ILSI Europe
Report Series

Assessing and Controlling Industrial Impacts on the Aquatic Environment

with reference to food processing

Summary report of a workshop held in March 2000

Organised by the ILSI Europe
Environment and Health Task Force

ILSI Press
1126 Sixteenth Street, N.W.
Washington, DC 20036-4810
USA
Tel: (+1) 202 659 0074
Fax: (+1) 202 659 8654

ILSI Europe
Avenue E. Mounier 83, Box 6
B-1200 Brussels
Belgium
Tel: (+32) 2 771 00 14
Fax: (+32) 2 762 00 44

Printed in Belgium

ISBN 1-57881-121-X

Report on Assessing and Controlling Industrial Impacts on the Aquatic Environment (with reference to food processing).

ILSI Europe Environment and Health Task Force, 83 Avenue E. Mounier, Box 6, B-1200, Brussels, Belgium.

ASSESSING AND CONTROLLING INDUSTRIAL IMPACTS ON THE AQUATIC ENVIRONMENT
with reference to food processing

SUMMARY REPORT OF A WORKSHOP HELD ON 28-30 MARCH 2000 IN BUDAPEST, HUNGARY

ORGANISED BY THE ILSI EUROPE ENVIRONMENT AND HEALTH TASK FORCE

July 2001

CONTENTS

BACKGROUND

The European Union (EU) has the objective of attaining "good water status" for all surface and ground waters as stated in the Council Position [1 *see References page 28*] 41/1999 of 22 October 1999 concerning the draft Water Framework Directive*. This proposed legislation incorporates a combined approach to controlling pollution at source through the setting of Environmental Quality Standards (EQSs) and Emission Limit Values (ELVs).

The ILSI Europe Environment and Health Task Force recognised that environmental risk assessment for chemical substances is of some relevance to food processing wastes. However, of more relevance for such wastes is the potential impact of those general determinants (e.g. biochemical oxygen demand, suspended solids), which are capable of influencing water quality and ecological status. The task force therefore organised a workshop on "Assessing and Controlling Industrial Impacts on the Aquatic Environment: with reference to food processing", in Budapest, Hungary, from 28 to 30 March 2000. Prof. Peter Calow (University of Sheffield, UK) chaired the meeting. A number of invited experts from academia, regulatory agencies and the food industry addressed the scientific basis for protecting and improving the ecological status of surface waters (as proposed in the EU Water Framework Directive) in relation to food processing. Discussions covered a variety of issues related to wastes from food processing (rather than the primary production of food), with emphasis on point sources. Widely used chemicals common to many industrial processes were not considered.

This summary report of the workshop is provided as a scientific contribution to the debate on the development of EQSs and ELVs within the context of the Directive.

* Since the workshop, the directive has been enforced (Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, *OJ*: L327, 1–73, 22 December 2000).

WATER FRAMEWORK DIRECTIVE AND EUROPEAN WATER POLICY

In introducing the proposed Water Framework Directive (pWFD), Mr. John Fawell (Warren Associates, UK) also on behalf of Mr. Friedrich Barth (European Commission – DG Environment, B) reminded the participants that although a policy on environmental protection was not specifically laid down in the Treaty of Rome (1957) a wide range of measures had been adopted as political programmes and as Community legislation. The importance of the aquatic environment in the Community is reflected in environmental action programmes and water-related directives from the early 1970s to the present day. The Maastricht Treaty (1992) further strengthened environmental issues, including the following specific agreements:

- adoption as Community policy of the objective of sustainable development;
- agreement that the Community is responsible for environmental policy, within the limits of subsidiarity;
- qualified majority decisions to be adopted for most environmental issues;
- environmental policy to be integrated into the other Community policies;
- a high level of protection to be required in all environmental measures;
- the precautionary principle, the principle of prevention of pollution at source and the "polluter pays" principle were all specifically adopted.

Following the Amsterdam Treaty (1997), a strengthening of the policy of integrating environmental protection into all Community policies was introduced. Improved options for Member States to impose more stringent national legislation and a co-decision procedure to allow for joint decisions by the Council and the European Parliament on environmental matters also resulted. In order to integrate policy on water, a new framework directive (the pWFD) was introduced and is now reaching its final stages.

Objectives of the proposed Water Framework Directive

The pWFD incorporates the following objectives:

- expanding the scope of water protection to all waters (groundwater and surface waters);
- achieving and / or maintaining "good" ecological status, within a set time-frame;
- basing water management on river basins, over-riding administrative structures / boundaries;
- combining the approaches for control of pollutants by emission limit values (ELVs) and water quality standards (WQSs), i.e. environmental quality standards (EQSs);
- reflecting true economic costs in prices and charges for all services related to water use;
- more closely involving both interested parties and citizens in the process of protecting water;
- streamlining water legislation (by incorporating / repealing seven earlier Directives).

The pWFD provides water quality objectives (WQOs) for rivers, lakes, coastal waters and groundwater, a programme of measures to achieve the WQOs, a framework for pricing policies, and stresses the need for river basin management plans and public participation.

The influence of the European Parliament has significantly increased, resulting in various changes to the pWFD and prolonged negotiations between Council and Parliament in search of agreements. The key elements of the amendments proposed by Parliament introduce wording agreed to by the Oslo Paris Commission (OSPAR) regarding both zero emissions of a number of chemicals, and legally binding environmental objectives explicitly prohibiting deterioration in quality. All discharges to surface water are to be controlled, with EU-wide emission standards for priority substances. Requirements for groundwater are now much more stringent. For heavily modified water bodies there are separate objectives and more stringent criteria for designation.

In emphasising the importance of water pricing policies Parliament has said that pricing policies must provide incentives for efficient water use and achievement of the environmental objectives. There is also a requirement that the various economic sectors adequately contribute to the cost of implementing the pWFD, having due regard to social and economic effects, geographic circumstances and climatic conditions. Parliament proposed shortening the implementation period from 16 years to 10 years, but made allowance for two possible extension periods.

Technical and scientific aspects of the proposed Water Framework Directive

Important technical and scientific dimensions to the pWFD cover the measurement of water quality, ecological status, target objectives and implementation measures.

The environmental objectives against which programmes of measures are to be drawn up and made operational have been defined as follows:

- **Surface waters:** good ecological and chemical status by a set deadline; no deterioration of ecological quality or pollution; restoration of polluted waters to achieve at least "good" status.
- **Groundwater:** good quantitative and chemical status in all waters by a set deadline; no deterioration of quality and restoration of polluted waters; a balance must be achieved between abstraction and replenishment of groundwater.
- **Protected areas:** compliance with all standards and objectives relating to protected areas by a set deadline, unless otherwise specified in Community, national or regional legislation.

As an example the classification "good ecological status" for rivers includes all the aspects required to support the biology, including:

- composition and abundance of flora, invertebrates and fish;
- hydrological regime; quantity and dynamics of water flow; connection to groundwater aquifers, river continuity and morphology (e.g. variations in river depth and width, structure and substrate of river beds and structure of riparian zone);
- general thermal conditions, oxygenation, salinity, acidification status and nutrient conditions.
- specific pollutants, especially pollution by all priority substances discharged to the river, but also other non-priority substances discharged to the river in significant quantities.

The classification and measurement of ecological quality will require determination of ecological status of an "undisturbed" equivalent water, determination of the ecological status of the water in question and calculation of the ratio between the two.

The pollutant inputs requiring control or reduction must be identified and controls implemented. Monitoring will ensure that improvement is achieved. Annex 5 of the Directive provides guidance, and defines the framework for the process, although details can be developed by individual Member States.

Control of emissions

A combined approach to the control of emissions to water is inherent to the proposed Directive. The proposed Directive requires both ELVs for relevant sources and/or pollutants and water quality standards (WQSs) for surface and groundwaters. These complementary strategies respectively deal with the quantity discharged from an individual source and also provide an integrated standard for the whole water body. In any particular situation the more rigorous approach will apply. Thus, if better standards can be achieved through the best available technology, while also taking into account excessive cost, the potential to pollute up to the standard is removed. No derogations will be available to existing emission-oriented Community legislation.

As well as emission-based legislation (as in the Urban Wastewater Directive, the Nitrates and Pesticide Directives, and the Integrated Pollution Prevention & Control Directive – IPPC), controls will be set for pollutants from sources not so covered. Water-quality based legislation will be introduced through the WFD, which will integrate the water quality standards introduced under the Dangerous Substances Directive and its daughter directives.

Non-IPPC discharges will include the priority substances determined by the Combined Monitoring-based and Modelling-based Priority Setting Scheme. The Commission has published the list of proposed priority substances for which WQSs will be developed, based on a scientific, simplified risk-based prioritisation method. It is not yet clear how the OSPAR wording (seeking zero emissions) will affect future standards.

The approach to developing WQSs broadly follows the approach used in risk assessment for new and existing substances. However, because these are "standards", allowance is made for the use of more precise safety or uncertainty factors in the light of scientific data. This approach also allows for revision following comparison with field data. Both peer review and public consultation are necessary, significantly increasing transparency and also uniformity with other directives, particularly those concerning new and existing substances.

Conclusions

The Water Framework Directive will bring far-reaching changes to environmental protection in the Community and is intended to bring a general improvement in water quality and in the way man impacts water quality. A considerable amount of activity towards implementation is already under way even before the pWFD is finally adopted. Research projects have started on groundwater conditions, on defining heavily modified water bodies and on establishing reference conditions for different regions and water types. Discussions have been held with Member States" water directors, and there are working groups on the implementation of the Directive in the Rhine and Danube basins. Member States are also holding workshops, establishing working groups and carrying out research.

There will, however, be many challenges for scientists to face in achieving an accord on the balance of science *versus* the precautionary approach, in ensuring that the science is transparent, and in avoiding the pitfalls and solving the problems of measuring ecological quality in a meaningful way.

AQUATIC ECOSYSTEMS: STRUCTURE AND RESPONSES TO WATER QUALITY, POLLUTION INDICATORS, CONTROL MEASURES

Freshwater ecosystems – structure and responses to water quality

Before it is possible to predict the impact of human activities on the natural environment it is necessary to understand the forces that drive and, therefore, control that environment. Prof. Gwynfryn Jones (Freshwater Biological Association, UK) discussed these driving forces (some of which are under human control), which can be divided into the physical and the chemical. The response of the ecosystem is, however, almost entirely biological. Although most impacts of the food processing industry might be perceived to be on running waters, this is not always the case. However, we can apply the same basic rules to both static and running waters.

The physical forces that determine how a lake functions are as follows. In early spring, in the temperate zone, the temperature of the surface water in lakes rises and the sunlight input increases. This results in stratification of the water body. The cooler, deeper water is separated, physically, by gravity. This isolated water plays a very different role in the function of the lake and is analogous to how a river works.

Human activities drive these systems by their input of inorganic and organic substances. The inorganic inputs – particularly of phosphorus – stimulate undesirable algal growths, some of which may produce particularly dangerous toxins. We must now accept that climate change (driven by human activities) will exacerbate these problems.

Organic inputs from the food industry (i.e. carbohydrate, lipid and protein) will all impact on lakes and rivers by increasing the biochemical oxygen demand (BOD). The worst-case scenario is total loss of oxygen from the water as a result of microbial activity. Lipids create the greatest oxygen demand, but carbohydrates (more easily biodegradable) also result in the unsightly bacterial growth known as “sewage fungus”. Protein waste can be degraded to produce ammonia and sulphide, both of which produce toxicity problems. Bioremediation processes, particularly phytoremediation, can alleviate these problems, in a cost-effective manner.

Ecological indicators and polluting effects

Dr. Dietrich Borchardt (University of Kassel, D) reminded the workshop that the proposed Water Framework Directive requires Member States to aim to achieve the objective of “*preventing deterioration of ecological status and pollution of surface waters and restoring surface waters, with the aim of achieving good surface water quality*”. To do this, a designation of all surface waters must be made, set against some unpolluted or pristine reference condition. The proposed Directive also states that “*deterioration in the status of bodies of water shall not be in breach of the requirements if this is the result of unforeseen or exceptional circumstances, in particular floods and droughts*”. Furthermore, the proposed Directive recognises “*heavily modified water bodies*” (selected sites affected by intense human activity). For these bodies of water, the reference conditions on which the ecological assessment is to be based are referred to as “*maximum ecological potential*”. This “potential” is defined by referring to a comparable but unimpacted surface water type as the benchmark, taking into account the characteristics of the heavily modified waterbody when all practicable remedial measures have been taken. The procedural basis given in Annex II of the proposed Directive includes the identification of reference conditions and maximum ecological potential either spatially based (comparison to existing sites), or based on modelling, or a combination of these. In this context relations between ecological indicators and polluting effects become an important issue in future European aquatic environmental management.

Although principally straightforward, several open questions are implicit in the proposed Directive, given our current understanding of functional relations between water quality, ecological status and anthropogenic impact. These questions focus on the need for integration of the many aspects of an ecosystem into an ecological assessment, tools allowing integration based on a functional understanding of the behaviour of ecosystems and anthropogenic impacts, ecologically sound spatial and functional scaling of river catchments, and the need to compare "traditional" objectives to those based on ecological assessments.

Measures for protecting water quality – current approaches and future developments

An important component in protecting the ecological quality of watercourses is the regulation of point source discharges, so that any unacceptable impact on biota in the receiving water can be minimised. Dr. Paul Whitehouse (Water Research Centre, UK) explained that where point source discharges to surface water are subject to such control, they are usually expressed in terms of "end-of-pipe" limits on the concentrations of chemicals or of such "sanitary" determinants as BOD, suspended solids or dissolved oxygen. Sometimes, discharge licences take the form of ELVs, which apply to all discharges irrespective of the dilution capacity of the watercourse into which they discharge. Alternatively, these licenses may be based on water quality standards (e.g. EQSs) for specific chemicals, which describe thresholds below which no adverse impact in the receiving water is predicted. The resulting licences incorporate an explicit acknowledgement of the capacity of the receiving water to dilute and disperse a discharge and, in this respect, differ fundamentally from the ELV approach.

Whilst such methods may be adequate for controlling releases of specific chemicals, there is a growing recognition of their shortcomings for regulating mixtures of substances. The control of certain well-defined mixtures of chemicals (e.g. discharges containing alkylphenol ethoxylates and their breakdown products) has been proposed on the basis of "Toxic Equivalent" approaches. However, for the regulation of complex and poorly defined mixtures, a fundamentally different approach involving the direct assessment of the toxicity of whole effluent samples (so-called "Whole Effluent Testing" or "Direct Toxicity Assessment") has been advanced.

An overview was given of chemical-specific and toxicity-based approaches to controlling point source discharges to surface waters. Some of the strengths and weaknesses of the different methods were highlighted, with suggestions of circumstances in which one approach may be favoured over another. Finally, opportunities were suggested for technical development, which should result in more effective regulation of point source discharges.

CASE STUDIES

Fats, oils, and greases

Mr. Roy Willey (Unilever, UK) described the three main stages in the production of edible oils and margarines: oil-extraction, refining and processing. Chemical refining involves an initial neutralisation process to remove phosphatides and the majority of the free fatty acids. This process is followed by a bleaching stage to remove pigments, peroxides and metals. Finally a deodorisation stage takes place to remove any off-odours and any residual free fatty acids. Physical refining involves steam distillation in a deodorisation stage and results in a much-reduced level of wastewater and associated organic load than the chemical process.

Many individual waste waters arise from refining and the production of margarine. Volume discharged, the organic load in terms of chemical oxygen demand (COD) and BOD, the level of fat as Total Fatty Matter and parameters such as pH and sulphate are all considered. The most significant polluting loads arise from acid water associated with the neutralisation process, barometric water used to maintain vacuum systems and cleaning operations within the margarine production process.

Pollution control measures involve improved operation, process modification or wastewater treatment and allow recovery of materials for re-use or as by-products with a saleable value, reduction of water consumption and the meeting of standards for discharge, thus reducing trade effluent charges.

Suspended solids

The reduction of suspended solids plays an important role in today's wastewater treatment as such solids can affect running waters. Prof. Karl-Heinz Rosenwinkel (Institute for Water Quality and Waste Management, University of Hannover, D) gave an account of the origins of suspended solids in municipal and industrial waste waters. Three types of suspended solids occur during the processing of vegetables, fruit, etc. and during transportation, washing, cutting, etc. These are: inorganic materials from the washing step, organic residues (e.g. the peel) and solids in the wastewater.

The cost of discharging wastes and current environmental awareness has led to higher rates of recycling of water and raw materials. Avoiding waste production should take precedence over utilisation, and utilisation should take precedence over disposal. A number of options for achieving these aims exist. However even avoidance and recovery give rise to large amounts of residues, which are the main sink for suspended solids. Disposal in land-fill sites occurs in some cases, but usually the residues are used in animal feed or are treated by aerobic (composting), anaerobic (digestion) or thermal (incineration) methods. Huge capacities for a co-digestion of agro-industrial residues (substrates) and wastewater sludge can be found in municipal digesters.

Most food processing factories discharge their waste to sewers for municipal wastewater treatment. The solids in the effluent of such plants mostly consist of structured floc or finely dispersed material. The characteristics of secondary settlement influence the solids in the effluent. Suspended solids removal can be enhanced by various effluent “polishing” methods such as filtration.

Eutrophication

Dr. Marie-Hélène Tusseau (Cemagref, F) defined eutrophication as the enrichment of water bodies with plant nutrients and precursors, typically nitrogen, phosphorus and organic matter. She distinguished "natural", slow eutrophication, over geological times (which turns a lake into a marsh and then converts the marsh entirely to dry land) from the human process that "*results in the stimulation of an array of symptomatic changes, among which increased production of algae and macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable and interfere with water uses*" (OECD, 1982). Eutrophication has many effects, such as increased macrophytic plant growth that can slow the flow of a river, leading to higher temperatures and modifying sediments. When the excessive amounts of organic matter decay, this can lead to enhanced oxygen demand so that water quality becomes inadequate for most animals and malodours can result. Lakes, some rivers (e.g. Loire), some estuaries and coastal zones (e.g. in the Northern Adriatic) may be susceptible. Key-indicators of the problem include the concentrations of nitrogen, phosphorus, chlorophyll and organic matter, biological productivity (generally phytoplankton photosynthesis) and oxygen decay in summer.

Research in the 1970s has shown that in most freshwater systems, phosphorus is the "limiting nutrient" for phytoplankton, so that in most lakes the standing crop of phytoplankton is proportional to the concentration of total phosphorus. Sources of phosphorus include natural (weathering of rock, leaching from soils, rain) and agricultural runoff, as well as sewage and industrial effluent. Detergents are usually considered the predominant source among the industrial wastes, but some food processing industries (meat, vegetables, cheese processing) also contribute significantly to the phosphorus budget, even though the pollution may be due to the washing of equipment rather than directly to food wastes.

Reduction of phosphorus in the environment is typically achieved by adding a costly tertiary stage to treatment plants. Data now show recovery of some aquatic systems as a result of such measures (Great Lakes, some Alpine lakes).

Detergents and biocides: Comparison of model prediction and ecosystem monitoring

During food processing, chemicals or organic wastes can be emitted to the aquatic environment. Impact depends, *inter alia*, upon the quantity emitted and the inherent properties of the compounds released. Dr. Erwan Saouter (Procter & Gamble, B) showed how Environmental Risk Assessment (ERA) could help companies understand and control the impact of their activities.

The assessment and management of "down-the-drain" consumer products (such as laundry detergents) represented one of the earliest applications of ERA and stimulated the development of a number of conventional fate and effects test methods, tools and approaches. Today, ERA is integral to product development for major detergent manufacturers. Assessments of environmental fate and effects guide companies in making a variety of sound business decisions. For the last 30 years, the detergent industry has been faced with two major environmental problems: the issue of biodegradability of surface active agents used in detergents, and the issue of eutrophication of rivers due to the use and release of phosphate.

The rather poor environmental profile of the first synthetic surfactants in the early 1940s led to severe foaming problems in wastewater treatment plants and surface waters. Resulting press coverage brought unwanted attention to the industry. The second major environmental issue to beset the detergent industry was eutrophication. Although the symptoms of eutrophication were abundantly clear, the relative contributions (detergents, agriculture, human wastes) varied widely according to region and demographics. Detergents were rarely a major source.

The industry responded by designing new molecules that could meet both performance and biodegradability requirements. Replacement of phosphate (used as a builder in detergents) also has been a major challenge. Research to understand the fate and potential impact of detergent chemicals is now a prerequisite before any molecule can be used in a final product. Research includes model predictions, laboratory experiments and field validation (ecosystem monitoring). At the higher tier in the risk assessment, the use of experimental stream ecosystems (or mesocosms) allows ecotoxicologists to understand impact and recovery in ecosystems. New technologies, improved understanding of local environments and development of new tools have led to sound management of environmental issues. Monitoring exercises (in France, the Netherlands and the United Kingdom) have demonstrated the validity of model predictions. The latest challenges relate to understanding the potential impact of mixture toxicity, multiple exposures and the issue of sustainable development.

OPERATING THE WATER FRAMEWORK DIRECTIVE: DISCUSSION OF SCIENTIFIC AND TECHNICAL ASPECTS – DISCUSSION GROUPS (Chairman: Prof. Davide Calamari, University of Varese, I)

To provide a structure to the workshop discussions, a series of questions relating to the operation of the proposed Water Framework Directive had been sent to all participants beforehand. These questions are listed below.

1. What, where, when, why, and how should measurements be made?
   How should biological, physical, and chemical quality be interpreted?
2. What constitutes an adverse effect in an ecosystem?
   What constitutes a non-adverse effect?
   What is an acceptable level of damage?
3. What are the scientific strengths and weaknesses of the proposed methods for establishing EQSs?
4. What are the parameters that could lead to an optimum geographic scale for the application of an EQS?
   How should risk assessment be carried out in a river basin receiving many waste inputs?

A number of general points should be mentioned concerning the questions. The questions exemplify those which Competent Authorities (CAs) might consider in relation to the proposed Water Framework Directive. The foods processors, as ILSI Europe members present in this workshop, may offer advice to the CAs and specific interpretation for the industry. Secondly, to some extent the workshop focused on the specific issues of the food industry and considered the particular waste issues of that industry. These specific points included:

- seasonality of foods processing;
- non-specificity of wastes (general organics, soil);
- relative rarity of emission of toxicants (biocides and pesticides will be among the exceptions);
- needs for food-grade processing water.

In the following summary, all the material from the discussion groups has been re-organised under a number of headings:

- measurement of environmental quality;
- interpretation of environmental status;
- deriving Environmental Quality Standards: Strengths, weaknesses and challenges;
- deriving an optimal geographic scale for application of an Environmental Quality Standard;
- clarifying criteria of acceptability: adverse and non-adverse effects;
- what is an acceptable level of change / damage?
- risk assessment in river basins having multiple waste inputs.

Each question was addressed by two groups, comprising on average nine participants per group and the composition of the groups was rearranged after the first two questions. In addition, the principal rapporteurs listed all the points made during the presentations and discussions of the papers and these were categorised according to the questions listed above. The lists were made available to the groups. The responses to each question were presented by the groups in plenary sessions and then discussed. A summary was then prepared overnight and again discussed on the final day, to ensure that all questions had been addressed and that there was agreement on the nature of the issues (not necessarily on their resolution).

MEASUREMENT OF ENVIRONMENTAL QUALITY

The Workshop proposed that a stepped approach should be taken to devise and activate a sampling strategy. The steps of this process are given below.

Steps in a sampling strategy

1. Characterisation and categorisation of the river basin using habitat types, hydro-morphology, land use, soil type

- Data to make an adequate description of natural variation in European waters are either insufficient or are held in disparate databases. This problem should be addressed.
- It is essential to integrate aspects of both terrestrial and aquatic systems (and the atmosphere) to characterise ecosystem change fully.
- The question was raised as to whether habitats alone could be a sufficient subject for protection. The conclusion was that habitat can certainly be important but should always be combined with other considerations. For example a river bank / bed (an example of a habitat) can be described as being in the eroding, transporting or depositing zone, but the addition of other physical information (e.g. temperature) and chemical data will enhance the description of the need for protection.
- Some land use changes (including some designed to improve environmental conditions) are occurring all the time, but their downstream impact is only rarely examined. Such changes will influence the aquatic ecosystem and, without thorough understanding of the events, may make apparent cause and effect more difficult to interpret.

2. Analysis of potentially damaging impacts

- Habitats may often be better described as a mosaic of sub-habitats; the differing sensitivity of these to potential impacts may make it important to assess the importance of each part of the mosaic. Sometimes a small number of these sub-habitats could drive the risk assessment process.
- Problems of analysis will arise from the nature of the waste water, extremes of flow regimes, variation in the current provision of waste treatment etc. All of these will influence the parameters to be measured.

3. The location of sampling

- Sampling location will depend on the stability and sensitivity of the system.
- Trans-boundary flows and estuaries may require special attention.
- Remote sensing may be utilised to identify locations and, with appropriate sensors, supplement or even supplant sampling.
- Geographic Information Systems (GIS) offer possibilities for analysing and displaying sampling strategies. (The pWFD requires the establishment of a network of reference sites).

4. *Frequency*

- Sampling frequency will need to take into consideration the inherent variability of the system to be monitored. Natural fluctuations in ecosystems need to be understood in order to design sampling strategies to identify man-made fluctuations.
- Events of a transient nature need to be investigated using appropriately frequent sampling. Episodic events are usually interpreted by using short-term data whereas effects may be long-term, distant or secondary.
- If an ecosystem seems to be close to an impact threshold this may also require more frequent monitoring.

5. *Subjects of monitoring*

Various ecological measurements may be made. Discussion included whether it was relevant to consider only certain trophic levels or taxonomic groups and ignore others (e.g. micro-organisms).

The main elements, all considered possible at times, were:

- Trophic levels – These may be monitored singly or in community systems as demonstrated by the River Invertebrate Prediction and Classification System (RIVPACS).
- Life cycle stages – The timing of sampling must match the needs of sensitive life stages including knock-on effects.
- Sensitive species: – The diversity of selected taxonomic groups must be recognised. Some families contain species with widely differing sensitivities to environmental variables. Others may be at the edge of their geographical range and only a small change may tip the balance towards severe impact on their populations.
- Physico-chemical characteristics to describe the ecosystem to a sufficient extent
- Functional measures: Interaction of relevant ecosystems – This was thought of more relevance to food processing where toxicity of effluents may be less of a problem than oxygen demand and suspended solids. (For the latter, monitoring of sediments may be relevant to account for effects in the overlying waters, and vice versa.)
- Monitoring of trends will often be of more importance than fixed “snap-shots” of environmental status. Long-term records, including amateur data on phenology, as well as complex measurements such as the position of the Gulf Stream, etc., may have great value in describing the present and predicting the future.
- Health of the highest trophic levels may provide valuable indications of stress, because these levels often integrate the responses of all the elements of the ecosystem on which they depend.
- Studies of recovery in damaged ecosystems are seldom made but can provide valuable insights.

N.B. The question of *how* measurements were to be made was not pursued in depth, but note the reference to GIS and remote sensing above.

INTERPRETATION OF ENVIRONMENTAL STATUS

One of the most important aspects of the proposed Water Framework Directive is the recognition of the central role of ecological quality in providing an indication of environmental status. Status here includes biological, physical and chemical aspects of an ecosystem or group of ecosystems. However, interpretation of such information is not without its difficulties. It is necessary to understand not only systems which are in equilibrium and relatively static but also systems which are changing. Changes may be a sign of the impact of progressive trends (such as climate change) which may have moved the boundaries of acceptable habitats close to threat levels, or they may be the result of a gradual erosion of the assimilation capacity of a water-body. In any case, it is necessary to adopt a holistic approach because what is visible today will be the result of all the current stresses on the river basin plus the historical events which have shaped the catchment area.

The following list of considerations put forward at the workshop must be taken into account when interpreting observed ecological status. Other considerations are included above.

- Data to make an adequate description of natural variation in European waters require harmonisation of monitoring programmes, including what is measured (total / dissolved), standardisation of data, analytical methods, etc.
- It is essential to integrate aspects of both terrestrial and aquatic systems (and the atmosphere) to characterise ecosystem change fully. In other words, it is the total river basin loads on ecosystems which matter, not just the loading from a limited number of types of input.
- The above should include the particular history of land use and its impact on water quality.
- Attention should be paid to the special case in the periodic recovery of those ecosystems in low-flow areas where the summer flow is the effluent flow.

DERIVING ENVIRONMENTAL QUALITY STANDARDS: STRENGTHS, WEAKNESSES AND CHALLENGES

ILSI is a science-based organisation. For this reason the workshop discussion groups made no more than a passing reference to Emission Limit Values (ELVs) because they are not defined by scientific risk assessment but are considered from the point of view of political expediency.

It is important to set out the assumptions made in discussing Environmental Quality Standards (EQSs). In the ILSI Europe workshop the following assumptions were made after some discussion:

- Protection of lower organisms will permit (or at least facilitate) the protection of the entire food chain. It is necessary, however, to take biomagnification into account in order to safeguard higher organisms.
- In identifying priorities EQSs may mislead by giving over-protective safety factors. There remains the question whether below a certain point further reductions in emissions will really deliver an environmental benefit.

Validation of standards is crucial. At present it must be said that the validation of standards is weak, but the intended linkage in the pWFD between chemistry and biology should lead to improved understanding and validation of appropriate standards. Ecosystems are complex, but their protection is the focus of the pWFD.

The Commission are to provide EQS values for 32 priority substances and are unlikely to produce more than one EQS value per situation (although the Freshwater Fisheries Directive did allocate different safe levels for metals – depending on hardness – as well as indicate mandatory and guideline values).

In any event, EQS values should take into account:

- the physico-chemical characteristics of the receiving water;
- the quality and quantity of data;
- toxicological variables such as the mode(s) of toxic action.

Table 1. Strengths and weaknesses of the Environmental Quality Standard Approach.

Strengths	**Weaknesses**
The EQS approach allows for different ecosystem conditions (e.g. factors modifying metal speciation and bioavailability). All the available data can be used. The approach is flexible. Margins of safety allow for some limited exceeding of standards without placing ecosystems at risk. Expert judgement can be used effectively, e.g. placing the Precautionary Principle on a scientific basis. EQSs encourage "thoughtful toxicology" – requiring data of suitable quality for the purpose, in contrast to the "check-list mentality" of some approaches. The development of analytical methods is encouraged where needed. The EQS approach is relevant to NH_3, dissolved oxygen, pH, turbidity, P. The strength of the pWFD is to link chemical and biological effects in the real world – this is not something we are good at now.	Nutrients and pathogens may not be easily taken into the EQS approach. (There is a variety of opinions on this subject). EQSs need good quality data and expert judgement. (The latter is a weakness where Member States have different political agendas). Extrapolation from laboratory studies to the field is an area requiring more experience. The standardised test methods used to derive ecotoxicological data are restrictive: Global Harmonisation will not help here. At present EQSs do not take sediments into account. (Some priority chemicals may be transported with sediments or suspended particulates). Bioaccumulation potential/body burden calculations would be the best approach for deriving EQS values for some chemicals, but there are few data on this subject. There is no mechanism yet for handling mixtures. Surrogate approaches include Direct Toxicity Assessment (DTA), and there may be instances where group parameters (e.g. absorbable organo-haloids [AOX]) may have value. The specific form of metallic elements needs to be considered. EQSs on total Cu, Fe, etc. is irrelevant.

Possibilities for improvement of the Environmental Quality Standard approach

(i) If testing is needed to derive the EQS, an understanding of the mode of toxic action of the particular substance may allow selection of the most relevant test species.

(ii) Quantitative Structure Activity Relationships (QSARs) allow outliers to be identified in a data set, but more research is needed on QSAR approaches.

(iii) Extrapolation from freshwater to marine species needs further work (but see Hutchinson *et al.* 1998).

(iv) Direct Toxicity Assessment (DTA) requires improvement but may offer an approach to establishing an EQS for complex mixtures.

(v) More indicator species are needed rather than more tests.

(vi) The possible linkages between bioaccumulation and ecosystem level responses need further study.

General discussion on establishing Environmental Quality Standard values

The statistical/probabilistic approach to setting predicted no-effect concentrations (PNECs) was briefly discussed. The approach needs at least 7-8 representative species, but its basic premise that individual EC_{50} values or other statistics are normally distributed has never been fully justified. Regulators like the simplicity of the application factor approach, which has always been found, empirically, to err on the safe side. There are possibilities for making better use of existing data. Too often it is the EC_{50} rather than its 95% confidence limits that are considered.

Sensors at the cellular level for early warning systems or DTA testing may have limited application. They provide a rapid means for investigating certain toxicological issues at a screening level.

Costs will limit monitoring which must therefore be supplemented by modelling (predictive tools to fill in missing predicted environmental concentrations).

The GREAT-ER model (Geography-referenced Regional Exposure Assessment Tool for European Rivers) (Feijtel *et al.* 1997) is being developed further under the CEFIC “Long-Range Research Initiative” and may be capable of handling diffuse sources within the next 3-5 years. Certainly GIS is one of the areas of advance in environmental exposure and risk analysis.

DERIVING AN OPTIMAL GEOGRAPHIC SCALE FOR APPLICATION OF AN ENVIRONMENTAL QUALITY STANDARD

There can be no single fixed geographic scale for application of an EQS in European systems. Each area where an EQS is to be applied may have particular requirements, characteristics and restrictions. There are probably many scales from entire river basins to small reaches and even single critical points.

Parameters to be considered when deriving the appropriate geographic scale include:

- the variability of land use in the river basin;
- geomorphology;
- receiving water chemistry and ecology (for which it is certain that background data will be needed);
- substance-specific factors (labile versus non-labile nature);
- the degree of uniformity of geographic units (GIS) could be applied.

Natural conditions will tend to ameliorate toxic potential compared with laboratory environments. It is normal in the laboratory deliberately to maximise bioavailability of substances in toxicity tests. This amelioration in nature means that Application Factors (which are intended to allow extrapolation of laboratory findings to the natural environment) are normally too wide for natural situations: the EQS approach will provide more favourable degrees of protection.

N.B. It is the Competent Authorities who are required to provide data in the above bullet points.

CLARIFYING CRITERIA OF ACCEPTABILITY: ADVERSE AND NON-ADVERSE EFFECTS

The pWFD provisions will certainly repeat some of the questions which have engaged ecologists for years: What constitutes an adverse effect and when can an effect be considered non-adverse?

One approach to the first of these two questions is to reverse their order: to identify what may be a non-adverse effect. For example, examine whether changes to populations are nevertheless going to lead to sustainability of those populations. If sustainability seems threatened, the change is adverse and unacceptable. For example the presence of a xenobiotic substance in an ecosystem is not, *per se*, evidence of harm, i.e. contamination does not necessarily imply pollution.

If ecosystem structure is maintained, it can be argued that ecosystem function is protected. Function is, *a priori*, more robust than structure since, to some extent, function can be maintained even though some species are lost. Whichever is chosen, the reasons for the choice and quantification of effects must be transparent.

On the other hand there is a view that damage to any aspect of an ecosystem, such as:

- its general system;
- its functioning;
- certain indicator species, or
- special species needing protection for altruistic or economic purposes

constitute an adverse effect.

Transient changes in structure or function may or may not be acceptable, depending in part on the magnitude and perceived severity of the change. The suggestion was made that adverse effects would be interpreted as such if they occurred at organisational levels higher than the species. Taking any transient change to be evidence of an adverse effect would be considered by some as an extreme application of the Precautionary Principle. The Precautionary Principle will be most relevant if applied

- when the potential for damage is very large,
- when risk assessment data are lacking.

A problem remains that where the missing data are provided there is unlikely to be the political will to overturn the original precautionary measure.

N.B. The recent Commission White Paper on the Precautionary Principle (EC, 2000).

WHAT IS AN ACCEPTABLE LEVEL OF CHANGE/DAMAGE?

A non-adverse and / or transient change could be taken as acceptable but only if relevant stakeholders agreed. Natural variations are acceptable, of course. Acceptability must be judged against the aim of the pWFD to improve and restore EU waters. Stakeholder opinion can be measured against various benchmarks such as natural changes. Acceptability of change is unlikely to be an absolute even for one stakeholder group. It will vary, depending on, e.g.

- the point of departure – (whether the change occurred from a good situation or a bad situation);
- the signal to noise ratio;
- the cause of the change. (It is instructive to contrast attitudes to examples of environmental damage which are the stakeholder responsibility with damage caused by someone else.)

It is certainly not acceptable to further load an already damaged ecosystem, thus delaying its restoration.

RISK ASSESSMENT IN RIVER BASINS HAVING MULTIPLE WASTE INPUTS

This discussion point will be encountered in all but a few river basins of any significant size. The issue of multiple inputs addresses two aspects of mixtures:

- reactions between chemicals in the environment;
- reactions between chemicals in the organism.

The issue of multiple inputs should only come into focus when there is a defined problem in a river basin, when a number of approaches to its solution could then be considered.

The opinion of the participants at the ILSI Europe Workshop was that Direct Toxicity Assessment (DTA) could eventually provide one type of baseline data, comparing the dilution available in the receiving water with the dilution needed to reduce concentrations of contaminants to a safe level. This could allow the regulator to examine the situation where cumulative loading occurs with successive inputs as the water passes downstream. For determining stress on an ecosystem, DTA methods and biomarkers may provide useful data, but both need further development before their use in the pWFD. For example, interactions between the overlying water column and the deposited sediments of a river or lake could not be adequately addressed by DTA alone. Such information would need to be supplemented by an EQS study.

Where contaminants can be clearly defined and methods are available, the critical body burden approach may offer an analytical means of examining the effects of multiple inputs. However, this begs the question of whether environmental risk assessment is then needed at all. Environmental risk assessments on single substances might be used, and this would be particularly valuable if it followed a holistic assessment. This overview would, in effect, provide a "mass balance" of the situation considering all the loads on the river basin, such as suspended solids, thermal energy etc. Indeed it is considered essential to integrate aspects of both terrestrial and aquatic systems (and the atmosphere) to characterise ecosystem change fully.

Characterisation of the principal stressors (input by input, chemical by chemical) and support from DTA (effluent by effluent) would then lead to a total appraisal of the basin. The biological community can be interrogated in such circumstances via the use of biomarkers, ecological parameters. It may be relevant to consider only certain trophic levels or taxonomic groups and ignore others (e.g. micro-organisms), but this will depend on the local situation and needs of the river basin. These two provide an integration of environmental variables. Finally, toxicity testing can be employed with or without fractionation of the contaminant classes. Studies of mechanisms of toxic actions help interpret short-term, long-term and delayed effects. Some substances (endocrine disruptors) may have no short-term impact but considerable implications for populations for the long-term sustainability of "healthy" river basins.

SCIENTIFIC ISSUES ASSOCIATED WITH IMPLEMENTING THE PROPOSED WATER FRAMEWORK DIRECTIVE – AND CHALLENGES FOR THE FOOD INDUSTRY

Finally, at the end of the meeting, Prof. Peter Calow (University of Sheffield, UK) gave a summary lecture* prepared following all the other presentations.

In introducing his talk, Prof. Calow explained that there are at least two kinds of targets that are used in environmental protection: those expressed in terms of causes to be controlled, (e.g. chemicals that cause adverse effects in the environment) and those expressed in terms of achieving effects (e.g. habitat quality, species composition). What matters most are effects rather than causes; but, somewhat paradoxically, more environmental legal instruments focus on causes rather than effects, i.e. on the presence, absence and concentrations of industrial chemicals in emissions and receiving environments. While the two approaches are not mutually exclusive – and indeed the one ought to lead to the other – they are often distinct, with causes being pursued for their own sake without much consideration of what ultimately we are trying to protect, and effects being observed without consideration of specific causes.

Prof. Calow identified several possible reasons for the predominance of cause-based legal instruments. First, from an environmental point of view we sometimes do not know what effects to measure. Because of this, and the often considerable spatial and temporal variability in biological systems, we frequently do not know how to interpret ecological data. Second, measuring chemical concentrations is often easier, quicker and less labour intensive than measuring ecological features. Third, measuring chemicals has often been portrayed as being more rigorous, even more "scientific', than measuring ecological responses.

Yet the proposed EU Water Framework Directive focuses on defining ecological status and requiring action on this basis. Notwithstanding the obvious logic in focusing on the effects rather than just on causes, there have been concerns expressed from both industry and environment group perspectives. The former fear increased uncertainties and costs associated with the new approach; the latter fear that the uncertainties might lead to less stringent controls.

In his presentation, Prof. Calow discussed what ecological effects the pWFD should be aiming to address; which it actually addresses; where the ecological problems might be; and what its implications would be for the food industry. He noted that pWFD also incorporates some causally-based criteria in terms of general physico-chemical requirements and some specific environmental quality standards (e.g. chemical concentrations), which also were briefly discussed.

Ecological systems

There can be sustainable yields of biomass from natural populations (e.g. in terms of fish and lumber). This implies that populations can be protected in a sustainable way without protecting all individuals within them. This is one reason ecological harm is judged in terms of collective groups of individuals, either of the same species (populations) or different species (communities), not just individuals.

* No citations are given, but a supporting bibliography can be found in: Calow P. (1997) *Controlling Environmental Risks from Chemicals*. Wiley, Chichester.

Defining harm for populations is relatively straightforward; they are harmed when their size is reduced to an extent from which they cannot recover, so they become extinct. Defining harm for species groups (communities/ecosystems) is more problematic. Whereas there are natural faunas and floras characteristic of particular places, they are not very precisely defined; and species within these communities do not work together for some common good. This implies that we cannot define ecological quality as some intrinsic property of a natural community. Another way of approaching this is anthropocentrically: what features of communities are necessary to deliver the services from ecosystems upon which we depend? Unfortunately, again these are not very precisely defined, not just because our understanding is limited, but because there can be redundancy in the relationship between species composition and both stability (in structure and process) and ability to process energy and matter that are at the basis of ecosystem processes and services.

Under these circumstances a pragmatic approach is to define quality in terms of what species are present under pristine conditions, and this is the kind of approach adopted by pWFD (see below). There are at least two challenges associated with this:

1) Finding "pristine conditions" in the first place will often involve compromise and judgement, and
2) Natural variability, both deterministic (e.g. through seasons) and stochastic (e.g. due to weather), will tend to obscure patterns.

What the proposed Water Framework Directive seeks to do

The overall purpose of the pWFD is to establish a framework for the protection of natural waters (inland waters, groundwater, estuaries, coastal waters) that uses both ecological status and physico-chemical criteria. Ecological status will be defined by comparison with reference sites that are considered representative of fauna and flora of particular eco-regions. For comparability a framework for the kinds of measurement that should be made is defined within an Annex to the pWFD (Annex V, at the time of writing). It will, nevertheless, be for competent authorities within member states to define detailed criteria, though there is provision for "intercalibration" between member states that will be facilitated by the European Commission. The Annex largely focuses on biological criteria, flora and fauna, but also specifies general physico-chemical conditions. The ecological criteria will involve taxonomic composition, population abundance/biomass, presence of sensitive species and, where relevant, age-structure of phytoplankton, macrophytes, benthic invertebrates and fish.

There are also provisions for specific measures against individual pollutants or groups of pollutants presenting unacceptable risks. There will be a priority list, and for substances on the list the Commission will define quality standards (both the list and EQSs to be defined in another Annex to the pWFD, i.e. Annex X, at the time of writing). This is the standard cause-based approach and though undoubtedly there will be much discussion about substances on the list and the concentrations that are deemed appropriate as quality standards, little more will be written about them here.

All the foregoing will be carried out on a river basin basis, with river basin management plans aimed at achieving the target ecological status through appropriate controls on both point and diffuse sources of contamination. There is also an explicit requirement to encourage active involvement of all interested parties in implementing the pWFD, and public consultation is actively encouraged.

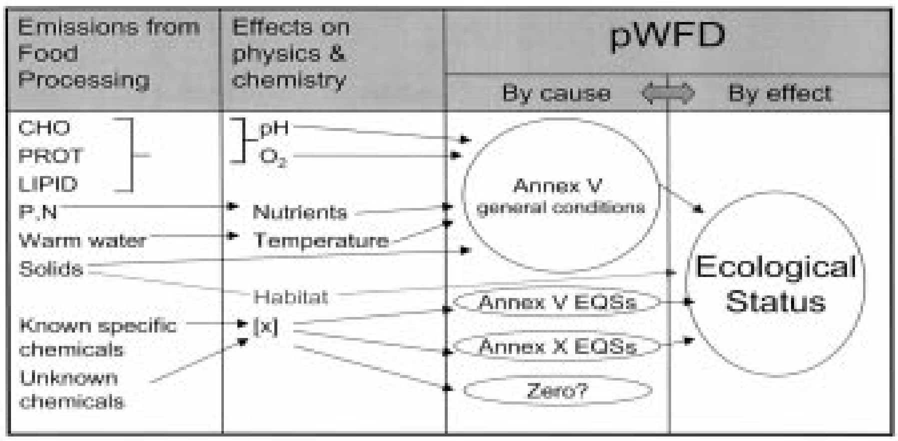
Some ecological challenges

On the presumption that relatively unimpacted sites can be located, the aim will be to compare the ecological status (in terms of the criteria defined in Annex V) representing "good" conditions (call it *x*) with the state at other sites (call it *y*). The comparison might then simply be *y/x*. However, this is deceptively simple since both *y* and *x* will be subject to variability (i.e. $y \pm w$; $x \pm z$) so whether we can distinguish between *y* and *x*, even if they are different, will depend upon the extent of the variability and the sampling design used in the work. Defining the level of sampling effort needed to achieve appropriate power (probability of finding a difference when there is one) will be important, and the amount of effort, given possible levels of variability in what are naturally dynamic systems (e.g. rivers and estuaries), is likely to be non-trivial. Responsibility for this will presumably be with the regulatory and competent authorities, but in situations of dispute others may also have to be involved.

Implications for the food industry

Table 2 summarises some of the relationships between food industry emissions and controls written into the pWFD.

Table 2. Some possible links (indicated by arrows) between common emissions from food processing (where CHO = carbohydrates, Prot = protein), effects on physiochemical properties of receiving environments and on aspects controlled under the proposed Water Framework Directive (pWFD).



Traditionally the food industry has been most concerned about emissions of "natural organics', especially carbohydrates and lipids, and nutrients. From a regulatory perspective these have been controlled relative to their effects on biochemical oxygen demand (BOD), pH and nutrient loadings. Any known anthropogenic chemicals in emissions, e.g. pesticides in washings from produce, have also been subject to controls in terms of quality standards.

The pWFD incorporates these kinds of controls in both Annex V and X provisions, but by further incorporating the ecological status of receiving water, it goes somewhat further. Any aspect of emissions that can be shown to cause a decline in ecological quality would in principle be subject to control. For example, this could involve the following:

a. Warm water emissions might lead to loss of temperature-sensitive species.
b. The release of solids could cause habitat destruction and hence species losses.
c. Chemicals, hitherto unrecognised by the producer, e.g. from washings or complex reactions in processing, could be causing ecological impairment.

d. Unknown properties of the emissions and the chemicals that they contain might be having effects at levels below the quality standards.
e. Combinations of stressors (physical and chemical) might be acting synergistically.

In principle, any or all these effects could be picked up by the effects-orientated pWFD, and if traced back to a particular industry would lead to controls over and above those associated with current environmental protection legislation.

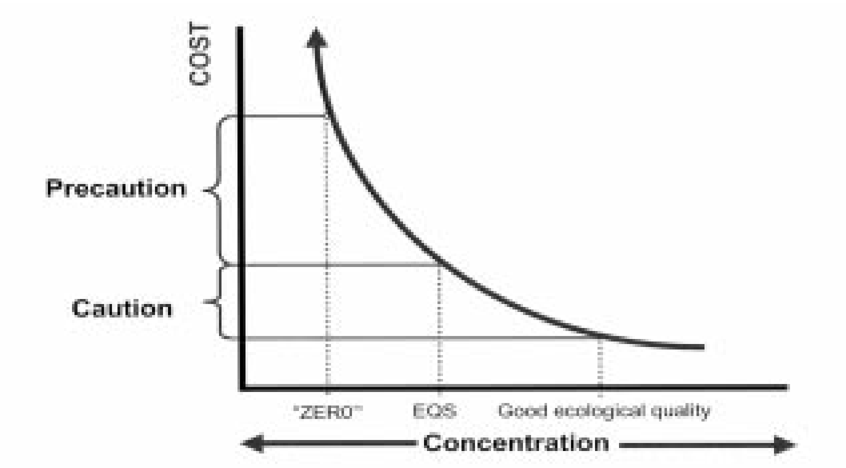
The bottom line

In principle, an effect-driven environmental protection legislation is likely to be more cost-effective than a cause-driven one. Basically, the "causes" chosen for control might be missing the point, and lead to wasted investment and wrong solutions. But still industry will be concerned if new legislation involves extra costs.

If it is done properly, there will certainly be increased costs in monitoring ecological criteria rather than just chemicals. This will be especially the case if adequate attention is given to developing monitoring programmes with sufficient power to distinguish between observed and expected ecological states. This will probably be a cost carried by society at large.

There are some reasons to believe that the costs of achieving "good" ecological quality may not be any greater than those involved in achieving environmental quality standards and certainly of achieving "zero" concentrations. Figure 1 makes the point. Because of "margins of caution" incorporated into EQSs, the concentrations to achieve good status are unlikely to be > EQSs, and will be invariably > "zero".

Figure 1. A cost effectiveness analysis of measures used to control some chemical emissions. Concentration of this chemical is depicted on the x axis and reduces to the origin. Costs of controls are representred along the y axis.



The costs of achieving lower and lower concentrations in emissions are likely to increase more and more ("law of diminishing returns"), and so the costs of caution (incorporated within EQSs) and precaution (aspiring to "zero") could be considerable. Of course if there were the kinds of effects listed in the last section, then undoubtedly these would be increased costs for industry, since new sources of problems would be uncovered. However, synergy between chemicals is not very common; and industry ought to want to know about previously unidentified causes of pollution.

REFERENCES

[1] EC (1999). Common Position (EC) 41 / 1999 of 22 October 1999 adopted by the Council, acting in accordance with the procedure referred to in Article 251 of the Treaty establishing the European Community, with a view to adopting a Directive of the European Parliament and of the Council establishing a framework for Community action in the field of water policy. *OJ:* C343, 42, 30 November 1999.

[2] EC (2000). Communication from the Commission of the European Communities on the Precautionary Principle. Brussels, 2.2.2000 COM (2000) 1 final. 28pp.

[3] Feijtel, T.C.J., Boeije, G., Matthies, M., Young, A., Morris, G., Gandolfi, C., Hansen, B., Fox, K., Holt, M., Koch, V., Schroder, R., Cassani, G., Schowanek, D., Rosenblom, J. and Niessen, H. (1997). Development of a Geography-referenced Regional Exposure Assessment Tool for European Rivers – GREAT-ER. *Chemosphere*, 34, 2351-2373.

[4] Hutchinson, T. H., Scholz, N. and Guhl, W. (1998). Analysis of the ECETOC Aquatic Toxicity (EAT) database: IV – Comparative toxicity of chemical substances to freshwater versus saltwater organisms. *Chemosphere*, 36, (1), 143-153.

Acknowledgement

ILSI Europe would like to thank Prof. Peter Calow, University of Sheffield (UK) for offering the summary lecture, Dr. John Solbé, Unilever Research (UK), for authoring this summary report, and Prof. Davide Calamari, University of Insubria (I), Mr. John Fawell, Warren Associates (UK) and Mr. Martin Holt, ECETOC (B) for reviewing this report.

ILSI Europe Report Series

The following titles are available in the series:

Approach to the Control of Entero-haemorrhagic *Escherichia coli* (EHEC), 2001
36pp, ISBN 1-57881-119-8

Method Development in Relation to Regulatory Requirements for the Dectection of GMOs in the Food Chain, 2001
26 pp. ISBN 1-57881-122-8

Markers of Oxidative Damage and Antioxidant Protection: Current status and relevance to disease, 2000
24 pp. ISBN 1-57881-102-3

Overweight and Obesity in European Children and Adolescents: Causes and consequences – prevention and treatment, 2000
24 pp. ISBN 1-57881-103-1

Packaging Materials: 1. Polyethylene Terephthalate (PET) for Food Packaging Applications, 2000
16 pp. ISBN 1-57881-092-2

Salmonella Typhimurium definitive type (DT) 104: A multi-resistant *Salmonella,* 2000
24 pp. ISBN 1-57881-094-9

Threshold of Toxicological Concern for Chemical Substances Present in the Diet, 2000
24 pp. ISBN 1-57881-101-5

Detection Methods for Novel Foods Derived from Genetically Modified Organisms, 1999
24 pp. ISBN 1-57881-047-1

Overview of Health Issues Related to Alcohol Consumption, 1999
16 pp. ISBN 1-57887-068-X
(Translations available in Chinese, French, German, Portuguese and Spanish)

Safety Assessment of Viable Genetically Modified Micro-organisms Used in Food, 1999
20 pp. ISBN 1-57881-059-0 (Translation available in Japanese)

Significance of Excursions of Intake above the Acceptable Daily Intake (ADI), 1999
24 pp. ISBN 1-57881-053-1

Validation and Verification of HACCP, 1999
20 pp. ISBN 1-57881-060-4

Addition of Nutrients to Food: Nutritional and Safety Considerations, 1998
24 pp. ISBN 1-57881-036-1

Food Safety Management Tools, 1998
20 pp. ISBN 1-57881-034-5

Recycling of Plastics for Food Contact Use, 1998
20 pp. ISBN 1-57881-035-3

Applicability of the ADI to Infants and Children, 1997
20 pp. ISBN 1-57881-018-3

Antioxidants: Scientific Basis, Regulatory Aspects and Industry Perspectives, 1997
28 pp. ISBN 1-57881-016-7

An Evaluation of the Budget Method for Screening Food Additive Intake, 1997
12 pp. ISBN 1-57881-019-1

Food Consumption and Packaging Usage Factors, 1997
12 pp. ISBN 1-57881-017-5

Food Additive Intake – Scientific Assessment of the Regulatory Requirements in Europe, 1995
13 pp. ISBN 1-57881-032-9

The Safety Assessment of Novel Foods, 1995, *reprinted 2001*
16 pp. ISBN 1-57881-033-7

ß-Carotene, Vitamin E, Vitamin C and Quercetin in the Prevention of Generative Diseases – The role of foods, 1995

Report Series Editor: Dr. Kevin Yates

ILSI

International Life Sciences INSTITUTE

The International Life Sciences Institute (ILSI) is a nonprofit, worldwide foundation established in 1978 to advance the understanding of scientific issues relating to nutrition, food safety, toxicology, and the environment. By bringing together scientists from academia, government, industry and the public sector, ILSI seeks a balanced approach to solving problems of common concern for the well-being of the general public.

ILSI is affiliated with the World Health Organization as a non-governmental organisation and has specialized consultative status with the Food and Agricultural Organization of the United Nations.

Headquartered in Washington, D.C. USA, ILSI has branches in Argentina, Australasia, Brazil, Europe, India, Japan, Korea, Mexico, North Africa and Gulf Region, North America, North Andean, South Africa, South Andean, Southeast Asia, Thailand and a focal point in China.

ILSI Europe
Avenue E. Mounier, 83, Box 6
B-1200 Brussels
BELGIUM
Telephone: (+32) 2 771 0014
Telefax: (+32) 2 762 0044
E-mail: publications@ilsieurope.be

ISBN 1-57881-121-X
9 791578 811211