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CL:AIRE research bulletins describe specific, practical aspects of research which have direct application to the characterisation, monitoring or remediation of contaminated soil or groundwater. This Bulletin describes EcoTRANS; a modelling system to enable the estimation of food-chain transfer of contaminants from soil to UK species and relate this to toxicological data.

Modelling Food-Chain Transfer of Contaminants in Soil to Terrestrial Ecological Receptors

1. INTRODUCTION

Urban ecosystems are increasingly being recognised as significant ecological resources. An independent review of the habitats and species coverage of characteristically urban environments concluded that there was a strong case for two new priority habitats to be incorporated into the UKBAP (UK Biodiversity Action Plan) as 'Open and mosaic habitats on previously developed land (OMHoPDL)', and 'Calaminarian Grasslands' (Biodiversity Reporting and Information Group, 2007; Tucker et al., 2005).

The UKBAP (UK Biodiversity Action Plan) is the UK Government's response to the obligations set out in the Convention on Biological Diversity and the EC Habitats Directive (92/43/EEC). The latter obliges Member States to implement 'measures to maintain or restore natural habitats and wild species at a favourable conservation status, introducing robust protection for those habitats and species of European importance' (source: www.jncc.gov.uk). UKBAP details the priority habitats and priority species within the UK, and therefore forms an integral part of the UK approach to conserving biodiversity (UK Biodiversity Partnership, 2007).

OMHoPDL may be found on a wide range of post-industrial sites including chemical wastes, colliery and quarry spoils, Pulverised Fly Ash, Leblanc waste, blast furnace slag, railway sidings and landfill sites. The diverse nature of these sites means that a number of habitats may be included in OMHoPDL such as areas of bare ground, pioneer species, open grasslands, scrub, heathland, swamp, ephemeral pools (Biodiversity Reporting and Information Group, 2007). Calaminarian Grasslands are found on substrates such as mine waste, rock outcrops and screes characterised by high concentrations of metals. As such these substrates often support vegetation that is specifically adapted to the site conditions. A lack of formal recognition of the importance of these habitats for nature conservation has meant that many have been lost due to rehabilitation of what were seen as 'derelict sites' or inappropriately managed. Whilst both priority habitats often possess communities with a high ecological significance a balance must be achieved between protecting valuable ecological resources and managing any contamination to ensure that other receptors are not at risk.

Ecological receptors are afforded the same protection under Part 2A of the Environmental Protection Act 1990 (Defra, 2006; Scottish Executive, 2006; Welsh Assembly Government, 2006) as other receptors such as controlled waters, humans and livestock. However, not all potential ecological receptors are included in Part 2A, they are instead restricted to those located in areas with statutory or local protection (for example Sites of Special Scientific Interest, National Nature Reserves, Areas of Special Protection for Birds). Where these sites are present within, adjacent to or influenced by, an area of potentially contaminated land, an Ecological Risk Assessment (ERA) is required. The Environment Agency's 'Ecological risk assessment framework for contaminants in soil' provides comprehensive information on the stages necessary to conduct an ERA (Environment Agency, 2008). This primarily relies on the use of site investigation, ecological surveying and bioassays.

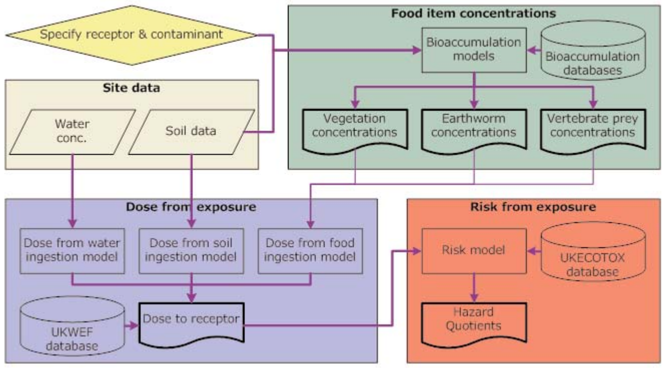

Figure 1. EcoTRANS methodology for modelling contaminant fluxes and their consequent risk to urban wildlife receptors.

Modelling has been used extensively for estimating the amount of contaminant that will be transferred through the food-chain and a number of platforms are currently available in the USA. When used appropriately the models provide a useful screening tool for identifying 'hotspots' of contamination, vulnerable groups of species and targeting further site investigation or ecological surveying. The models for predicting contaminant transfer to mammals and birds are not species-specific. However, their use relies on a series of 'Wildlife Exposure Factors' which have been collated for use in the USA platforms. The species used in these platforms are, with the exception of the red fox, not found in the UK or Europe. This Bulletin describes EcoTRANS; a modelling system developed by Forest Research from those available in the USA to enable the estimation of food-chain transfer of contaminants from soil to UK species and relate this to toxicological data.

2. MODELLING FOOD-CHAIN TRANSFER OF CONTAMINANTS USING ECOTRANS

A review of available frameworks and models for predicting food-chain transfer of soil contaminants identified the most appropriate approach to use in the development of EcoTRANS (Figure 1). The frameworks reviewed from those available in the USA included Spatial Analysis and Decision Assistance (SADA; University of Tennessee, 2005), Multimedia, Multi-pathway, Multi-receptor exposure and Risk Assessment (3MRA; USEPA, 2003a) and Total Risk Integrated Methodology: Environmental Fate (TRIM.FaTE; USEPA, 2003b). The approach in EcoTRANS is based on a combination of that of SADA and 3MRA, but also utilises regression models where they are available in the literature. The approach in EcoTRANS consists of three steps:

1. Modelling bioaccumulation of contaminants into food items;
2. Modelling the dose-from-exposure to wildlife receptors;
3. Modelling the risk to wildlife receptors from exposure.

Each step comprises empirical models, which rely on five databases:

- Three bioaccumulation databases to cover the different food items in the receptor food chain: vegetation, invertebrates (earthworms) and vertebrate prey;
- A database of wildlife exposure factors for the terrestrial wildlife species selected for inclusion in EcoTRANS; named UKWEF (UK Wildlife Exposure Factors) that has been developed specifically for EcoTRANS;
- A database of ecotoxicological benchmarks for the terrestrial wildlife species selected for inclusion in EcoTRANS; named UKECOTOX (UK ECOlogical TOXicity).

The input data for EcoTRANS at the most basic level are concentrations of contaminants in the soil for each sampling point, presented in an Excel file. The user can also provide concentrations in water (to allow an estimation of dose from the ingestion of water) and soil pH and concentration of Ca (these allow more complex bioaccumulation models to be used).

Data are output in both Excel files and spatially as images (.png), and include concentrations in food items, dose to receptor from ingestion of food, soil and water, and hazard quotients.

3. MODELLING THE DOSE-FROM-EXPOSURE TO WILDLIFE RECEPTORS

The 'Framework for Metals Risk Assessment' recently published for terrestrial ecosystems (USEPA, 2007a) stresses the potential for trophic transfer of metals and metalloids through the food web and the need to calculate total exposure by including at least dietary intake as well as intake from contaminated environmental media (soil and water). EcoTRANS, which is focused on metal contamination, is based on this approach. Hence, modelling contaminant uptake to terrestrial wildlife receptors is based on receptor ingestion of contaminated food, water and soil.

Inhalation of contaminated dust and dermal contact with contaminated soil are usually considered negligible when compared to oral exposure (McGeer et al., 2004; USEPA, 2003a); they are therefore not taken into account in EcoTRANS. Exposure to metals and metalloids through the incidental ingestion of soil (i.e. through grooming or consumption of soil adhering to food items) is a significant route for wildlife species foraging near the ground surface and/or feeding on soil invertebrates (McGeer et al., 2004).

It is important when modelling contaminant exposure to terrestrial wildlife species to bear in mind that the higher in the food chain the receptors are, the more likely the exposure to contaminants may differ between individuals due to variations in prey and food items ingested. Many parameters will influence wildlife exposure to contaminants including the trophic level, species (e.g. specific exposure parameters such as body weight, food ingestion rate), age and sex of individuals (life stage) and seasonal variability (e.g. due to changes in weather and food availability and during the breeding season for females and juveniles). The models in EcoTRANS endeavour to capture some of these variations whilst accepting that the uncertainties associated with higher trophic level exposure modelling are, to a certain extent, unavoidable.

Modelling ingestion of contaminated food

The terrestrial habitat food web modelled in EcoTRANS consists of vegetation and three trophic levels. Trophic level 1 (T1) consists of species that consume the vegetation (i.e. herbivores) which are potential prey for higher trophic levels species; this includes small mammals and invertebrates. T2 consists of species that consume plants and/or animals (i.e. omnivores and carnivores) and includes small-to-medium sized mammals and birds. T3 consists of apex species, or those that do not have any predators (other than humans) in their natural habitat. Therefore, there are three categories available to model wildlife receptor diets: vegetation, invertebrate prey and vertebrate prey.

The lack in availability of bioaccumulation data means that there are not currently any refinements possible within each category. In the case of vegetation this means that one model is used for each contaminant to estimate the concentration in all species and in all plant parts. Therefore it is assumed, for example, that the concentration in the root tissue is equal to that in the above-ground tissue and that leaf concentrations will be the same as seed concentrations. Similarly, there is no distinction between invertebrate species; the models are based on data for earthworms and are applied to all invertebrates including insects and snails. In the case of vertebrate prey, three concentrations are estimated (one for each trophic level), but because predator diet descriptions are not sufficiently detailed, it is not yet possible to account for proportions of various prey in predator diets. Consequently, a geometric mean of the three concentrations (herbivores, insectivores/carnivores and omnivores) has been used for vertebrate prey concentration, which therefore assumes equal proportions of vertebrate prey categories ($P_{herbivore}=1/3$, $P_{insectivore/carnivore}=1/3$, $P_{omniivore}=1/3$) within the predator diet.

The daily dose from ingestion of food is calculated from the concentrations of contaminant in the food items and the proportion of food item in the diet. Allometric equations from Nagy (1987) have been used to estimate receptor food ingestion rates in EcoTRANS for the magpie and robin.

As the bioaccumulation models were derived using a large data set and a range of soil conditions, bioavailability is intrinsically accounted for in the models.

EcoTRANS also has the capability to use site-specific vegetation and invertebrate data that have been collected during the site investigation process. Where such data are available they can be used instead of the modelled bioaccumulation data for these food groups, and therefore can reduce the reliance on, and the errors associated with, one level of modelling.

Modelling bioaccumulation into plants

When modelling bioaccumulation into plants using EcoTRANS, no distinction is made between plant species. This is due to the lack of urban plant species-specific bioaccumulation data; most studies rely on a mixture of plants including agricultural crops. In developing EcoTRANS a review was conducted of the available models for estimating the transfer of soil contaminants to plants and the following sources were selected for inclusion:

1. Baes et al. (1984), IAEA (1994) and NCRP (1989) as reported in University of Tennessee (2005), Bechtel-Jacobs (1998), Efroymson et al. (2001) and USEPA (2007a) for inorganic contaminants;

2. USEPA (2007a) for organic contaminants.

Three types of empirical models are available to predict the accumulation of contaminants into plants, depending on the contaminant. These models differ in their complexity and the soil characteristics they rely on. EcoTRANS selects which model to use based on the availability of soil data.

Modelling bioaccumulation into soil invertebrates

Currently the only soil invertebrate models that are available have been derived from the relationship between metal concentrations in soils and earthworms, with no distinction being made between species. The receptors that have been selected are those that would be expected to consume earthworms, although in the case of robins, great tit and magpie (see below) other invertebrate groups will also be consumed.

In developing EcoTRANS a review was conducted of the available models for estimating the transfer of soil contaminants to invertebrates and the following sources were selected for inclusion:

1. Neuhauser et al. (1995) and Sample et al. (1998a, 1999) for inorganic contaminants;

2. Sample et al. (1999a) and USEPA (2007a) for organic contaminants.

Four types of empirical models are available to predict the accumulation of contaminants into invertebrates, depending on the contaminant. These models use different levels of soil information to achieve increasing levels of accuracy. EcoTRANS selects which model to use based on the availability of soil data.

Modelling bioaccumulation into vertebrate prey

The diets of vertebrate species vary significantly and this will influence both their exposure to contaminants as well as that to their predators. Therefore, the vertebrate prey considered in EcoTRANS was selected to represent three trophic levels: herbivore, insectivore/carnivore and omnivore small mammals and birds. Herpetofauna are not considered in EcoTRANS.

In developing EcoTRANS a review was conducted of the available models for estimating the transfer of soil contaminants to vertebrate prey. This review was based on Sample et al. (1998b), SADA software (University of Tennessee, 2005) and the 3MRA (USEPA, 2003c) and TRIM.FaTE methodologies (USEPA, 2003b).

All empirical models selected to estimate bioaccumulation of metals into vertebrate prey in EcoTRANS come from Sample et al. (1998b). This study derived regression models and uptake factors (UFs) from the scientific literature which describe the relationship between soil concentrations and small mammal whole body concentrations. Whenever possible, regression models were included in EcoTRANS in preference to uptake factors as the latter are less likely to consistently provide the best estimate of small mammals' body burdens (Sample et al., 1998b); the bioaccumulation process is unlikely to be linear.

Two types of empirical models are available to predict the accumulation of contaminants into vertebrate prey, depending on the contaminant. These models have been derived from literature covering 21 species of mammal (6 carnivores, 8 herbivores and 7 omnivores). Unfortunately, no models have been published in the available literature for birds. Therefore, bioaccumulation into small birds was assumed to be equivalent to that into small mammals, with respect to each trophic group as is the case in both the SADA (University of Tennessee, 2005) and 3MRA (USEPA, 2003c) platforms.

Modelling ingestion of contaminated soil

Soil is ingested both intentionally and accidentally by many species of wildlife (USEPA, 1993); hence soil ingestion can be a significant exposure pathway for some contaminants. This exposure pathway is more important for animals foraging near or on the ground surface and is especially true for mammals and birds that feed on earthworms which typically contain 20 to 30% soil (Beyer et al., 1994). However, the literature is scarce on soil ingestion by wildlife. Therefore the calculation developed by Beyer et al. (1994), which takes into account the food ingestion rate, the proportion of the diet which is soil and the receptor's body weight, has been adopted in EcoTRANS. The proportion of soil in the diet was not available in the literature for the robin, great tit and magpie, so that of the American robin was used as a surrogate.

Modelling ingestion of contaminated water

This parameter is difficult to estimate. The 'Wildlife Exposure Factors Handbook' (USEPA, 1993) reports allometric equations for drinking water ingestion for mammals and birds. These equations were developed by Calder and Braun (1983) from measured body weights and water consumption and have been used to estimate receptor water ingestion rates in EcoTRANS for the common kestrel, great tit, magpie, robin and common shrew.

4. SPECIES SELECTION

Ten species were selected for inclusion in EcoTRANS; five mammals and five birds (Table 1). These were based on the work of Baker and Harris (2007) and the definition of urban species in Tratalos et al. (2007). However, it was not feasible to model exposure to contaminants and risk for all wildlife receptor species likely to be present on contaminated sites, primarily due to limitations in the wide range of ecological and toxicological data required. The species were chosen using the following criteria:

1. Representative of terrestrial urban ecosystems based on their distribution in the UK;

2. Representative of different trophic levels and feeding strategies with a range of diets likely to result in contact with contaminated environmental media (herbivores, insectivores, carnivores and omnivores);

3. Sufficient ecological and toxicological data available in the literature to run the models;

4. Indicative of some contaminants (e.g. *Sorex araneus* for metals).

Table 1. List of wildlife species selected for inclusion in EcoTRANS.

Species type	Trophic level	Species common name	Species scientific name
Mammal	Herbivore	Bank vole	*Myodes glareolus**
		Rabbit	*Oryctolagus cuniculus*
	Insectivore	Common shrew	*Sorex araneus*
	Omnivore	Badger	*Meles meles*
		Red fox	*Vulpes vulpes*
Bird	Insectivore/ Omnivore	Robin	*Erithacus rubecula*
		Great tit	*Parus major*
		Magpie	*Pica pica*
	Carnivore	Common kestrel	*Falco tinnunculus*
		Tawny owl	*Strix aluco*

*Formerly *Clethrionomys glareolus.*

A simple food web for these indicator species was created (Figure 2) to demonstrate the potential predator-prey relationships in urban habitats for the UK.

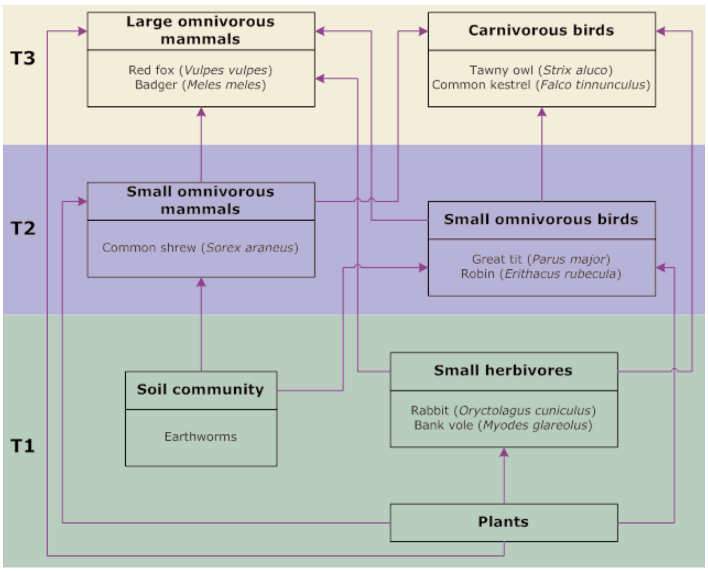

Figure 2. Food web for the species selected for inclusion in EcoTRANS. T1=trophic level 1, T2=trophic level 2, T3=trophic level 3.

5. CONTAMINANT SELECTION

Data for metal and metalloid contaminants were required for the three steps of modelling in EcoTRANS (bioaccumulation, dose and risk estimation). Where available, data have been included for organic contaminants, but the inconsistency in these data means that it is not possible to follow the entire methodology to give the risk to ecological receptors. Data that are currently available for organics have been included in the databases to allow additional data to be included in the future. It should be noted that the focus on inorganics is not a reflection of the relative importance of one group of contaminants.

The combination of receptor species and contaminant currently available is presented in Table 2.

6. WILDLIFE EXPOSURE FACTORS

The models included in EcoTRANS are not species-specific, but the data, or Wildlife Exposure Factors, required to run them are. Therefore, as part of the development of EcoTRANS Wildlife Exposure Factors (UKWEF) had to be derived for UK species. The following exposure factors are included in the UKWEF database:

- Body weight
- Diet description
- Daily food ingestion rate (FIR)
- Daily water ingestion rate (WIR)
- Fraction of roots, foliage and seeds in diet (where available)
- Total fraction of vegetation in diet
- Fraction of invertebrate prey in diet
- Fraction of mammals and birds in diet (where available)
- Fraction of vertebrate prey in diet
- Fraction of scavenged food
- Fraction of unknown food
- Fraction of soil in diet
- Home range size.

These data were taken from a number of sources including peer-reviewed papers (65), books (11), unpublished reports (4), theses (2), conference papers (1) and websites (3).

For apex species, a category was added to conventional diets to represent the scavenging behaviour of some species in urban areas (i.e. red fox and badger). Similarly, the parameter 'fraction of unknown food' was included where there were uncertainties in the literature.

7. MODELLING THE RISK TO WILDLIFE RECEPTORS FROM EXPOSURE

The risk to wildlife receptors from exposure to contaminants is estimated in EcoTRANS using a hazard quotient (HQ) approach. The method (also called risk quotient - RQ) is widely used in ERA for evaluating the toxicity/exposure relationship. It compares a parameter representing the exposure to a contaminant with a benchmark (also called 'threshold' or 'measurement endpoint') in relation to a specific effect or assessment endpoint (e.g. development or reproduction data, mortality, etc.).

An HQ above 1 indicates that ecological risks are above levels of concern, and an HQ below 1 indicates that ecological risks are below levels of concern. This approach implies that a HQ much greater than 1 (say, two orders of magnitude) represents a more serious ecological threat than a HQ of 2. But because HQ calculations do not represent an actual dose-response relationship, a HQ of 20 does not imply that the effect would be 10 times more severe for a receptor than a HQ of 2.

In EcoTRANS the modelled dose to the receptor is divided by the Lowest Observed Adverse Effects Level (LOAEL) for the wildlife receptor.

When a LOAEL is not available for a contaminant, the dose may be compared to the No Observed Adverse Effect Level (NOAEL). This method requires deriving estimates of LOAELs and NOAELs for the wildlife species identified as indicators for UK terrestrial urban habitats.

Wildlife NOAELs and LOAELs were developed for each of the receptors used in EcoTRANS using the methodology from Sample et al. (1996). For each trophic group of wildlife mammals and birds, a species is selected for which toxicological data are available ('test species') and then the data are extrapolated for other species in the same trophic group using body size scaling factors (Figure 3). This scaling methodology has been used by the USEPA since 1992 in carcinogenicity assessments, for adjusting from animal data to an equivalent human dose.

Table 2. Receptor species and contaminant availability in EcoTRANS.

Contaminant	Mammals					Birds				
	Bank vole	Rabbit	Common shrew	Badger	Red fox	Robin	Great tit	Magpie	Common kestrel	Tawny owl
Aluminium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Antimony	✓	✓	✓							
Arsenic III	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Barium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Beryllium	✓	✓	✓							
Cadmium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chromium III	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Copper	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fluorine		✓								
Lead	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Manganese	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mercury	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nickel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Selenium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Thallium		✓								
Vanadium		✓				✓	✓	✓	✓	✓
Zinc	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

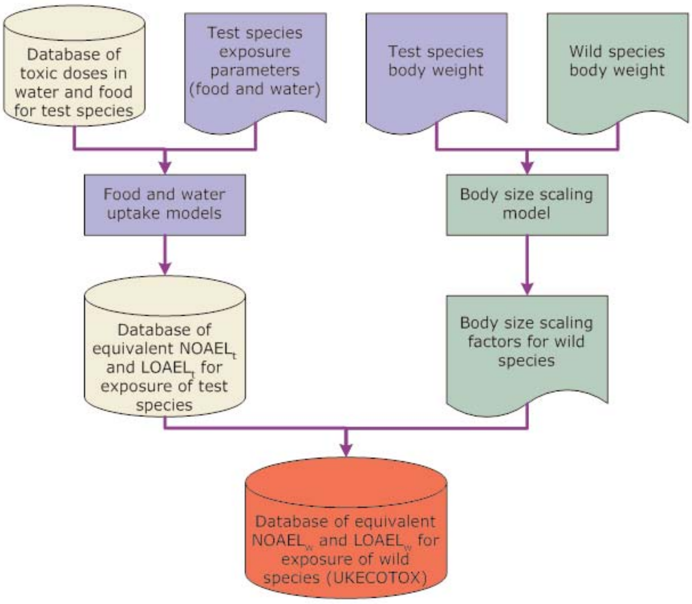

Figure 3. Method for deriving wildlife NOAELs and LOAELs (Sample et al., 1996).

8. CASE STUDY

Soils were collected from an area that had been subject to aerial deposition of metals near to the former Britannia Zinc smelter (Avonmouth, Bristol, UK). The smelter was active for 75 years and ceased operation in 2003. Soils were collected from an unmanaged area of grassland 250 m to the NE of the former smelter site on Lawrence Weston Road (National Grid Reference ST531791, 2º40.38'W, 51º30.33'N).

Soils were collected as part of a wider study. Surface vegetation was removed to expose the soil surface and samples were taken from the top 20 to 30 cm of the soil profile. The location of the samples was chosen in an attempt to achieve a range of metal concentrations. In addition, Kettering loam was used as a control soil. The soils were air-dried, ground and sieved to obtain the less than 2 mm fraction.

Three sub-samples from each location were analysed for total Ca, Cd, Cu, Pb and Zn by aqua regia digestion using ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometer, Spectro Analytical Instruments, West Midlands, UK). Soil pH was determined using a 1:10 suspension with 0.01M $CaCl_2$ solution. The soil properties are displayed in Table 3.

There are two potential ecological receptors near to the former smelter. The Avon Wildlife Trust Reserve is a 10 ha site 1 km to the NE of the smelter. It is a butyl lined reservoir which was once part of the sewage works and now consists of two edged ponds and a shallow more natural pond with emergent vegetation. The surrounding land was tipped on and now has rough grassland with some amenity planting. This site is important for a number of bird and mammal species, particularly water fowl. The second site was Lawrence Weston Moor Nature Reserve. This 12 ha site is 2 km east of the smelter site and consists of grassland, marsh, flooded areas and scrub vegetation. Both sites are important for a number of mammal and bird species and the following species also contained in EcoTRANS have been recorded there: common kestrel, great tit, magpie, robin, common shrew, badger, rabbit and red fox.

Table 3. Soil metal and Ca concentrations and pH from soils near the former Zn smelter at Avonmouth (mean±standard deviation).

	pH	Ca (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Avonmouth 1	5.7±0.1	4333±72	97.7±2.1	393±15	3867±404	9167±153
Avonmouth 2	6.5±0.2	6635±971	46.3±3.2	233±31	2400±265	4133±321
Avonmouth 3	5.6±0.1	4157±249	75.0±2.6	270±10	2767±252	5900±200
Kettering loam	6.7±0.1	8441±1015	3.7±0.1	24.2±0.3	42.6±2.7	102±1.1

EcoTRANS was used to estimate the risk to the receptors from the Cd, Cu, Pb and Zn concentrations in the soil; HQs are shown in Figure 4. Dose from the ingestion of water was not estimated as it was not possible to collect water samples at the time of soil sampling. Although the data for Cd are presented, the models for Cd accumulation into omnivores and insectivores are outside of the range for which the models have been developed, which may affect the estimates to common kestrel, badger and red fox.

As expected the HQs for the Kettering loam soil were below 1 for all metals and all species. Concentrations of Cu in the soils from Avonmouth were relatively low so the HQs for this metal were also below 1 for all species. HQs for Cd were above 1 for badger, common shrew, great tit and robin which reflects the higher proportion of earthworms in their diets which have greater concentrations of this metal than vegetation and vertebrates. Only the badger has a HQ above 1 for Pb out of the mammals, and this is only in the Avonmouth 1 soil. However, all of the bird species have HQs above 1 for Pb in the soils from Avonmouth; those for the common kestrel are much lower than the other species due to the lower proportion of invertebrate prey and vegetation consumed by this species. The LOAEL for Pb is significantly smaller for bird species compared to mammals resulting in differences in the HQs for these groups. Similarly, the LOAEL for Zn is also smaller for birds, so the HQs for this metal are also above 1 for great tit and robin.

EcoTRANS assumes that the receptor spends 100% of its time on the site in question. This may lead to greater doses and therefore conservative HQs for some species, particularly higher predators that have very large home ranges. If, for example, the site used here was 10 ha in size the home range

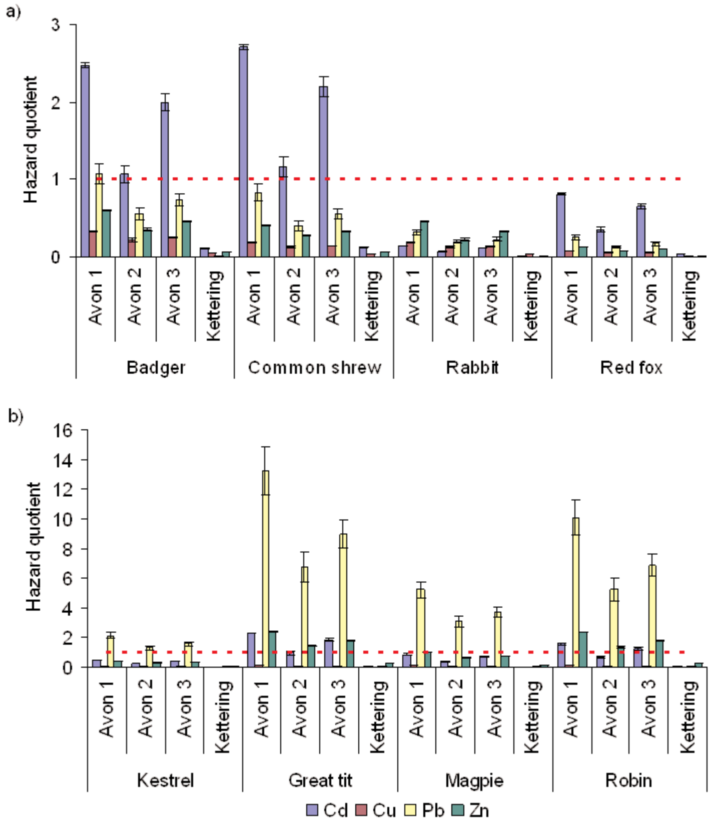

Figure 4. Hazard quotients for a) mammals and b) birds from exposure to Cd, Cu, Pb and Zn in the vicinity of the former Zn smelter at Avonmouth (n=3; error bars indicate standard deviation).

of the kestrel, badger and red fox would all be larger than the site. An Area Use Factor (AUF) could therefore be applied to the dose data from EcoTRANS to take account of the reduction in time spent on site (University of Tennessee, 2005). The AUF factor is calculated as the area of the site divided by the home range to give the proportion of the site which falls in the receptor's home range (maximum value of 1). This can then be multiplied by the dose and this new dose compared to the LOEAL to give an adjusted HQ.

In the example used above, the dose of Pb to the common kestrel from Avonmouth 1 was 24.2 mg/kg BW/d, but adjusting this to account for the home range of this species (400 ha) gives a dose for a 10 ha site of 0.60 mg/kg BW/d. This would result in a HQ of 0.05 as opposed to 2.14. The choice of whether to apply the AUF factor will depend on the site in question, the species and the surrounding area.

9. CONCLUSIONS

EcoTRANS provides a valuable tool for use in the wider ERA process. It provides the ability to quickly and effectively estimate the risk to ten ecological receptors commonly associated with contaminated and brownfield land. It allows the user to target further site investigation or ecological survey to areas with the greater risk (for example based on habitat type) or those species groups with greater HQs (for example Pb in birds). Similarly, if a greater risk was being predicted for those receptors consuming higher proportions of vegetation and/or invertebrates site-specific data can be used instead, for example if soils have a low availability.

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This bulletin was written by Cécile De Munck, Danielle Sinnett, Andy Brunt and Tony Hutchings.

For further information please contact Tony Hutchings at the Land Regeneration and Urban Greenspace Research Group, Centre for Forestry and Climate Change, Forest Research, Alice Holt Lodge, Farnham, Surrey, GU10 4LH, UK.

Email: tony.hutchings@forestry.gsi.gov.uk

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