Correcting depositions for sea salts

In the current version of the Mapping Manual (see www.icpmapping.org) the procedure for correcting total depositions for their sea salt contribution is missing (Chapter 2 refers to Chapter 5, and *vice versa*). On the following page this procedure is described. This description can also be found in the Annex of Chapter 6 of the book by De Vries et al. (2015). It can also be found in the 2003 CCE Status Report (Posch et al., 2003). This text should be included in the next update of the Mapping Manual.

De Vries W, Hettelingh J-P, Posch M (eds), 2015. *Critical Loads and Dynamic Risk Assessments: Nitrogen, Acidity and Metals in Terrestrial and Aquatic Ecosystems.* Environmental Pollution Series Vol. 25, Springer, Dordrecht, xxviii+662 pp.; ISBN 978-94-017-9507-4; DOI: 10.1007/978-94-017-9508-1

www.springer.com/environment/pollution+and+remediation/book/978-94-017-9507-4

Posch M, Hettelingh J-P, Slootweg J, Downing RJ (eds), 2003. Modelling and mapping of critical thresholds in Europe: Status Report 2003. RIVM Report 259101013, Coordination Centre for Effects, Bilthoven, Netherlands, iv+132 pp; www.wge-cce.org

Addendum: Correcting depositions for sea salts

Acidity critical loads are often compared with *anthropogenic* S deposition, i.e. the contribution due to sea spray is not included. If this is the case, the critical load of S has to be reduced by the S deposition originating from sea salts, i.e.

$$(A.1) \qquad CL_{max}(S^*) = CL_{max}(S) - SO_{4,dep,ss}$$

where the asterisk indicates a sea salt corrected quantity and the subscript 'ss' stand for sea salt derived. Ignoring ions such as Br, F, Sr, boric acid and bicarbonate, which occur only in traces in seawater (and which we thus ignore), the charge balance of sea salt derived deposition reads:

$$(A.2) \qquad SO_{4,dep,ss} = BC_{dep,ss} - Cl_{dep,ss}$$

Subtracting this from the critical load equation (eq. 6.19) yields for the sea salt corrected critical load:

$$(A.3) \qquad CL_{max}(S^*) = BC^*_{dep} - Cl^*_{dep} + BC_w - Bc_u - ANC_{le,crit}$$

How are those sea salt derived deposition obtained for a given location? First, the amounts of those ions in ocean water (unaffected by land drainage) are remarkably constant. This has been established by Dittmar (1884); and Dittmar's results were so consistent that later investigations introduced only minor changes, mostly with respect to more accurate atomic weights. Here we report the values given in Sverdrup et al. (1946), which are in turn based on data by Lyman & Fleming (1940). Table A-1 lists the amounts of the six major ions in seawater, their atomic weights and the calculated equivalents.

Table A-1: Major ions in seawater and their abundance.

Ion	Amount in seawater[a] (g/kg)	Molecular weight of ion[b] (mol/g)	Equivalents in seawater (eq/kg)
Ca^{2+}	0.4001	40.078	0.01997
Mg^{2+}	1.2720	24.305	0.10467
K^+	0.3800	39.098	0.00972
Na^+	10.5561	22.990	0.45916
Cl^-	18.9799	35.453	0.53545
SO_4^{2-}	2.6486	96.064	0.05514

[a]Sverdrup et al. (1946; p. 173); [b]Weast et al. (1989)

Secondly, it is assumed that either the sodium or the chloride deposition at a given location derives only from sea salts. Using their globally constant ratio in sea water, the depositions of base cations, sulphur and chloride (given in equivalents) are corrected according to:

$$(A.4) \qquad X^*_{dep} = X_{dep} - r_{XY} \cdot Y_{dep}$$

where $X = Ca,Mg,K,Na,Cl$ or SO_4, $Y = Na$ or Cl and r_{XY} is the ratio of ions X to Y in seawater. Ratios r_{XY} can by computed from the last column of Table A-1 and are shown in Table A-2 with 3-decimal accuracy. Note that if Na (Cl) is chosen to correct for sea salts, $Na^*_{dep}=0$ ($Cl^*_{dep}=0$).

Table A-2: Ion ratios $r_{XY}=[X]/[Y]$ (in eq/eq) in seawater (computed from Table A-1).

Y	X					
	Ca	Mg	K	Na	Cl	SO₄
Na	0.043	0.228	0.021	1	1.166	0.120
Cl	0.037	0.195	0.018	0.858	1	0.103

It should be noted that the above procedure assumes that all quantities involved disperse in the atmosphere in the same way, which is not entirely true, especially for chloride. Nevertheless, given the dearth of dispersion modelling results for sea salts, the above procedure is widely used for locations not too far from the sea.

References:
Dittmar, W. (1884). Report on researches into the composition of ocean water, collected by H.M.S. *Challenger*, during the years 1873–1876. *Physics and Chemistry 1*, 1-251.

Lyman, J. & Fleming, R.H. (1940). Composition of sea water. *Journal of Marine Research 3*, 134-146.

Sverdrup, H.U., Johnson, M.W. & Fleming, R.H. (1946). *The Oceans – Their Physics, Chemistry and General Biology.* New York: Prentice-Hall, 1087 pp.

Weast, R.C., Lide, D.R., Astle, M.J. & Beyer, W.H. (Eds.) (1989). *CRC Handbook of Chemistry and Physics (70th edition).* Boca Raton, FL, USA: CRC.