Establishing environmental sustainability thresholds on water quality with focus on eutrophication

Concept of environmental sustainability thresholds

Human activities continue to put pressure on the world's natural resources and ecosystems. Many of these natural systems can withstand this pressure only up to a certain threshold – a so-called tipping point – beyond which serious negative and possibly irreversible consequences occur. As the exact thresholds are often unknown, prudence requires identifying danger zones before the threshold is reached, or safety zones in which humanity can safely operate. It is therefore important to find out where environmental thresholds exist, what values they have and to measure the distance to this threshold. This should help to alert policy makers in due time before a danger zone is reached and enable them to respond effectively to avoid unsustainable consequences. One objective of the study to which this factsheet is linked was to propose indicators for environmental thresholds relevant in the EU policy-making context.

Relevance of the topic

Eutrophication is one of the most pervasive water quality problems in Europe and around the world and affects 53% of lakes in Europe, 48% in North America, 54% in Asia, 41% in South America, and 28% in Africa (ILEC/Lake Biwa Research Institute, 1994). Eutrophication occurs not only in surface freshwater systems but also in marine and groundwater bodies. Reduced water quality due to eutrophication has negative consequences for many uses, including for drinking, cooking and bathing, for industrial use, and for maintaining species health and diversity. The causes of eutrophication, including those resulting from human activities, are well understood (Carpenter and Lathrop, 2008) and can be traced to the discharges of nutrients – organic compounds involving phosphorus und nitrogen - into water bodies. The main sources of human-released phosphorus and nitrogen are (a) non-point effluences from fertilizer- and livestock intensive agriculture, (b) untreated human waste and sewage, and (c) emissions and discharges of nitrogen from industry and transport. While small increases in nutrients that can be taken up by plants and trees can be beneficial and increase the production of new biomass, too much of it can severely degrade water quality, reduce the ability of fish and other oxygen-depended species to reproduce, and threaten human health.

Eutrophication exhibits strong but locally varying threshold patterns: as the absorptive capacity of ecosystems varies, a single threshold for a tolerable load or concentration of nitrogen or phosphorus does not exist. Instead, the two main approaches used, i.e., that of *maximum allowable concentrations (MAC)* of nitrogen and phosphorus in the EU and their *total maximum daily loads (TMDL)* in the USA (EPA, 2010), are established as thresholds for individual watershed. Similarly, danger zones depend on the size, depth, temperature of the freshwater body, its hydrology, sediment characteristics, climatic conditions, and many other factors.

Readily available and potential future threshold variables

The 2000 EU Water Framework Directive (WFD) aims to achieve "good status", including ecological and chemical parameters, for freshwaters, transitional waters, rivers, lakes and coastal waters by 2015. This holistic approach includes eutrophication. Thresholds for eutrophication will be available from a large-scale scientific review and intercalibration study, which will use the existing science to determine the boundary values between five water quality classes ranging from 'high status' to 'bad status' for ecological criteria for all waterbodies, including phosphorus and nitrogen as well as many other water quality parameters. Member States are currently developing proposals for standards on ecological status in accordance with the intercalibration exercise, which entails *maximum concentrations* for phosphorus and nitrogen. Although alert levels or danger zones are not explicitly formulated in the WFD, they could be defined using the boundary standards between the 'moderate' and 'poor' water quality classes (cf. Annex V of the WFD for the exact definition of water quality classes). In addition, existing directives such as the Drinking Water Directive, the Groundwater Directive, and the Nitrate Directive provide for blanket maximum concentrations for nitrate of 50 mg/l (in some cases also permitting Member States to set lower permissible thresholds).

As implementation of the WFD progresses and countries put their water quality management plans into practice, it will be possible to assess the attainment or surpassing of thresholds as specified, for example, in the WFD's five water quality classes. The WISE portal, developed under the WFD, already offers a convenient and informative tool for accessing information and it is only expected to grow in utility as more data and assessments are accessible through this system.

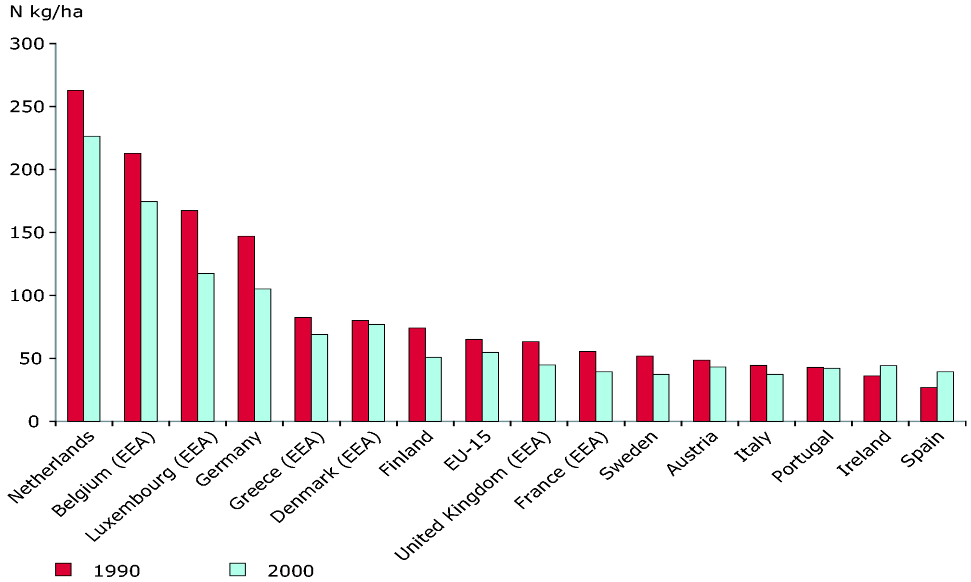
Advantages and disadvantages of suggested threshold indicators for water quality

	Ratio of actual to maximum allowable concentration of nitrogen and phosphorous
Advantages	• Underlying concept easy to understand and communicate • Monitoring data available and in required spatial and temporal density by 2015 as mandated under WFD implementation plans • Consideration of local watershed and surrounding conditions • Compliance assessment and trend analysis (with potential evaluation of policy effectiveness) possible • Scientifically sound conceptual basis, although the separate specification of values for N and P may not reflect important N and P interactions
Disadvantages	• Determination of maximum allowable concentration carries varying levels of uncertainty, assumptions, and validity over time • Monitoring of concentrations does not allow source apportionment and hence more effective control of major emitters • Time lags in ecological, sediment and hydrological processes delay the exposure-event chain such that detrimental practices may go unabated until their harmful effects are measured years later.

Exemplary illustration

The following graph does not show an individual watershed's eutrophication pattern relative to an established threshold, but it does show the trend of nutrient loads in general in selected EU Member States. WISE can be used to extract local, time-specific monitoring data and relate it to scientific threshold values.

Figure 1 Gross nutrient balance (N kg/ha) at national level in 1990 and 2000
Source: OECD and EEA calculations



Data availability to measure and monitor thresholds of water quality (eutrophication) in the EU

Concentrations of phosphorus and nitrogen (and their various compounds) are routinely measured at the majority of European water quality monitoring stations. Therefore, actual concentrations – averaged or maxima over specified periods – are generally available and reliable, although spatial and temporal densities of monitoring vary across the EU. It appears that data collection for eutrophication is relatively advanced but often too infrequent and spatially dispersed to detect sudden eutrophication episodes in time before the local threshold is actually crossed. Full implementation of the WFD is expected to increase monitoring information, especially for waterbodies vulnerable to eutrophication.

Ratio of actual maximum to maximum allowable concentrations of nitrogen and/or phosphorus

Unit of measurement	mg/litre
Most suitable level of measurement (e.g. national / regional / river-basin)	local river-basin segment or lake segment
Current availability of data at the most suitable level in the EU, best practice example (with data source and update frequency)	National or sub-national water quality monitoring databases; EEA Waterbase; WISE; EIONET; Assessments possible for EU27 but with locally varying resolution (i.e., monitoring station density) and trend assessment (i.e., length of available time series) and a 1-2 year time lag, remote sensing data available to support eutrophication assessments
Current availability of data at the national level in the EU, data source and update frequency	Possible to draw national and EU-wide conclusions using the information available through WISE.

Conclusion

Indicators of "good ecological status" under development as part of the WFD are largely not yet operational but can be expected to be by 2011 or 2012. The proposed ratio indicators of actual to maximum allowable concentration can be computed for selected river basins and lakes, one of the main challenges being the determination of the threshold value (and a danger zone). To be useful for policymaking, the thresholds should be as accurate and precise as possible, the danger zones be balanced between indicating a true approach of the threshold value (as opposed to a false positive) yet give as much lead time for response as possible. For the future, the full implementation of the Water Framework Directive will bring Europe much closer to managing its waters with ecological and human health in mind and to do so with meaningful, robust threshold indicators.

Further Reading

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