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## **Acidity-based regulatory physico-chemical standards for the “high-good” and “good-moderate” boundaries for UK lakes**

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This document is a response to a request from SNIFFER to identify appropriate acidity-based water quality standards for UK (and Irish?) lakes, with particular regard to the health of phyto-benthic algal and macroinvertebrate communities. At this stage values are required for the high-good and good-moderate boundaries.

The following is based on the contemporary water chemistry of low alkalinity lakes, i.e. those which are potentially vulnerable to acidification. We have used a Cantrell-type estimate of Acid Neutralising Capacity or ANC as a summary chemical indicator of current acidity status, and compared this with the amount of pH change inferred from diatom assemblages (DI-pH) in the top (contemporary) and bottom (pre-acidification) of sediment cores taken from these lakes. The water chemistry is based on the mean of four or more water samples collected at regular intervals over a period of one year. ANC is particularly well suited for this task as it integrates geological sensitivity to acidification with the current acid deposition pressure, while also taking into account the buffering effect of organic acids. For example, lochs in the relatively unimpacted region of north-west Scotland will almost invariably exhibit strongly positive ANC (i.e.. more than 20  $\mu\text{eq/l}$ ) regardless of their acid sensitivity. This applies even to lochs of relatively low pH as this acidity is likely to be of a less biologically toxic organic, rather than mineral form.

pH change is the only stress considered here. pH is often identified as the single chemical factor which best explains between-site differences in the assemblages of diatoms and macroinvertebrates. We accept that ANC change may occur without an accompanying change in pH in well buffered systems as a result of acid deposition, but we do not have sufficiently well developed tools to “reconstruct” ANC using diatoms. It is also possible that high quality ANC data may better discriminate between some biological groups than pH (particularly macroinvertebrates) since it allows for the relatively benign influence of organic acidity. However, at this stage in the WFD60 project we have little understanding of the likely importance of change in ANC at the higher end of the gradient for macroinvertebrate community structure. At the more acid end of the gradient, which we are most concerned with here, however, the relationship between ANC and pH is relatively linear, although the relationship is complicated by variation in organic acidity.

This analysis is based on chemistry and palaeo data for 116 sediment cores from a total of 98 UK lakes. The relationship between DI-pH change and contemporary ANC is provided in Figure 1. We observe the following:

- There is a clear relationship between the amount of inferred acidification and current ANC.
- Above an ANC of around 40  $\mu\text{eq/l}$  a number of sites indicate small positive or negative deviations, roughly equally distributed around zero. As most of this

variability lies within 0.3 pH units of zero we take this to be the limit for “no significant pH change”.

- With the exception of two sites from north-west Scotland, where it is unlikely that significant deposition –related acidification has really taken place there is no indication that any site which currently has an ANC of more than 40  $\mu\text{eq/l}$  has acidified.
- We therefore propose an ANC of 40  $\mu\text{eq/l}$  to represent the “High-Good” Boundary. We are confident that acidification is highly unlikely to have significantly affected biology at any site with a current ANC higher than this value. This value is currently adopted by Norway as the critical ANC ( $\text{ANC}_{\text{crit}}$ ) necessary to ensure the health of salmonids in Norwegian waters, and thus underpins their critical loads policy.
- We now double the DI-pH change threshold to 0.6 pH units and take this as the limit for “mild acidification”. There is an apparent step change at around 20  $\mu\text{eq/l}$  below which the likelihood that a site is more than mildly acidified appears to increase. This threshold has recently been adopted by the UK government as their  $\text{ANC}_{\text{crit}}$  following advice from the DEFRA funded Freshwater Umbrella programme (see attached documents which summarise this advice). We propose, therefore, that 20  $\mu\text{eq/l}$  ANC would make an appropriate “good-moderate” boundary.
- In our dataset, 64 sites lie above the 20  $\mu\text{eq/l}$  threshold. Of these, 70% show no significant acidification and 89% can be considered to have experienced mild acidification at most. The remaining 11% of sites have experienced more than mild acidification although in all cases pH change is still less than 1.0 pH unit (which we consider to be the lower limit for sites deemed to be severely acidified).
- If we lump the “high” and “good” classes to encompass the range of variability exhibited by sites which are effectively biologically unimpacted by acidification, 19% of sites with a current ANC of greater than 20  $\mu\text{eq/l}$  would be argued to be misclassified by one class (i.e. they are deemed to be within the “high to good” region when they are actually mildly acidified) and a further 11% would be misclassified by two classes (i.e. they are actually substantially acidified). No site in this group was severely acidified, so the probability of mis-classification by 3 classes is below 2%. It is likely that these misclassification levels represent the worse case as there are doubts about the diatom inferences of substantial acidification made for some sites in north-west Scotland. We require more time to investigate the reliability of each pH reconstruction in more detail.
- Clearly this approach can be extended further for the more acidic and acidified systems, although there are only two more obvious divisions. Between 20 and 0  $\mu\text{eq/l}$  the probability that sites are substantially acidified increases and severely acidified sites are included, as a small percentage, for the first time. However there is an increased probability that sites which are not significantly acidified are misclassified as being impacted. Beneath zero ANC there is

about a 60% probability that a site is at least substantially acidified and about a 30% probability of being severely acidified. It may be necessary to consider the use of a second parameter, possibly calcium concentration, to better discriminate between these groups at the poor/bad end of the gradient.

- It is possible to use a similar approach to classification using contemporary pH rather than ANC. Boundaries of around pH 6.4 and 6.0 provide similar results to the upper ANC boundaries proposed above. However, at lower pH the chance of misclassification is much higher. A substantial proportion of sites with lowest pH provide little indication of having been acidified – probably largely because of the influence of organic acids in these naturally acidic systems.

In summary, and in the absence of the intensive analysis of lake macroinvertebrate data which will conduct over the course of the WFD60 project, we tentatively propose:

40  $\mu\text{eq/l}$  ANC as the boundary between high and good status

20  $\mu\text{eq/l}$  ANC as the boundary between good and moderate status

**Figure 1**

