Critical loads in Europe: overview and latest developments

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Alterra, Wageningen UR and RIVM-CCE

Wageningen UR

Environmental Sciences Group

National Institute for Public Health and the Environment (RIVM)

Other science groups

Alterra (Applied Research)

Environmental sciences (University)

20 years cooperation

Other

CCE

NADP-CLAD meeting Indianapolis 2014
The critical load process in Europe: The 1979 Geneva Convention on Long-range Transboundary Air Pollution

Integrated assessment and policy support

NADP-CLAD meeting Indianapolis 2014
Achievements: emission reductions $\text{SO}_x$

Source: LRTAP/EEA

Chart — Change in emissions of sulphur oxides compared with the 2010 NECD and Gothenburg protocol targets

Source: LRTAP/EEA
Achievements: emission reductions NO$_X$

Source: LRTAP/EEA
Achievements: trends in exceedances: acidity

Areas where critical loads for acidification are exceeded by acid depositions (EMEP50 model; Revised Gothenburg Protocol (RGP))

Source: ICPM&M/CCE

NADP-CLAD meeting Indianapolis 2014
Achievements: trends in exceedances: CLnutN

Areas where critical loads for eutrophication are exceeded by nitrogen depositions (EMEP50 model; Revised Gothenburg Protocol (RGP))

Source: ICPM&M/CCE
Emission trends

Source: EMEP REPORT 1/2014
Future directions: Critical loads based on biodiversity endpoints

![Graph showing Calluna vulgaris probability vs pH and NO3 concentration](image)
From response to critical load

Who defines the target?
Part 2: Critical loads for heavy metals
Critical load for terrestrial ecosystems: uptake + leaching:

$$ CL(M) = M_u + M_{le(crit)} $$

$$ M_u = f_{Mu} \cdot Y_{ha} \cdot [M]_{ha} $$

- $f_{Mu}$ = fraction of metal uptake within the considered soil layer
- $Y_{ha}$ = yield of harvestable biomass ($kg.ha^{-1}.a^{-1}$)
- $[M]_{ha}$ = metal content in harvestable parts of the plant ($g.kg^{-1}$)

$$ M_{le(crit)} = c_{le} \cdot Q_{le} \cdot [M]_{tot,sdw(crit)} $$

- $Q_{le}$ = leaching flux ($m.a^{-1}$)
- $[M]_{tot,sdw(crit)}$ = critical total concentration of $M$ in soil water ($mg.m^{-3}$)
- $C_{le}$ = unit conversion factor
Which critical concentration?

- Critical metal concentrations in ground water (Cd, Pb, Hg) in view of human health effects through intake of drinking water
- Critical concentrations of free metal ions in soil solution (Cd, Pb) in view of ecotoxicological effects on soil microorganisms, plants and invertebrates
- Critical metal contents in the soil (Hg) in view of ecotoxicological effects on soil microorganisms and invertebrates in the forest humus layer

WHO criteria:
- Pb: 10 mg.m⁻³
- Cd: 3 mg.m⁻³
- Hg: 6 mg.m⁻³

From toxicity data, as a function of pH and DOC:
Compute Hg in solution from critical Hg in soil.
From toxicity data to critical concentrations
1: Toxicity data

*Q* represents \( \log M_{\text{soil,toxic}} + \frac{b}{c} \log OM \)

Source: Lofts *et al.*, 2004
From toxicity data to critical concentrations

2: Critical limit functions

Based on the protective effect of H+ and other cations

Source: Lofts et al., 2004
From toxicity data to critical concentrations 3: Total critical concentrations

Critical total concentrations as a function of pH and DOC using the WHAM model

Source: De Vries, Lofts et al., 2007
Hg: two approaches
1: Using critical limit for the solid phase

\[
[Hg]_{\text{dis, sdw (crit)}} = [Hg]_{\text{OM (crit)}} \cdot f_f \cdot [\text{DOM}]_{\text{sdw}} \cdot csdw
\]

- \([Hg]_{\text{dis, sdw (crit)}}\) = critical total Hg concentration in soil drainage water (mg m\(^{-3}\))
- \([Hg]_{\text{OM (crit)}}\) = critical limit for Hg concentration in solid organic matter (OM) (0.5 mg (kg OM\(^{-1}\))).
- \(f_f\) = fractionation ratio, describing the Hg on organic matter in solution (DOM) relative to that in solids (OM) (–),
- \([\text{DOM}]_{\text{sdw}}\) = concentration of dissolved organic matter in soil drainage water (g m\(^{-3}\)),
- \(csdw\) = 10\(^{-3}\) kg g\(^{-1}\), factor for appropriate conversion of mass units.

This is the approach given in the mapping manual (but is pH independent)
Hg: two approaches

2: Using critical free concentrations

Critical limit about 3.3 mg.kg\(^{-1}\)

(manual: 0.5 mg.kg\(^{-1}\))

Source: Tipping, Lofts et al., 2010

17 countries participated

Effect 1-4: terrestrial
Effect 5: freshwater

Source: RIVM-CCE
Some results: using the CCE background database

Simple critical load approach was also used for Cr, Ni, Cu, Zn, As, Se
Modelled depositions

**Fig. 27.** Spatial distribution of depositions in Europe in 2003

**Fig. 22.** Spatial distribution of sulfate depositions in Europe in 2003

**Fig. 32.** Spatial distribution of mercury depositions in Europe in 2003

*Source: EMEP MSC East, 2005*
Exceedances (deposition year: 2006)
Conclusions, N + S

- Critical loads of N and S have been and are the basis for successful emission reductions.

- Substantial reduction of NH$_3$ emissions remains difficult in Europe; exceedances of CLnutN persist in the future.

- Future CL(N) could/will be based on biodiversity endpoints, rather than abiotic limits; this work is under development within EU FPVII Eclaire project.
Conclusions, heavy metals

- For heavy metals, critical loads, depositions and exceedances have been computed but have not been used directly in emission abatement.
- Other activities (UN Minamata convention) halt the use of CL(HM) for ecosystems, human health is considered more important.
- There is a substantial uncertainty in critical limits for HM as well as in emissions and depositions especially for Hg.
- Preliminary results show no or very little exceedances for metals other than Cd, Pb and Hg.
End