THE ROLE OF ECOTOXICOLOGY FOR MONITORING ECOSYSTEM HEALTH

ERIC VINDIMIAN

(Dr E. Vindimian, Institut national de I 'environnement industriel et des risques BP2, 60550 Vemeuil-en-Halatte, France.)

Introduction

The proposed EC Water Framework Directive (WFD) incorporates some new concepts in the field of water protection. Most of these concepts rely on the use of applied ecology of water ecosystems. The most important feature is that the classification of water quality is to be based on direct *biological* measurements of ecosystem health. It means that real biological communities should be sampled and the taxa identified. A diagnosis on ecosystem health should result from this. The diagnosis is derived from comparing impacted zones with reference zones, where minimum human pressure is proven.

The quality of aquatic ecosystems will thus be geographically referenced and their evolution with time recorded. Regulators and managers of environmental quality will get precise and relevant information and will report this information to the European Union. Remediation plans can then be decided and checked for their real performance at the ecological level.

Such an improvement of environmental management, although already performed by several European countries, is very new in this context. Most of the actions in the past have used chemical analyses of several parameters mainly dealing with organic pollution. The new WFD will allow us to check the eco-epidemiological results of several human impacts on aquatic ecosystems, such as toxic pollution and habitat modification.

My text intends to show some consequences of the WFD in the field of ecotoxicology.

Ecotoxicology couples two different approaches

Ecotoxicology is an area of science that aims to determine the impact of toxic chemicals on ecosystem health. The first approach is Ecotoxicological Risk Assessment (ERA), which compares the fate of chemicals in the environment with the effect of those chemicals. The ratio of the predicted concentration to the no effect concentration is the indicator of risk. The fate is evaluated by means of chemical analyses or by modelling. The effects are measured by the use of standard biological tests, some of which involve studies in mesocosms and are quite complex. ERA is used at the European Union level for regulations on chemicals. Risks from new and existing substances may be assessed using a unified procedure based on the Technical Guidance Document issued by the EU [1]. Moreover, these methods may be used to establish water quality criteria for chemicals in the environment. In that case, effects of chemicals in the environment are derived from test results in the different compartments of aquatic ecosystems. Models may be used to comply with missing values, assess the effects of mixtures of pollutants or evaluate effects in sediments using tests from the water column. These quality standards are necessary for implementing the WFD since they allow classification schemes for chemicals to be determined. For instance, different quality levels may be assigned to acute effects and to chronic effects. The level of protection of the different taxa may also be a criterion for the quality of waters.

The second approach is eco-epidemiology. Epidemiology is the study of human diseases or mortality in relation to different variables. Eco-epidemiology tries to relate observed modifications of fauna and flora in the environment to different variables characterising human pressures on ecosystems. As in studies of epidemiology, biomarkers are often used because they reveal the presence of bio-available toxicants at toxic levels. The WFD will certainly give rise to a huge amount of data where the presence of toxic chemicals in waters could be related to ecological impacts.

The above two approaches have advantages and disadvantages. Risk assessment is impaired with uncertainty, although it gives relevant information on relationships between cause and effect. Eco-epidemiology only reveals correlations, with no proof of causative relationships, but it deals with measurable real effects at the ecosystem level that cannot be denied.

Has ecotoxicology anything to do with the ecology of organisms? There has been always a strong debate amongst ecotoxicologists on the ecological relevance of their findings. However, it seems almost impossible to extrapolate from biological tests using a single species to the real environment. Therefore, ecotoxicologists use safety factors to ensure that decisions made from their results are safe to the environment. Moreover, multiple species tests on wild species are increasingly used and increase the predictive capacity of the tests. Models for extrapolation from tests to ecosystems are now developed by scientists and should be available soon for regulation purposes. Finally, studies using reconstituted ecosystems or enclosures are now encouraged to give rise to a more realistic measurement of effects at the community level.

An example of both approaches

French water agencies have controlled industrial effluents for more than 20 years using one well known aquatic toxicity test: the acute toxicity test on *Daphnia magna*. The results shown in Fig. 1 clearly indicate that the toxicity of effluents has decreased dramatically in the last twenty years. The amounts of toxic units released into receiving waters have been reduced by two-thirds, and amounts of reducing substances have also decreased. This shows that considerable efforts have been made to treat effluents before disposal into the environment. The fact that industry has been charged by a taxation mechanism based on the amount of toxic units released into the environment is probably the best explanation for their efforts to reduce the disposal of toxicants.

However, the main question concerns the impact that such a reduction has had on the environment. Fig. 2 shows an improvement of the ecological status of rivers in the Seine catchment during the same period. It is based on a standardised index, IBGN [2], which scores the benthic invertebrate communities and is represented here by five quality classes. The clear improvement of ecological water quality is correlated with the decrease of the toxic content of effluents.

These results show that an ecotoxicological control of effluents may result in a measurable improvement of effluents and river quality. It advocates the fact that biological and ecological methods may be used for control and regulation purposes. It also stresses that the implementation of the WFD will enlarge our knowledge of water quality at the European scale and will probably result in an improvement of the ecological status of European waters.

Water quality monitoring based on ecotoxicity

Establishing priority lists of toxicants

The WFD requests member states to monitor toxic substances in the aquatic environment. However, a list of substances was not established within the text of the Directive. Such a list needs to be discussed among experts from the different member states and is a great challenge since many candidate substances might be included. Inclusion of any manufactured substance implies considerable economic consequences, and

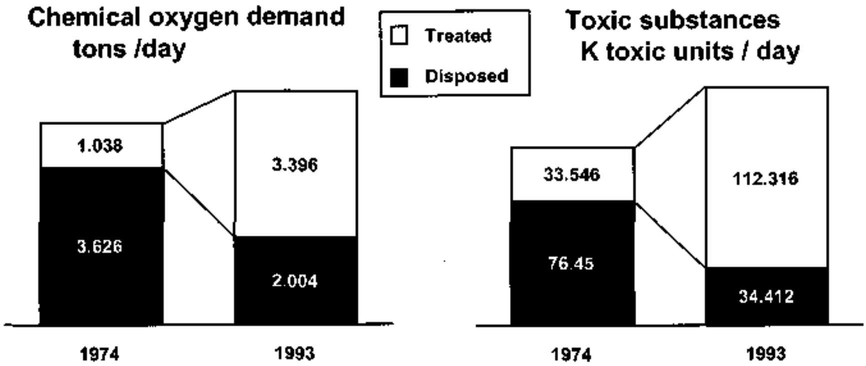

FIG. 1. Improvement in quality of industrial effluents in the catchment of the River Seine.

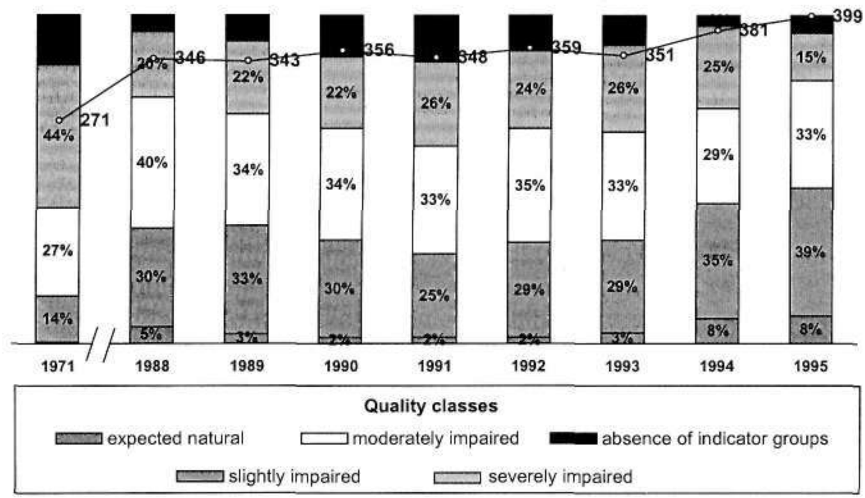

FIG. 2. Improvement of ecological status of waters in the catchment of the River Seine, using the 1BGN standardised index [2].

this probably explains the harshness of the discussions. A need for methods to classify substances is urgent. It should be based on the results of risk assessment of substances using, for instance, the Technical Guidance Document from the European Union. It was recently pointed out by the US Environmental Protection Agency that the data necessary for risk assessment is available for only a small part of the five hundred most produced substances (High Production Volume substances or HPV) in the world [3]. It is therefore doubtful that the list of priority substances for monitoring in the European waters will be established only by risk assessment.

Some scoring methods have been proposed in that context. OECD working groups are now discussing several scoring methods for establishing priority lists of pesticides. Some of them include expert judgements based on basic parameters for each substance or risk assessment procedures. The European Union is promoting a method called COMMPS (Combined Monitoring-based and Modelling-based priority setting) developed by the Fraunhofer Institute for Environmental Chemistry and Ecotoxicology in Germany [4]. This method couples data on monitoring substances, modelling the fate of substances, and expert judgements. The proposal for a decision from the European parliament and council, issued from the COMMPS method, gives a list of 32 chemicals that should be included in the WFD. However, the WFD, as agreed between the parliament and the commission, did not formally accept this list. Further discussions and work is needed to establish this list, but the commission is requested to provide a list and to submit it to interested parties prior to its inclusion as Annex X of the WFD.

The need for ecotoxicologically-sound water quality standards to set quality limits

Once the list of substances is agreed it becomes necessary to provide information on the concentrations of hazardous substances that should be used for characterising the chemical status of waters. This should be achieved by establishing Water Quality Criteria [5]. The WFD gives guidance to member states for establishing water quality criteria for chemical substances. This guidance stresses the need for ecotoxicity tests on several trophic levels. However, it also points out the need for comparisons of water quality criteria with field data before completion of their values. This gives rise to a serious scientific challenge which lies in understanding the ecological significance of laboratory tests.

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Furthermore, no mention is made on the need to monitor the water column and the sediment. This last compartment is very important as it shelters communities of organisms that are important for the functioning of the ecosystem. Sediments also store most of the persistent, poorly soluble substances that are unlikely to be found in the water column. For the moment, only a little effort has been made to develop and standardise sediment toxicity tests and models to derive sediment concentrations from those present in the water column. It is necessary that these useful tools should no longer be objects simply for research, but should now enter the field of routine methods by means of standardisation.

Relationship between eco-epidemiology and ecotoxicology

The coherence of the different monitoring needs of the WFD is very important since the objective of reaching good status for each member state lies within the Directive and is not specific to any of the parameters. The ecological spirit that inspires this directive makes it reasonable to think that ecological status will be the most important feature used to verify member states' compliance with the WFD objectives. Incompatibilities between the results from hydro-ecological surveys and monitoring of human impacts by means of, for instance, chemical pollution, would lead to a very unpleasant situation. Such a situation would mean that the lack of a scientifically sound knowledge of the effects of human pressure on ecosystems misled the actions taken to comply with a good ecological status. It is therefore necessary that predictive methods derived from ecotoxicology and used for risk assessment must be linked with *a posteriori* hydrobiological methods that diagnose the ecological status of ecosystems.

Such discrepancies in the two different approaches are likely to occur. The most probable reason for such difficulties is the potentially huge number of molecules that may be encountered in fresh waters. Ecotoxicity tests have considerable difficulties in coping with mixtures where additive, synergistic or antagonistic effects may occur. As unavoidable methodological problems arise, the most important being the fact that it is not possible to test all the possible mixtures of several pollutants, it will be necessary to develop *in situ* tests, tests on effluents, and models to bridge the gap between laboratory observations and reality. Establishment of water quality standards will need such tools to be able to give relevant levels of pollution for mixtures in the environment. Otherwise analytical detection limits will govern determinations of the chemical quality of waters. This will lead to disasters in understanding the causes of ecosystem impairment, a lack of sound remediation policies, and cost inefficiencies.

As in the case of human epidemiology, the use of biomarkers would be a great help to the solution of such problems. Biomarkers provide useful information on the presence of bioavailable toxicants in the aquatic environment and on some effects at a subcellular level. Since they may be used in the laboratory as well as in the field, they are one of the best candidates to provide the link between studies on ecotoxicology and eco-epidemiology.

Conclusion

This short overview of the main consequences of the WFD for studies on ecotoxicology shows that many scientific problems still need to be solved. Standardisation is also, necessary to help environment managers to use state of the art methods in implementating the WFD. Ecotoxicity tests for sediments, methods for setting up water quality criteria, and the use of biomarkers, are scientific tools that probably should be amongst the first priorities requiring development. A co-operative effort at the European scale is necessary in order to allow the aims of the WFD - establishing good ecological quality of fresh waters in Europe - to be achieved.

References

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