STAR Wildlife Dosimetry Workshop – Discussion sessions

This documents presents a record of discussions during the workshop, they do not necessarily reflect conclusions or consensus between participants.

Discussion session 1: Internal dosimetry and biokinetics in wildlife

Chaired by Jose Maria Gomez-Ros (CIEMAT) and Jordi Vives I Batlle (SCK•CEN)

Topics proposed for the discussion:

1. Are biokinetic models required for assessment of doses to biota? When are they needed instead of equilibrium models? Do they improve the calculation of dose?
   - Use of Concentration Ratios (CRs) is a very approximate way to estimate the activity concentration in the whole body. They add considerably to uncertainty. Likely most uncertainty, but that's likely to be dependent upon other assumptions of the assessment. This is due, among other reasons, to the fact that they are site specific. CRs are element specific, not isotope specific – they do not take decay into account. But many people apply them as if they were isotope specific (which will generally be conservative). However, there are correction values that can be applied to account for this (see IAEA TRS 472 – estimate of biological half-life is required).
   - On the question of whether we need biokinetic models – it depends on what you want to assess – emergency or existing. For the latter – maybe OK with CR since more or less equilibrium conditions. Biokinetic models are not necessarily less uncertain than CR models, partly because they themselves usually rely on CR, as well as other assumptions which may have high uncertainties (e.g. assumptions on animal diets and transfer to those dietary components).
   - Exposure may also be dynamic as a consequence of an organism moving through a heterogeneous environment.

2. Is there enough effects data at organ level to justify modelling doses to organs?
   There is not enough effects data at organ level to justify modelling doses to organisms. There may be instances where knowing organ doses can help understand effects observed or should not be totally neglected (post accident ioding being the example we discussed).

3. What specific radionuclides/organs would be particularly appropriate for using with biokinetic modelling
   Biokinetic modelling is needed for transfer, but not for internal since we do not have the effects data yet – we do not know the effect levels.

4. What are the data gaps – can we use allometry?
   - For inhalation, you can extrapolate from other mammals, but ingestion more complex (ingesting grass *vs* soil etc.).
   - Regarding the use of allometry, there is uncertainty around this too – an example was given of the relationship between mass and breathing rate – there's an allometric

relationship but also scatter (normally distributed) around the relationship. There are also differences with age (humans) but these lie within the scatter. For chemicals, allometry generally works for uptake but not effects (because not enough chronic effects data)

- Elena – you can not eliminate real biological variability (though you can improve its quantification by data collection), but we CAN try and tackle systemic variability/uncertainty. She brought up the example of the small mammal data from Ural area – 30 y of good quality exposure and effects data. However dosimetry maybe not of the same quality.
- Other approaches exist: dynamic radioecological models (based on biological and ecological processes; radionuclides are considered as tracers together with stable elements) to calculate dynamic CRs – has been done in Chernobyl, Fukushima (Sazykina, JER 50 (2000) 207-220; http://www.sciencedirect.com/science/article/pii/S0265931X99001198)

5. What can human/mammal pharmacokinetic models teach us?

- There is a large experience in the pharmaceutical industry on biokinetic models, especially for mice, and on how to scale-up to other organisms such as humans to calculate the distribution of substances within the body. This has been done mainly for toxic chemicals (e.g. arsenic, mercury, heavy metals) and organochemicals but by the analogue approach can be adapted for radionuclides. So there is a lot we can learn from these models, adapting them to our use, without reinventing things. However, ultimately, enthusiasm on this type of research should be compensated by the lack of effects data at the internal body level, as said previously.
- The biokinetic models present in the PHE/HPA (previously NRPB) reports should be considered, for example those included in PC-CREAM.

6. What may hinder wider acceptance with operators and regulators?

- It´s important the issue of communicating uncertainty to stakeholders and how it effects our credibility.
- Assessors need something that can be explained. Need to be clear/careful about the purpose – science vs regulation. Otherwise risk of losing credibility with assessors!

Discussion 2: Wildlife dosimetry fit for purpose

Chaired by Justin Brown (NRPA) and Elisabeth Hansen (NRPA)

Topics proposed for the discussion:

What are the potential purposes/applications of wildlife dosimetry?

Environmental management/regulatory – planned exposures

- Integral part of setting limits on concentrations of radionuclides in the environment for screening purposes
- Integral part of calculating dose-rates to biota for routine discharges – planned exposure situations for screening purposes
- Detailed site specific assessments (representative organisms)

Environmental management/assessment – emergency and existing exposures

- Providing indications of doses to biota post-accident: emergency exposure situations
- Providing indications of doses to biota: existing exposure situation
- Long term assessment (planned) – HLW

Research – external/internal, lab/field exposures

- External exposure experiments in the laboratory – deriving whole-body or organ specific dose rates for biota at a given distance away from a point source
- Internal exposure experiments in the laboratory – deriving time-dependent organ specific dose rates for biota for internally incorporated radionuclides
- External exposure calculations for field experiments – deriving whole-body or organ specific dose rates e.g. for (i) animals traversing large territories or organ specific dose rates for (ii) specific components of plants (e.g. meristems), etc.
- Deriving whole-body or organ specific dose rates from internal exposures for plants and animals under field conditions

What are the available tools for wildlife dosimetry?

Simplified, 'off the shelf' models (e.g. ICRP-108, ERICA, RRESRAD-Biota, EA R&D128)

- Typically simplified (i) geometries (e.g. ellipsoids), (ii) sources (e.g. semi-infinite, volumetric, planar) (iii) target source configurations (e.g. at soil-air interface) and (iv) assumed homogeneity of radionuclides within organisms

Complex, 'ad hoc' models

- Monte Carlo radiation transport models (e.g. EGSnrc, MCNP, Geant4) in conjunction with computational (stylized, voxel or BREP) phantoms, apical meristem models

Traditional (analytical, semi-empirical) methods

- Loevinger's beta point-source dose distribution function, Berger equations (absorbed-dose rate at a distance r from a point source of monoenergetic photons), inverse square law, etc. *Although typically providing kerma – require conversion to absorbed dose-rate.

Measurements

- Electron paramagnetic resonance (EPR),
  Thermoluminescence Dosimeters (TLD), Optically Stimulated Luminescence dosimeters (OSL) – integrated doses
  Electronic dosimeters (e.g. Si-Diode)

How do the tools most appropriately map onto applications?

The chairs of the session suggested mapping the tools on to the purposes and giving the rationale (Table below). However, the discussion revolved more around the question of - how do we demonstrate fit for purpose? (see comments below). It was suggested that we could fill in the table afterwards.

Purpose	Tool	Rationale
Environmental management/regulatory • Setting limits on concentrations of radionuclides (screening) • Dose-rates to biota for routine discharges (screening) • Detailed site specific assessments		
Environmental management/assessment • Emergency exposure situation • Existing exposure situation • Long term assessment		
Research • External exposure lab experiments • Internal exposure lab experiments • External exposure field experiments • Internal exposure field experiments		

The rationale might also say why a particular approach is not applicable.
This may help us to identify where appropriate tools might not be available.

How do we/can we demonstrate fit for purpose?

- Regarding the models used: It was mentioned that regulators only use models to estimate dose. Dosimetry models are often 'validated' against other models, not against measurements. There are a limited number of such studies, although more are being started. Historical papers like the study done by Woodhead in the 1970s on fish should be reviewed, since they can give valuable inputs.

  We can not make everyone do probabilistic modelling! How do we make use of the individual-level data for assessments at population level? (especially for planned situations). The models we have are fine for screening, but above that they are not sufficient. There is a need to provide more advice on what to do when screening levels are exceeded. Usually, there is not enough site-specific field data to support Tier 3.

- The purpose of radiation protection of the environment is protecting populations (ICRP). In some cases there was a suggestion that probabilistic modelling might be required and a need to think in terms of distributions instead of single numbers. However there may be communication issue. 'Maximum exposed individual' is not a helpful concept in the environment because the general aim of protection is at the population level. Could it be better to use 95% percentile? Some participants were against a fixed percentile. The uncertainty of the percentile is important. And how does a manager deal with a percentile?

  Life history types are important. We cannot just talk about populations as if they were collections of uniform individuals (that is a statistical population, not a biological population). Better to identify groups of species that could be particularly at risk?

- How do we demonstrate fit for purpose? Are whole body doses fit for purpose? Maybe not for specific radionuclide-organ combinations?

  For example Iodine-thyroid: thyroid can be a very relevant organ in animals living in cold weather (the damage of the thyroid can have a big influence in these animals). Risk of thyroid cancer in animals needs to be demonstrated (there is a wildlife cancer database in US (old), but none of the participants in the workshop has analysed this database in detail). It was also mentioned that leukaemia is an important effect in mice. But someone

else pointed out that in nature, it is not cancer that kills them, but predation, though that may be because they are weakened by cancer… Overall fitness is most important.

- It was mentioned that we must put radiation in the context of other environmental issues (other contamination etc). How relevant is ionising radiation compared to other environmental risk? Or to natural variation? Must be able to justify resource use, convince public…. However, a participant advised that we should be careful with looking at comparative risk. The issue is more to do with public perception, degree of control over the situation etc.
- The question was raised on: Can we conclude that the technical tools we have for dosimetry are fit for purpose, but that the issue is lack of dose-effects data and the risk assessment part? It was mentioned that each dose-effect study must assess the degree of advanced dosimetry needed in each specific exposure scenario utilized, and that sometimes these tools are not easily accessible to the researchers who do the effect studies. The researchers who do effects studies do not always have access to dosimetric models or are qualified to use them.
- The Ecomod group (Russia) responsible for developing new Russian guidelines/criteria/ tools for environmental protection…outlined their approach. They were told by the government that these should be simple and easy to understand by nuclear industry.
- The dosimetric models available are appropriate for regulatory purposes, especially in light of missing effects data and approximate concentration ratios, and that an important current challenge lies in improving the dose assessments of the effects studies.

Discussion 3 – Uncertainties in wildlife dosimetry

Chaired by Tom Hinton (IRSN) and Karolina Stark (SU)

Ten points were outlines based around the theme 'Uncertainties are in the assumptions'.
Assumptions are made about:

1. **DEPOSITION** of the contaminant
   Spatial heterogeneity in deposition can be quantified (if we put enough money in), but models do not usually use the information. Similar issue with concentrations in organisms – we can measure them, but predicting is more difficult. The exception to this was the human chain (and mammals in general) where the situation is better.
2. **SOIL characteristics** and the depth distribution of the contaminant
3. **UPTAKE** of contaminant into plants and animals (i.e. concentration ratios)
4. **AGE, SHAPE** and **SIZE** of the plant or animal

   Concerning age, so far we mostly consider adult stages. Important to also include other life stages. Regarding the effect of shape and size on the dose we are more certain than uncertain.
5. **DISTRIBUTION** of contaminant in the body
6. **SPATIAL** homogeneity of the contaminant (externally)
7. **TEMPORAL** use of the habitat by free-ranging animals

8. **VARIATION** in dietary uptake or habitat use **WITH SEASON OR AGE**
9. **ORGAN SPECIFIC DOSES, WEIGHTING FACTORS** and **RBE**
10. **MODEL VALIDATIONS**; that if several different models predict somewhat similarly then the **MODEL PREDICTIONS** are ok….even though none of the models are compared to real dosimetry data on free ranging animals.

    Intercalibrations have shown quite good agreement, but that does not mean that they are accurate! If they were compared to real environmental data they may not be! May all be based on the same underlying (possibly poor and/or limited) data.

    Realistic assessments and/or probabilistic assessments to account for uncertainties

General comments on uncertainties made by participants:

- Uncertainties scare people – focus more on certainties?
- Are physics most certain? The further along the complexity scale you go, the more uncertainty.
- Make more use of probabilistic approaches. But could be a communication problem? But probability of effect is in the context of natural variation. And we often don't know what % decrease of a pop is acceptable (and it will differ between species). From a communications perspective it is easier to talk about no expected effect levels.
- A key problem might be in the interpretation of ICRP wording ('population').
- There is large uncertainty in how exposure changes with life stage – and how this is used in dosimetric assessments. Especially regarding differing sensitivity at different life stages.
- It was suggested that we may try to identify which of these uncertainties were largest. However we did not progress on this point. There was a comment that it depended on the situation.
- We do not need to make the wildlife assessment framework better than the human system!
- There is also user and tool uncertainty. Different users can get different answers based on the same data and also they can make different interpretation of the results. Related to this it was earlier cautioned against overusing the default CRs that are available as in commonly used models (REASRAD-Biota and ERICA Tool) these were derived for conservative screening level assessments (above this site specific data are recommended).

Discussion 4: What improvements are needed in wildlife dosimetry and why? Chaired by Nick Beresford (CEH) and Karine Beaugelin (IRSN)

They suggested returning to discussing the key issue, which they saw as the 'fit for purpose' discussion… screening vs realism: earlier we had talked about three purposes.

- Environmental management / regulatory
- Environmental management / assessment
- Research – internal/external, lab/field exposures

- Coming from previous discussions: the most uncertain parameter in dose assessment is not DCC, then perhaps not really useful to focus on dosimetry improvement
- The effects of interactions of species and their environment are important to understand.
- Modelling – voxels good for effects studies.
- Important to think about temporal changes in dose over an organism's lifespan - both internal and external (e.g. in fish as it grows). Regarding life span issues. Screening models may be misleading – they may just consider the organisms that get the most dose and these are not necessarily the ones that are the most sensitive. (This is especially the case for models that have a single screening level for all species).
- All agreed that plant dosimetry need to be improved: Several people though it would be better to focus on apical parts (root and shoot) and cambium, not the trunk. There was also a discussion about the plans for doing the voxel tree. Use Frederica data to identify parts of the plant to focus on? Previous focus has been very much above ground rather than below. There are a lot of old physiological studies from the 1950s/60s – e.g. using radioactive PO_{3-4} to trace root uptake – not all roots active at same time… And don't forget direct deposition to plant surfaces.
- Returning to the EURADOS lessons: benchmarks and intercomparisons are needed with real field data. This is one of the things that is planned at the Radioecology Observatory sites, as well as within TREE (https://wiki.ceh.ac.uk/display/NRT/NERC+RATE+TREE+Home) and other projects.
- At detailed research level people will probably need to develop their own methods
- Avoid over-complication (don not try to make everything same complexity level as for humans). The problem of acute vs chronic data (and lack of chronic effects data) was also brought up.
- Be careful if the models do agree – it might be coincidence!

Other points that came up in discussions:

- It is important to think of wildlife dosimetry in connection with the effects issues.
- In assessing emergency situations – for short lived organisms, this is whole life time. For longer-lived ones total dose will average out over whole life (except – that it depends if breeding season etc.)
- Fractionated dose of an organism moving in a heterogeneous environment; noted that if assumptions are conservative then likely acceptable for screening purposes.

The participants shortly discussed about a potential publication(s) from this workshop. All agreed that what is important is to publish a "position paper" with the main conclusions of the workshop. The possibility of doing a "monograph" (special volume of the JER) on wildlife dosimetry, including in addition to the position paper, other articles on specific relevant topics/background information in relation to wildlife dosimetry (e.g. micro and nanodosimetry concepts; voxel phantoms for animals and plants, etc.). The participants will be contacted to see their interest in contributing to this potential monograph.