9
Loss of Species due to Cadmium and Lead Depositions in Europe

9.1 Introduction
One of the endpoints for the critical loads of cadmium (Cd) and lead (Pb) is the eco-toxicological effect of metal ions in soil solution on soil micro-organisms, plants and invertebrates. Depositions will (eventually) result in a concentration in soil solution in equilibrium with each other, depending on the ecosystem properties like leaching, uptake and soil properties (pH, organic matter and clay contents) as described in section 9.2. The European background database (EU-DB), as used by the CCE to compute critical loads provides these properties and is used to map the concentrations for ecosystems in Europe, given the depositions at current legislation (CLE). The concentration can be high enough to intoxicate part of the species present in the ecosystem. The dose-response relationship between concentration and fraction of species lost is described in section 9.3. With the concentration-response relationship the fraction loss of species can be computed for the ecosystems in EU-DB at CLE, and section 9.4 shows the results. The results are not completely in line with the exceedances of the critical loads as mapped in Chapter 8. To explain the discrepancies, the response functions are compared to the critical concentrations as used in the critical load computations in section 9.5.

9.2 Steady-state total metal ion concentration in soil solution computed from metal input and runoff

At steady state, $[M]_{tot}$ can be computed from the net input of metal $M$, $M_{in}$ (Posch and De Vries 2009):

$$[M]_{tot} = \frac{M_{in} - M_u}{Q}.$$

where $Q$ (in m/a) is the water flux leaving the soil layer (assumed equal to the precipitation excess), $M_{in}$ (in mg/m$^2$/a) is the input flux of metal $M$, i.e. the sum of fertilisers, manure and deposition, and $M_u$ (in mg/m$^2$/a) is the net growth uptake (biomass removal) of metal $M$ from the soil layer considered.

9.3 Loss of species estimated by species sensitivity distributions

Analyzing the results of the world’s resources on laboratory derived toxicity observations revealed that species
differ in their sensitivity towards a single chemical. This may be due to differences in life history, physiology, morphology and behaviour. Without attempting to explain the cause of variability in species sensitivity, this recognition led to attempts to describe the variation with statistical distribution functions, thereby putting the concept of species sensitivity distribution (SSD) into existence (Posthuma et al. 2002, Van Straalen and Denneman 1989). The basic assumption of the SSD concept is that the sensitivities of a set of species can be described by some kind of statistical distribution. The available eco-toxicological data are seen as a sample from this distribution and are used to estimate the moment parameters of the SSD. The moments of the statistical distribution are used to calculate a concentration that is expected to be safe for most species of interest, which can be used to set an environmental quality criterion. A more recent application is the use of SSDs in risk assessments of contaminated ecosystems. For setting quality standards SSDs are commonly constructed in a more conservative manner by using chronic no observed effect data (NOEC). For environmental risk assessment related to the loss of biodiversity, the SSD curves are generally based on acute mortality data (LC50).

Toxicity data for soil dwelling organisms and terrestrial plants are comparatively scarce. For the present study we therefore used publicly available data on acute median lethal or effective concentrations (LC50 or EC50) based on aquatic toxic tests to derive SSDs. These SSDs reflect the concentration-response relationship between total dissolved porewater concentration and the loss of species. In the literature there is no indication that the sensitivity of organisms living in soil is intrinsically different from the sensitivity of organisms living in surface waters, provided that the evaluation is based on the truly bio-available fraction of the toxicants.

For both cadmium (Cd) and lead (Pb) an SSD is obtained from the literature derived toxicity data by fitting a normal model to the log toxicity data. For the log-normal procedure, the SSDs are fully characterized by the median (Mu) of the distribution which is equal to the average (Sigma) of the log-transformed toxicity data and by the slope of the distribution that equals the standard deviation of log-transformed toxicity data. The moments (Mu and Sigma) of the acute SSD curves for Cd and Pb are given in Table 9.1.

The SSDs reflecting the concentration-response relationship between total dissolved porewater concentration ([M]) and the loss of species are given in Figure 9.2.

Figure 9.1 Exemplary cumulative distribution function of species sensitivity log-normally fitted (curve) to observed chronic toxicity values (NOEC; dots). The arrows indicate the inference of risk as a Potentially Affected Fraction of species (PAF-value) and the inference of an environmental quality criterion as a hazard concentration for 5% of the exposed species (HC5).

Figure 9.2 SSD curves for cadmium and lead as used in the present risk assessment.
9.4 Loss of species in Europe

For the European critical load background database (Reinds, 2008) and given the depositions at current legislation (CLE) the metal concentration has been calculated according to the formula in Section 9.2. The loss of species, according to the response function for the concentration in soil solution for each of the 1.6 million ecosystems has been mapped for Cd and Pb and the 99th percentile in every EMEP grid cell are shown in Figure 9.3. The 99th percentile is shown, because the vast majority of the ecosystems are not affected.

The loss of species has also been calculated for the combined effect of Cd and Pb (Figure 9.4). Because most ecosystems are unaffected, but the combined effect of the sensitive ecosystems is much higher than the individual metals, it seems likely that the same ecosystems are sensitive to both metals.

As stated earlier in this chapter, the loss of species is depicted in the maps for the 99th percentile, which means that 99 % of the ecosystem area within a grid has a lower (or equal) value than the values in the maps. Figure 9.5 shows the cumulative distribution of the combined effect of both metals to the loss of species. It shows that effects are close to zero in the vast majority of the ecosystems.

### Table 9.1 The moments for the acute SSD’s for cadmium and lead.

<table>
<thead>
<tr>
<th>CAS</th>
<th>English name</th>
<th>chemical code</th>
<th>#Species</th>
<th>MuAcute (µg/L)</th>
<th>SigmaAcute (µg/L)</th>
<th>TMoA</th>
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<tr>
<td>7439-92-1</td>
<td>lead dissolved</td>
<td>Pb dis</td>
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<td>3.72</td>
<td>0.707</td>
<td>Pb</td>
</tr>
<tr>
<td>7440-43-9</td>
<td>cadmium dissolved</td>
<td>Cd dis</td>
<td>68</td>
<td>2.90</td>
<td>1.016</td>
<td>Cd</td>
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<table>
<thead>
<tr>
<th>% loss</th>
<th>loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>no loss</td>
<td>0.0 - 0.5</td>
</tr>
<tr>
<td>0.5 - 1.0</td>
<td></td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td></td>
</tr>
<tr>
<td>&gt; 2.0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9.3 The 99th percentile of loss of species at steady state with CLE depositions for cadmium (left) and lead (right).

Figure 9.4 The 99th percentile of loss of species at steady state with CLE depositions for the combined effect of Cd and Pb.
Why are much less than 5% of the ecosystems affected in grids in which critical loads are exceeded for each of the individual metals? (Compare with the top centre maps of Figures 8.4 and 8.5). The major difference is that the SSD reflects the acute lethal effects, and that the critical load approach is based on (De Vries et al, 2007) critical concentrations derived from NOEC values that protect 95% of the species from damage. Other differences are related to the fact that the limits for the Mapping Manual (UBA 2004) are
- not based on a postulated statistical distribution, like the log-normal distribution in the SSD, but by a bootstrapping method;
- include a toxicity-dependence on pH;
- related to the free concentration rather than the total concentration;
- corrected for described deviations for toxicity in ecosystems from laboratory experiments.

References


UBA 2004. Manual on methodologies and criteria for modelling and mapping critical loads & levels and air pollution effects, risks and trends. UNECE Convention on Long-range Transboundary Air Pollution, Federal Environmental Agency (Umweltbundesamt), Berlin