4.2.3.2.	berries
4.2.3.3.	wood
4.2.3.4.	game/animals

4.3.	**Radionuclide transfer in other semi-natural systems**
5.	**RADIONUCLIDES TRANSFER IN FRESHWATER ECOSYSTEMS**
5.1.	**Flux from soils to river systems**
5.2.	**Exchanges between water and particles**
5.2.1.	***Suspended particles***
5.2.2.	***Bottom sediments***
5.3.	**Advection/ Dispersion/ Sedimentation**
5.4.	**Transfers to biota**
6.	**FOOD PROCESSING**
6.1.	**Processing of plant products**
6.2.	**Processing of animal products**
6.3.	**Processing of mushrooms and berries**
6.4.	**Processing of fish**
Annex 1	**List of parameters**
Annex 2	**List of tables**
Annex 3	**Tables of original values**

7. Conclusion

The revision of the IAEA TRS No. 364, "Handbook of parameter values for the prediction of radionuclide transfer in temperate environments", published in collaboration with the IUR, is an ambitious effort which is required by the progress of radioecology, expected by numerous users, and made possible by an international collaboration launched through the IAEA/EMRAS programme

Since such an activity demands expertise and resources, all institutions, all experts are welcome to contribute and participate through the existing channels: IAEA/EMRAS, IUR or even personal contacts.

8. References

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