Towards good ecological status of surface waters in Europe – interpretation and harmonisation of the concept

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Abstract The Water Framework Directive (WFD) is a new legislative framework to manage, use, protect, and restore surface water and groundwater resources and coastal waters in the European Union (EU). The aim is to ensure sustainable water management and to reach good water quality by 2015. The assessment of the ecological status and setting of the practical management goals require several steps. The process has started with the characterisation of the river basins including identification of surface water bodies and types, and identification of significant anthropogenic pressures and impacts. The water bodies will be classified in five quality classes (high, good, moderate, poor, bad) based on the Ecological Quality Ratio, which is a ratio between reference conditions and measured status of the biological quality elements. The normative criteria for high, good and moderate ecological status described in the WFD need to be made operational because those will be used to set the practical quality targets for surface water management. National ecological assessment systems and classifications will be harmonised through the WFD intercalibration exercise in order to ensure an equal level of ambition in achieving good surface waters status all over Europe.

Keywords Classification; ecological quality ratio; intercalibration; reference conditions; typology; Water Framework Directive

Introduction
The Water Framework Directive (2000/60/EC) creates a new legislative framework to manage, use, protect, and restore surface water and groundwater resources within the river basins (river catchments) and in the transitional (lagoons and estuaries) and coastal waters in the European Union. The WFD aims to achieve sustainable management of water resources, to reach good ecological quality and prevent further deterioration of surface waters and groundwater, and to ensure sustainable functioning of aquatic ecosystems (and dependent wetlands and terrestrial systems). One of the main environmental objectives of the WFD (i.e. the good ecological quality of natural water bodies and good ecological potential of heavily modified and artificial water bodies) should be reached in 2015. The implementation timetable requires several intermediate steps in the fulfilment of the technical specifications outlined in the Annexes of the WFD, the first of those are already due at the end of 2004 (i.e. requirements of Article 5, and Annexes 2 and 5: analysis of river basin characteristics, pressures and impacts, and economic analysis).

The overall complexity of the WFD and a very tight implementation timetable create challenges for the fulfilment of the requirements. Therefore the European Commission and the Member States started a Common Implementation Strategy (CIS) in 2001 (Anonymous, 2001). This has resulted in a number of guidance documents, where the various technical issues related to the WFD implementation requirements are interpreted according to the common understanding of the Member States (Anonymous, 2003b–g). The guidance documents are based on a large number of preparatory documents and expert meetings where various issues were discussed and agreed. They are not legally binding, but present examples of best practices and common understanding of the legal requirements.
The WFD stipulates that the ecological status of the surface water is defined as “... an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters, classified in accordance with Annex V.” (Article 2: 21). This implies that classification systems for the ecological status should reflect changes in the structure of the biological communities and in the overall ecosystem functioning as a response to anthropogenic pressures (e.g. nutrient loading, acidification, exposure to toxic and hazardous substances, physical habitat alterations, etc.). Such requirements are a novel approach in the European water policy, which has been mostly based on the regulation of emissions at the source through the establishment of emission limit values (ELV) or setting of chemical quality standards for particular uses of water (drinking water, fish and shellfish). The establishment of ecological objectives for the recipient ecosystems has been more seldom the target of legislation. Nature conservation legislation such as the “Birds Directive” (79/409/EEC) and the “Habitats Directive” (92/43/EEC) have established a legislative framework for protecting and conserving Europe’s wildlife and habitats (creation of a coherent ecological network of protected areas across the EU – NATURA 2000). While the Nitrates (91/676/EEC) and Urban Waste Water Treatment (91/271/EEC) Directives have already required that the vulnerability or sensitivity of the recipient surface waters to pollution (mostly caused by nitrogen and phosphorus compounds) should be assessed, the criteria for how the sensitivity should be identified has been subject to Member States’ interpretations. Although these interpretations may differ, no mechanism was foreseen to harmonise these interpretations as yet.

In this paper we will discuss the novel approach required by the WFD for a EU wide classification of the ecological quality of surface waters and the requirement for the harmonisation of the national classification systems. We will also highlight management implications and some research needs. The paper is based on the analysis and review of the WFD legal text and the relevant CIS guidance documents, as well as on review of some other relevant publications. Please note that the opinions expressed in this article are those of the authors, and are not necessarily the position of the European Commission.

Discussion

In the following discussion we will present the WFD requirements for the assessment of the ecological status of surface waters in a stepwise approach. We also present and analyse the agreed approaches outlined in the WFD CIS guidance documents, and discuss the potential problems and benefits of those approaches.

The process for the assessment of the ecological status requires several steps:
2. WFD compatible monitoring programmes established and operational (due December 22, 2006)
3. Type-specific reference conditions for biological quality elements (due December 22, 2004)
4. Classification of all surface water bodies using Ecological Quality Ratios based on biological quality elements (due December 22, 2009)
5. Intercalibration of the Member States’ biological monitoring results (due December 22, 2006)

The WFD implementation timetable for the preparation of the first river basin management plan is not completely in line with the order of the tasks to fulfil the classification and intercalibration requirements as shown above. The WFD requires that steps 1, 3, and 5 be carried out simultaneously starting already in 2003. The monitoring systems need to be operational only by the end of 2006, which implies that there will be little WFD compatible monitoring data available for carrying out the steps 3 and 5. Although step 4 (Classification of surface water bodies) is only due to be reported in 2009, first steps towards the ecological
status classification of surface water bodies should be already initiated in 2003 for the selection of sites for the intercalibration network (since the intercalibration process will start in 2003). The classification task needs to be continued in 2004 in the characterisation and assessment of sites that are in risk to fail the environmental objectives (e.g. those that are likely to be classified as moderate ecological status or below). Provisional decisions on class boundaries between “high” – “good”, and “good” – “moderate” status are needed already in 2003 and 2004, for the site selection for the intercalibration network and in 2004 for the characterisation and risk analysis of the water bodies (identifying water bodies that are in risk of failing the environmental objectives). The final classification of water bodies is needed in 2009 for the first river basin management plan.

The first step – characterisation of surface waters – requires an assignment of all rivers, lakes, transitional and coastal waters into geographic units: river basin districts, which may comprise one or several river basins (Anonymous, 2003a). This includes identification of surface water bodies, grouping them into types, and the definition of biological and chemical reference conditions (natural baseline) for those types. Water bodies should be discrete and significant sub-units with uniform typology and quality status. Water bodies as such will be the basic unit for reporting and assessing compliance with the directive’s environmental objectives (Anonymous, 2003b). Concurrently, the significant anthropogenic pressures must be identified, and their impacts on the surface water status must be analysed (Anonymous, 2003c).

Typology

The main purpose of typology is to enable type specific reference conditions to be defined which in turn are used as the anchor of the classification system (Anonymous, 2003d). Water body types should be characterised based on geographical, geological, morphological and physical factors. The typology should group sites where the biology is similar in the natural baseline conditions, to enable the detection of the effects of human disturbance. This is only meaningful when the variability of the biological parameters is smaller within types than between types, depending not only on the typology, but also on the biological parameters chosen. The typology should therefore identify physically and morphologically distinct water body groups enabling comparison of “like with like” (Anonymous, 2003d, e). This means, for instance, that naturally eutrophic lakes have different reference conditions than oligotrophic lakes, resulting in different scales and requirements for good ecological quality for these different lake types. The WFD allows two different approaches for typology – “System A” and “System B”. The difference is that System A prescribes how water bodies shall be characterised spatially (ecoregions) and with respect to specific altitude, size and depth intervals, and that System B, besides lacking this prescription, permits the use of additional factors (Anonymous, 2003d).

Validation of different types by evaluating the within-type variability of biological communities requires good quality biological data from unimpacted sites, which is currently not available from many Member States (Anonymous, 2003d). For many types, most of the water bodies are significantly impacted by human pressures, and therefore it will be difficult to distinguish statistically between the impact of pressures and the type specific factors that shape the aquatic biological communities.

In the WFD implementation process, typology is also needed for two other purposes: Reporting and Inter calibration. For those typology should ideally be simple and applicable all over Europe for all quality elements. On the other hand, defining reference conditions may require complicated typologies. Different regions and different quality elements may also require different typologies. Typology systems should have a certain level of flexibility, with the possibility to adapt and refine them when more and better biological monitoring data become available.
Two main approaches can be taken in the determination of the surface water body types: 1) types are defined from knowledge of how physical drivers determine biological communities (“a priori” approach), and 2) types are distinguished by analysing survey data from reference sites (“a posteriori” approach) (Table 1). System A of the WFD is an example of an “a priori” example; system B typologies can be defined using both approaches.

It is possible that “a priori” typologies will not be biologically meaningful due to an incomplete understanding of what drives the biology. An advantage of a verified “a priori” typology is that it is likely to be relatively robust, because it is based on knowledge of the biology rather than purely on statistical correlation. The “a posteriori” approach requires a sufficiently large number of sites in natural baseline conditions (reference sites) and good quality biological data. An advantage of the “a posteriori” approach is that it has a high degree of objectivity. On the down side, “a posteriori” typologies depend on the data available and therefore those are usually specific for a specific quality element.

Only very few countries have established advanced “a posteriori” systems for classification and typology. One of the main reasons preventing the development of such systems is that it requires the availability of high quality data from many water bodies, sampled in a standardised way. The UK RIVPACS approach (Wright, 2000), developed to predict reference macroinvertebrate communities in rivers, is a very good example. The potential of this approach is demonstrated in Swedish studies, where RIVPACS-type models (SWEPACS) have been successfully developed for both lake (littoral) and stream (riffle) macroinvertebrate communities (Johnson 1995). The European research projects STAR1 and FAME2 are extending such an approach over a larger geographical area, including wider range of river types, and more biological quality elements collected using harmonised methods. Furthermore, another European research project, CHARM3 is developing harmonised typology for the coastal Baltic Sea first starting from “a priori” typology that will be validated using existing biological monitoring data from the countries around the Baltic Sea.

Reference conditions and classification
The WFD stipulates that the ecological quality classification “… shall be represented by lower of the values for biological and physico-chemical monitoring results for the relevant

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Features of “a priori” and “a posteriori” typology systems</th>
</tr>
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<tbody>
<tr>
<td>“a priori” typologies</td>
<td>“a posteriori” typologies</td>
</tr>
<tr>
<td>Should be based on knowledge of how biology is determined by geography/physical conditions</td>
<td>Based on physical and biological monitoring data from reference sites</td>
</tr>
<tr>
<td>Few data needed to define typology</td>
<td>Typology depends on available data (what quality elements, what parameters, from which region), and on the quality of the data</td>
</tr>
<tr>
<td>Types not necessarily biologically meaningful because of incomplete knowledge – need for validation using targeted field sampling</td>
<td>Types biologically meaningful</td>
</tr>
<tr>
<td>Reference conditions can be determined by different approaches (expert judgement, spatial, historical/paleoreconstruction, modelling)</td>
<td>Reference conditions implicit</td>
</tr>
</tbody>
</table>

1 Standardisation of river classifications: Framework method for calibrating different biological survey results against ecological quality classifications to be developed for the Water Framework Directive, http://www.eu-star.at
3 Characterisation of the Baltic Sea Ecosystem: Dynamics and Function of Coastal Types. http://www.dmu.dk/1_Viden/2_Miljoe-tilstand/3_vand/4_Charm/charm_main.htm
Furthermore it is required that the ecological quality of water bodies should be classified into five quality classes (high, good, moderate, poor, and bad) using the Ecological Quality Ratio (EQR), defined as the ratio between reference and observed values of the relevant biological quality elements (Table 2).

The roles of the supporting hydro-morphological (such as quantity of water flow in rivers or residence time of water in lakes) and physico-chemical elements (such as salinity, acidification status or nutrient conditions) in the classification process are not completely clear at the moment. A likely solution is that together with the status of biological quality elements those also should be in the “high” status, if a site should be classified as “high”, and likewise those should be of “good” status if the site would be classified as “good”. Therefore if hydro-morphological or physico-chemical quality elements of a water body would be in “good” status while the biology would imply “high” status, the water body should be classified as “good”.

Reference conditions can either be spatially based, i.e. defined by collecting biological information from water bodies, which are (almost) in natural base-line conditions (sites with minor anthropogenic impacts), or derived by modelling, or by a combination of those. If reference conditions are to be defined using modelling, either predictive models or hind-casting using historical, paleolimnological, and other available data can be applied (Anonymous, 2003d). In many countries there may be no reference sites available or data are insufficient to carry out statistical analysis or validate models. In that case, expert opinion may be the only possibility to define reference conditions. Also the establishment of common networks of reference sites could help in setting type specific reference conditions in a comparable way between different countries.

A stepwise procedure for establishing reference conditions, based on availability of data, is suggested (Figure 1). The most unimpacted sites for different types can be selected using both available monitoring data and/or pressure criteria (Anonymous, 2003d). This approach would also allow establishment of a reference site network, where data for biological quality indicators in reference conditions can be obtained. In combination with that predictive models can also be validated and used to establish reference values for the parameters that represent the different biological quality elements, and these models applied to sites where biological data may be scarce or not available for all quality elements. In some cases collaboration across national borders is required since natural base-line sites for a given type may be found in other countries. If there are no sites with minor anthropogenic impacts, historical monitoring data or paleoecological methods should be

Table 2 Biological quality elements and composition metrics required for the classification and assessment of the high, good, and moderate ecological quality status of different surface waters according to the normative definitions described in Annex V of the Water Framework Directive. 1 = taxonomic composition, 2 = abundance, 3 = biomass, 4 = plankton blooms, 5 = diversity, 6 = sensitive taxa (e.g. sensitive vs. insensitive species of organisms), 7 = age structure

<table>
<thead>
<tr>
<th>Quality element</th>
<th>Rivers</th>
<th>Lakes</th>
<th>Transitional waters</th>
<th>Coastal waters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytoplankton</td>
<td>1, 2, 3* , 4</td>
<td>1, 2, 3, 4</td>
<td>1, 2, 3, 4</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>Aquatic flora</td>
<td>1, 2</td>
<td>1, 2</td>
<td>1**, 2</td>
<td>1**, 2, 6</td>
</tr>
<tr>
<td>Benthic invertebrates</td>
<td>1, 2, 5, 6</td>
<td>1, 2, 5, 6</td>
<td>1, 2, 5, 6</td>
<td>1, 2, 5, 6</td>
</tr>
<tr>
<td>Fish</td>
<td>1, 2, 6, 7</td>
<td>1, 2, 6, 7</td>
<td>1, 2</td>
<td>–</td>
</tr>
</tbody>
</table>

* transparency as a proxy of phytoplankton biomass
** macroalgal cover as a proxy for biomass

4 This interpretation is based on the recent communication by the Drafting group on Classification, under the WFD CIS Working Group 2A ‘Ecological Status’. Also suggested by the REFCOND Working Group (Anonymous, 2003d).
used to reconstruct reference conditions before the onset of significant human impact. Expert judgement may be needed to evaluate when the human impact started to increase, and which period would represent conditions with a minor impact. Finally, if neither a site nor any data is available for a given type, expert judgement remains the only alternative.

In the WFD, high ecological status is defined as “slight” or “minor” deviation from the reference conditions of a surface water body type, while the good status is defined as “small” deviation. The CIS guidance documents suggest that due to the variability of type specific reference conditions, it will be more practical to consider that high status is equal to reference conditions (Anonymous, 2003d,e). In order to be able to set the quality classes and their borders, more detailed criteria are needed. There should also be an agreement on how the quality borders are set statistically (Anonymous, 2003d). The WFD requires a “one out – all out” approach for classification, potentially using a high number of quality elements, and the status of a site should be determined by the lowest value of the quality elements used. Various quality elements have different sensitivity to pressures, thus they may reflect the impacts of pressures differently. Because all quality elements have a certain error (that can be very high), the potential of misclassification is amplified by the number of quality elements included in the “one out – all out” system. Therefore clarification is needed how to integrate different quality metrics derived from different quality elements into a single assessment of the water body.

At the moment there is no sound scientific basis for setting the class boundaries. In “good” status the biological quality elements should indicate only “slight” deviation from reference conditions, and the hydromorphological, physico-chemical, and chemical quality elements should ensure ecosystem functioning (Anonymous, 2003d). However, it is not clear how the ecosystem functioning in good status should be defined. The functional diversity of the ecosystem’s trophic structure may display high variability of response (Chase and Lieibold, 2002) when subjected to human impacts such as nutrient loading (Worm et al., 2002). More specific definitions and functional relationships between biological and chemical status need to be established in order to develop operational tools for setting the quality targets in the practical management of water bodies. This requires expertise and availability of comparable biological monitoring data where functional relationships can be established across pressure gradients. Applied research supporting the implementation requirements of the WFD on this issue will be initiated under the 6th

**Figure 1** A step-by-step approach for selection of the method for determination of reference conditions for surface water bodies based on available information and data.
European Framework Programme for Research. More detailed guidance on principles setting the class boundaries will be one of the next steps in the CIS Working Group 2A on Ecological Status in 2003–2004.

**Intercalibration**

In order to ensure comparability of the Ecological Quality Ratio (EQR) scales between the different EU countries and to obtain a common understanding of the good ecological status of surface waters all over the EU, harmonisation of the ecological classification systems is needed. To achieve this, the WFD requires an “intercalibration exercise”, that will be completed by the end of 2006. Prior to this an intercalibration network consisting of selected intercalibration sites needs to be established by the end of 2004 (Anonymous, 2003f).

Member States and Accessions Countries have agreed on common intercalibration types for the network, as well as pressures and quality elements that will be the focus for the intercalibration. Each of these common types is shared by a number of countries. For example, in the northern intercalibration group for lakes, seven common types have been identified (Table 3). These types are shared by five countries, which will select water bodies for the intercalibration network.

The present quality status of the water bodies selected for the intercalibration network should be provisionally representative of the border between high and good or good and moderate classes. In the selection process either pressure criteria (Anonymous, 2003d) and/or available biological and chemical data can be used. Each country should select at least two sites for each quality border, resulting in a number of comparable sites for each type within each intercalibration group (Anonymous, 2003f). In a similar manner, all present and future EU countries have identified types and geographical intercalibration groups for all surface water categories. This will make groups of countries that will carry out the intercalibration exercise together using the intercalibration sites as common test sites to compare their national assessment systems for surface water ecological quality (Figure 2).

The aim of the intercalibration exercise is to set EQR values for the relevant class boundaries (high-good, good-moderate). The selection of the intercalibration sites will reflect the Member States’ perceptions of the quality classes. Since the WFD compatible monitoring program is not yet operational during the intercalibration process (Anonymous, 2003g), the site selection and the exercise have to be based on existing data. Since current biological monitoring data is scarce, or even non-existing in many EU countries, the intercalibration exercise has to be focused on biological quality elements and assessment methods that have been most commonly used in Europe to assess impacts of most widespread pressures (Anonymous, 2003f). This implies that the assessment methods for the “ecological status” will not be compared and harmonized as a whole, but merely “trophic status” or “organic pollution status” depending on availability of data and methods for the intercalibration exercise. Although not required by the WFD, revision of the intercalibration network and

<table>
<thead>
<tr>
<th>Characterisation of the common lake type</th>
<th>FI</th>
<th>IE</th>
<th>NO</th>
<th>SE</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowland, shallow, siliceous, moderate alkalinity, large</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lowland, shallow, siliceous, low alkalinity, large</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lowland, shallow, peat, large</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Boreal, large, very shallow, siliceous, moderate alkalinity</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Boreal, shallow, siliceous, low alkalinity, large</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Boreal, shallow, peat, large</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Highland, shallow, siliceous, low alkalinity, large</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
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repetition of the intercalibration exercise would be useful also after 2006, when WFD compatible monitoring data starts to be available. This would enable setting revised management targets for the next river basin management cycle (revision of the characteristics and reference conditions of water body types is required after every six years by Article 5 of the WFD), and finally intercalibration of the ecological status of surface waters as a whole.

The task of the European Commission is to assist Member States to carry out the intercalibration exercise. The Joint Research Centre, in collaboration with the Directorate General Environment, has undertaken the initiative to launch the European Centre for Ecological Water Quality and Intercalibration (EEWAI; http://ies.jrc.cec.eu.int/eewai/) as an organisational body for the scientific and technical coordination of the intercalibration exercise. The long-term objectives of EEWAI are to provide a focal point for the further harmonisation of national ecological quality assessment systems in the EU.

Conclusions

Implementation of the WFD requires a setting of operational definitions for “high”, “good”, and “moderate” ecological status classes in order to establish practical targets for the environmental objectives of the directive. Classification of water bodies into ecological status classes requires establishment of reference conditions and identification of boundaries between “high”–“good” and “good”–“moderate” quality classes. The boundary between good and moderate status will be especially important because it will set the targets for restoration plans of water bodies which fail the environmental objective of achieving good ecological status. Since the classification is mostly based on the biology of the water bodies, good quality biological monitoring data will be needed in order to have a sound basis for the establishment of the class boundaries. The implementation timetable of the WFD does not completely match with the order of steps that are needed to fulfill classification requirements. This requires Member States to take a pragmatic approach to the classification task, and to start to evaluate the ecological status of their water bodies based on pressure criteria and available biological data, although the current monitoring networks of the most Member States are not WFD compliant (EEA, 2003). The required
harmonisation (i.e. intercalibration exercise) of the ecological quality classification scales in 2005 and 2006 will probably be difficult because of the heterogeneity of national assessment systems and scarcity of biological data available. However, WFD requires only one intercalibration exercise with the aim to fix the relevant class boundaries for management purposes. Hopefully, a new intercalibration and a revision of the ecological status class boundaries could be possible also after 2006, when new biological data will become available from the restructured monitoring systems, which are compliant with the WFD requirements.

References