Commission of the European Communities

environment and quality of life

WATER QUALITY CRITERIA IN ENVIRONMENTAL MANAGEMENT

Report

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CONTENTS

SUMMARY

The perception of the harm caused to natural environments which occurred in the sixties has made it necessary for the political and legislative authorities of industrially developed countries to introduce or renew regulations to protect the environment.

This report examines what is actually necessary for the definition, on a scientific basis, of regulatory actions that operate effectively for the control and prevention of water pollution.

It has been considered desirable to summarize in table form the water quality criteria for some water uses, so that they can be readily compared, issued by international authorities such as the European Community, the World Health Organization, the United States Environmental Protection Agency, the Food and Agriculture Organization of the United Nations, and Inland Waters Directorate of Canada.

With regard to pollution of inland waters in Italy, some possible future research lines are identified and discussed in detail.

An analysis of how scientific knowledge has been used up to now has been made with the intention of verifying how further development may help to improve the present method for control of pollution and in order to show the concrete role that science can play in this process.

Figure captions

Table captions

1. PROBLEMS IN THE DEFINITION AND FOR THE APPLICATION OF WATER QUALITY CRITERIA

The most common definition of water pollution is: "The discharge by man, directly or indirectly, of substances or energy into the aquatic environment, the results of which are such as to cause harm to living resources, hazards to human health, damage to amenities or interference with other legitimate uses of water" /1/.

Water pollution is considered as a limitation to possible uses and, therefore, quality criteria have been formulated in function of various uses. Over the years, however, the definitions of quality criteria were rejected for uses requiring not high quality of water and four main uses were taken into consideration: potability, agricultural, bathing and amenities, aquatic life. Since for potable waters the hygienic and sanitary aspects request a specific scientific and regulatory approach and agricultural and esthetic uses are generally less demanding, the practice of considering the quality criteria for aquatic life as the most important in planning environmental policy, with the necessary exceptions, has developed.

In the recent past years, the opinion has been diffused and consolidated that an aquatic ecosystem in which structures and functions are not disturbed certainly possesses in every moment a water quality that is immediately suitable or suitable after simple treatment for a variety of uses. This concept, together with the one by which every recipient body has a certain capacity to receive contaminants, has been the basis for the definition of quality criteria for aquatic life by different international and national organizations. In fact, it may be presumed that for each pollutant there is a margin of safety between zero level or the natural concentration and that concentration in which observable and undesirable disturbances may occur. This margin can be identified and quantitatively utilized.

The fundamental point of departure in evaluating criteria for water quality is that the assignment of a level of quality is relative to the use man makes of that water. To evaluate the quality of water required for various uses, it is essential to know the limits of quality that have a detrimental effect on a designated use. As a corollary, in deciding whether or not water will be of suitable quality, one must determine whether or not the introduction into, or the presence of any material in the resource interferes with, alters, or destroys its intended use.

The distinction between criteria and standards is important, and the words are not interchangeable nor are they synonyms for such commonly used terms as objectives or goals.

- The term 'standard' applies to any definite rule, principle or measure established by authority. The fact that it has been established by authority makes a standard somewhat rigid, official, or quasi-legal; but this fact does not necessarily mean that the standard is fair, equitable, or based on sound scientific knowledge, for it may have been established somewhat arbitrarily on the basis of inadequate technical data tempered by a caution factor of safety. Where scientific data are sparse, such arbitrary standards may be justified.
- The word 'objective' represents an aim or a goal toward which to strive and it may designate an ideal condition. Most certainly, however, it does not imply strict adherence nor rigid enforcement by an agency or health department. It is gaining favour among engineers on boards and commissions who strive to achieve water pollution control by persuasive methods and cooperative action.
- A 'criterion' designates a condition defined by means of a critical review on scientific information and suitable to conserve structures and functions in the ecosystems. Unlike a standard it carries no connotation of authority other than that of fairness and equity; nor does it imply an ideal condition /2/.

As a clarification of the distinction that must be recognized and the procedural steps to be followed in developing standards from criteria, a conceptual framework is presented in Fig. 1.

Two different approaches for obtaining water quality criteria have been followed by different countries:

- without taking into any consideration the type and use of the water body receiving the contaminant;
- adapting the quantity of the pollutant to the natural characteristics of the receptors (rivers, lakes, coastal waters) and taking into account the characteristics of the pollutants (toxicity, persistence, bioaccumulation).

The first approach, which requires a uniform quality from any type of discharge (rigid effluent standards) no matter what the destination

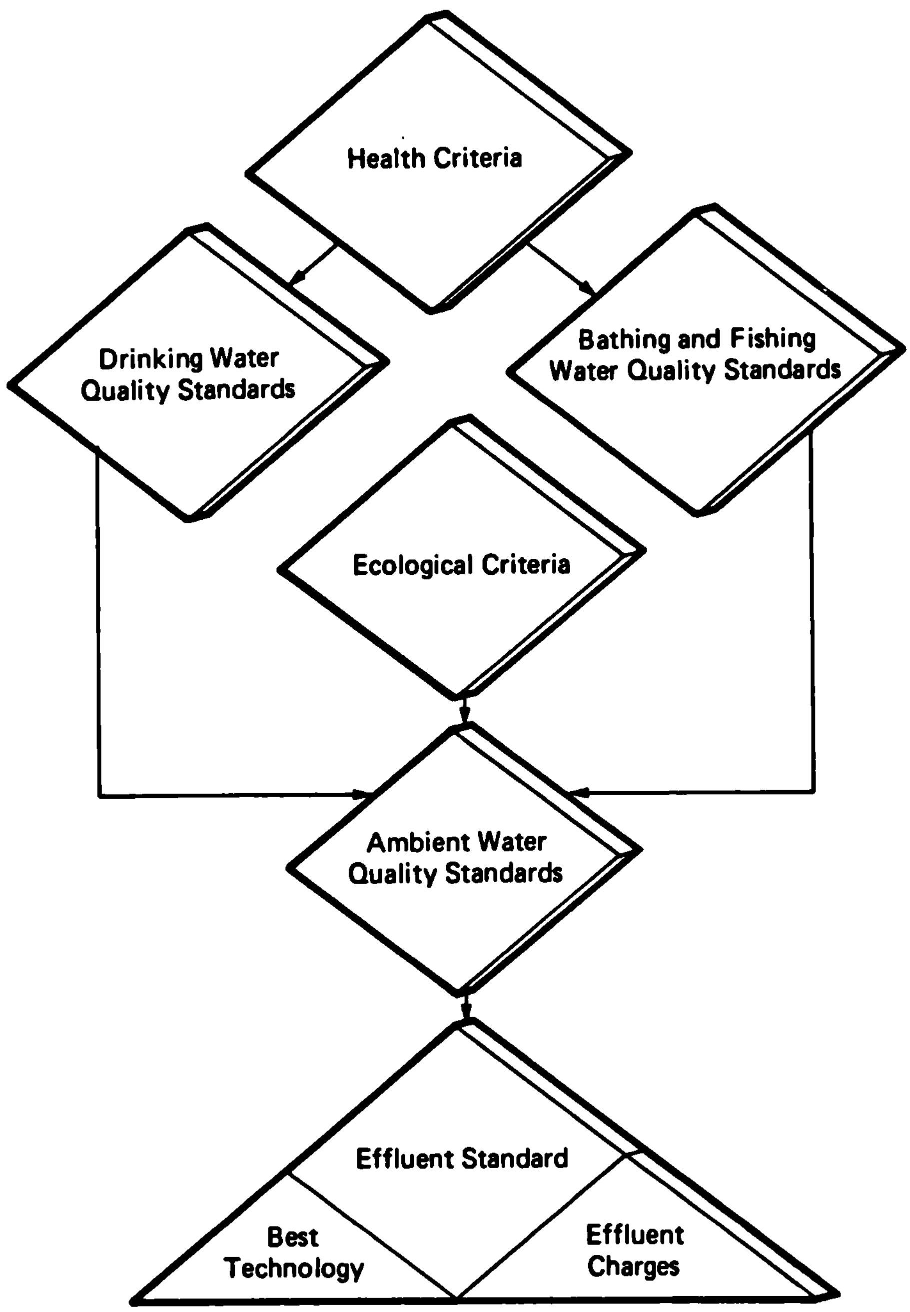

Fig. 1 Dependence of water quality standards. (29)

might be, must necessarily be very restrictive in order to be effective as it must protect with a single regulation even the most critical situations. As a result, in many cases, the application of this criterion can lead to the requirement of a higher level of restoration than is actually necessary in the situation considered, and hence to excessive and unnecessary cost.

More permissible limits, if on the one hand being more economical, on the other may lead to a reduction in the level of protection. In fact, this procedure does not include - by definition - the quantity of pollutant discharged over a period of time, nor the number of discharges ending in the same receptor, nor does it take into account the capacity of assumption of the receptor. The main advantage lies in the facility of administrative management.

The second approach, on the other hand, appears to be excellent from many points of view, especially because it requires case by case a treatment level which is suitable to the receptive capacities and to the use for which the water is to serve (flexible effluent standards). This procedure, therefore, is considered as the most economical, offering the highest reliability as regards the protection of the environment.

On the basis of these premises, it might be concluded that of the two approaches, the second is certainly to be preferred in the setting up of regulatory action for the acceptability of effluents, but this conclusion, if perfectly valid theoretically, would be difficult to apply from the practical point of view. In fact, the knowledge of a number of basic elements is requested:

- knowledge of the receptive capacity of the water body: such knowledge implies a thorough study case by case of the typology of the receptor, of its hydrological balance with particular reference to the critical flow, of its actual dilutant/capacity, its oxidizing capacity, its chemistry, its biological structure, its thermic variations, its relationship with underground waters, the pre-existence of other sources of pollution and all other factors that can influence the actual maintenance of a safe concentration of the pollutant discharged;
- knowledge of the development in the course of time of the sources of pollution: this last requirement involves information on population characteristics, lines of urban and industrial development, etc., which

should be solved in detail in accordance with the variety of local situations - and obviously - within the framework of general economic planning. Actually, however, in many countries an intermediate approach was followed. This procedure allows an adaptation for the effluents standards to the typology of receptors and groups of pollutants.

Over the past years a tendency has been established to consider the subject case by case, to separate the ways of operating on different kinds of pollutants, to set up different criteria for receptors with different characteristics. Typical in this matter are the regulations and different scientific background for mercury and phosphorus; or among the regulations concerning fresh water, the differences existing between flowing water and lakes and marine waters. It is also to be remembered that the classification of certain substances in a "black list" and a "grey list" is commonly accepted. The "black list" includes substances not to be discharged and not to be used. In the "grey list", there are instead those substances which may be discharged within certain limits and under controlled conditions.

Toxicity is another much misunderstood and misused term. Many pollution control laws state that no toxic materials shall be added to a stream. Experience has shown that this is not enforced, due in large part to its ambiguity. Waste dischargers point out that certain potential toxicants are already present at low concentrations in many receiving waters and they inquire as to why they must entirely remove these toxicants from their wastes before discharging them to a stream. Toxicity is a quantitative term. The mere presence of a potential toxicant does not necessarily create pollution. Materials become toxic only when their concentration, coupled with a time of exposure, exceeds a certain level. Mostly any material becomes toxic if it is present in excessive amounts. A good example of this, which made headlines some years ago, was the mistaken addition of salt instead of sugar to the babies' formulas in a hospital. Salt, universally used as a food item, in this instance became toxic when too much was added. Furthermore, many of the materials which are considered extremely toxic, are needed in trace amounts for life. Selenium, for example, is essential in the human body but becomes harmful or toxic when its concentration exceeds a certain level.

The same is true of copper, zinc, manganese, boron, molybdenum, silicon, sodium, iodine, magnesium, iron, potassium, sulphur, and phosphorus. All these materials can be toxic when present above certain concentrations, but their presence in low concentrations is essential for life.

It should be clearly understood that water quality criteria for different water uses may differ widely. What may constitute pollution for one use may be beneficial for another use and have no effect on a third use. For example, the organic enrichment of a lake could result in increased production of algae and other organisms in the food chain of fishes which would be desirable from the fisherman's standpoint. However, increased growth could be undesirable from the standpoint of bathers or boaters. Organic enrichment can very easily be carried too far because when too much of such materials is added, dissolved oxygen is lowered or depleted in some areas and pollution results. In the same way, if you add too much fertilizer to your lawn you kill rather than help the grass. Similarly, some trace elements are needed for growth but when present above certain levels they become toxic. Therefore, the approach to this problem would be not to exclude all organic enrichment or toxicants but to say that the concentration of these materials and potential toxicants shall not exceed the maximum level which is not harmful under conditions of continuous exposure. These levels are water quality criteria.

What is the need for and the value of water quality criteria? As has been stated before, if we are to re-use our fresh waters effectively and efficiently, each user must return his used water to its source or to another waterway in such condition that the receiving water is not rendered unsatisfactory for a desired use or uses. To do this economically, he must know the water quality requirements for each of those desired uses, for how else can he meet the requirements or know if or how much he should treat his waste.

2. WATER USES AND RELEVANT QUALITY CRITERIA

The first step in setting consent conditions for a discharge is to state objectives for the receiving water in terms of the uses to which the water is to be put. For each use it is necessary to define a standard to protect that use. In a body of water subject to more than one use, the most stringent standard applies. Each standard applies at the point of use, but may involve the limitation of a discharge at a considerable distance from the point of use. Apart from reservoirs, for which it can attribute - case by case - a particular kind of prevailing use (potable, agricultural, industrial, etc.), natural waterbodies can be used for multiple purposes, much of which require particular qualitative characteristics.

2.1 Potable use

Although the major percentage of water for drinking purposes is coming from ground or spring sources, it is expected for the future an increase of water abstraction from surface sources because of increasing demand associated with population growth and new habits and requirements (Table I and II).

The Council of Ministers of the European Communities has adopted on June 30, 1980, the directive relating to the quality of water for human consumption. This adoption is considered as a very important step, since agreement has been reached between 9 Member States on 62 parameters, their numerical values and their monitoring /3/. The 62 parameters selected for standards, its classification, and 4 types of analysis of these standards are shown in Tables III to X. The Guide Levels (GL) chosen represent target quality objectives. Most of the standards defined by the directive are listed in the first two numerical columns of Tables XI and XII.

Guidelines for drinking water quality, developed by WHO /4/ are summarized in Tables XIII - XVII. These guidelines are intended to supersede both the European standards for drinking water /5/ and the international standards for drinking water /6/ which have been in existence for over a decade.

2.2 Irrigation use

Irrigation is one of the largest consumers of water for agricultural use. Polluted waters can be detrimental to animal health and to the safety and value of agricultural products. Plants may be adversely affected directly by either the development of high osmotic conditions in the plant substrate or by the presence of a phytotoxic constituent in the water. The presence of sediment, pesticides or pathogenic organisms in irrigation waters, which may not specifically affect plant growth, can affect the acceptability of the product.

Water quality characteristics for irrigation can be defined taking into account the following items:

a) Crop tolerance to salinity: The effect of salinity, or total dissolved solids (TDS) on the osmotic pressure of the soil solution is one of the most important water quality considerations. This relates to the availability of water for plant consumption. Table XVIII presents recommended guidelines for salinity, proposed by USEPA /7/.

b) Sodium concentration in relation to divalent cations: Sodium in irrigation waters may become a problem in the soil solution as a component of total salinity, which can increase the osmotic concentration, ana as a specific source of injury to fruits. Since adsorption of sodium from a given irrigation water is a function of the proportion of sodium to divalent cations (calcium and magnesium) in that water, sodium hazard is evaluated as the sodium adsorption ratio (SAR)

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \quad \text{expressed as meq/litre}$$

In Fig. 2 the classification of water quality is shown based on the SAR and electrical conductivity values, according to the U.S. Department of Agriculture /8/.

c) Phytotoxic trace elements: Since no EC directive has been adopted up to now, indicative values for trace element concentrations for irrigation waters are shown in Table XIX. In addition, the US Department of Agriculture has suggested a classification scheme, that

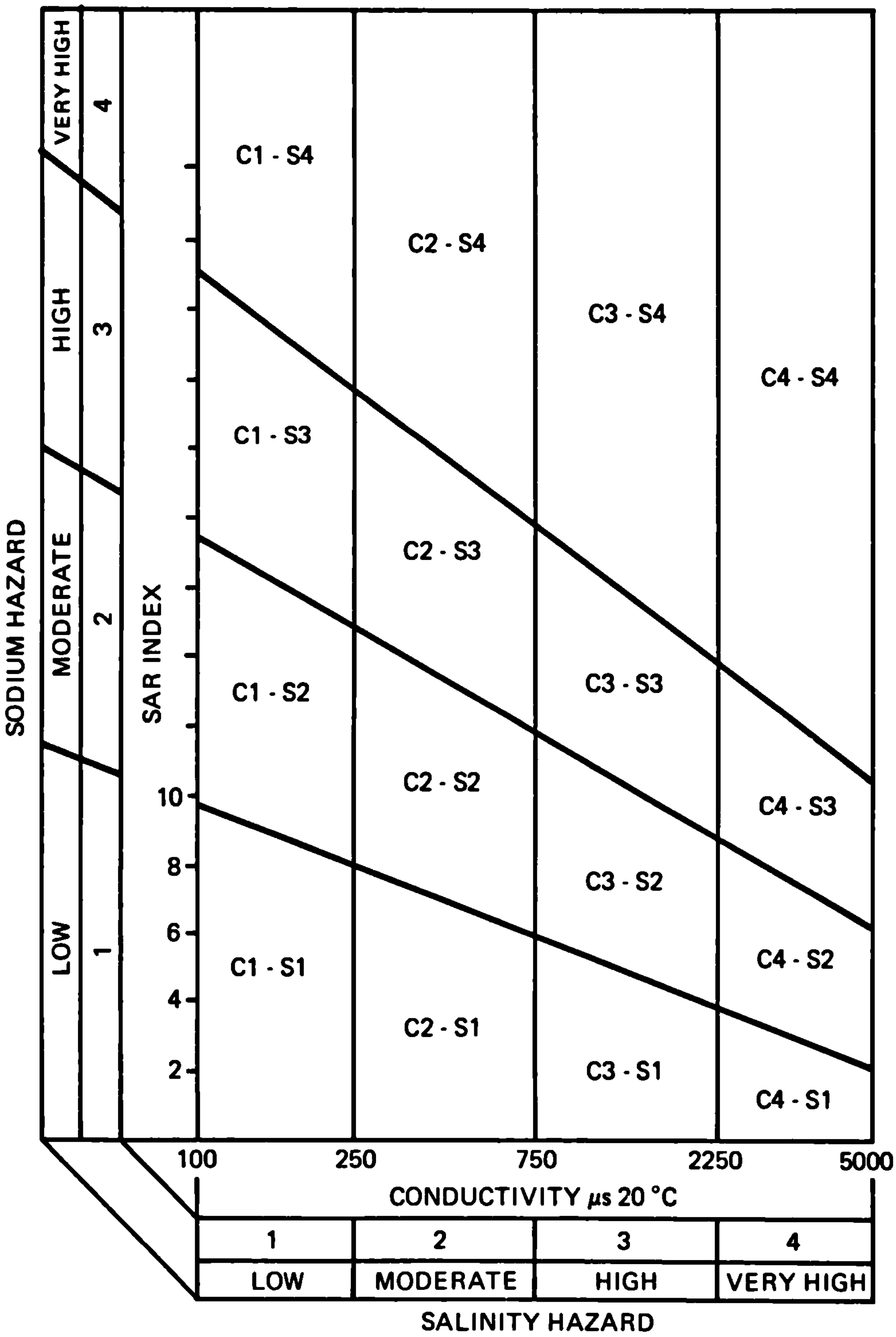

Fig. 2 Classification of irrigation waters related to the SAR index and conductivity. /30/

subdivides irrigation waters into three classes in function of some particular chemical parameters (Table XX).

2.3 Industrial use

Industry's use of water is either direct in productive processes or indirect in cooling and washing treatments. Table XXI summarizes water quality criteria for process waters of major industries. Because of the diversity of industrial water quality requirements, it is evident that no natural water can be utilized without preventive treatment, in some cases even too excessive. With regard to waters used for cooling purposes, the parameter usually considered is Langelier index or index of saturation (I_L), that measures aggressive and fouling characteristics of water on concrete manufactured goods.

2.4 Recreational and aesthetic use

The many factors that influence the recreational and aesthetic value of water may be broadly grouped into two categories: physical and biological. Physical factors include geography, management and land use practices, and carrying capacity. The carrying capacity of a body of water for recreation is not a readily identifiable finite number. It is a range of values from which society can select the most acceptable limits as the controlling variables change. The schematic diagram (Fig.3) provides an impression of the number of relationships involved in a typical water body recreation system. Recreational carrying capacity of water is basically dependent upon water quality but also related to many other variables as shown in the model. At the threshold level a relatively small decline in water quality may have a considerable effect on the system and result in a substantial decline in the annual yield of water-oriented recreational opportunities at the sites affected. Biological factors involve the effects of nuisance organisms and eutrophication, species diversity and the introduction of exotic species.

In making water quality recommendations for these uses of water we cannot but examine the fact that recreation and aesthetics are related to any of the major concerns of living: work and education, social duty, or bodily needs. Consequently, criteria for recreational and aesthetic

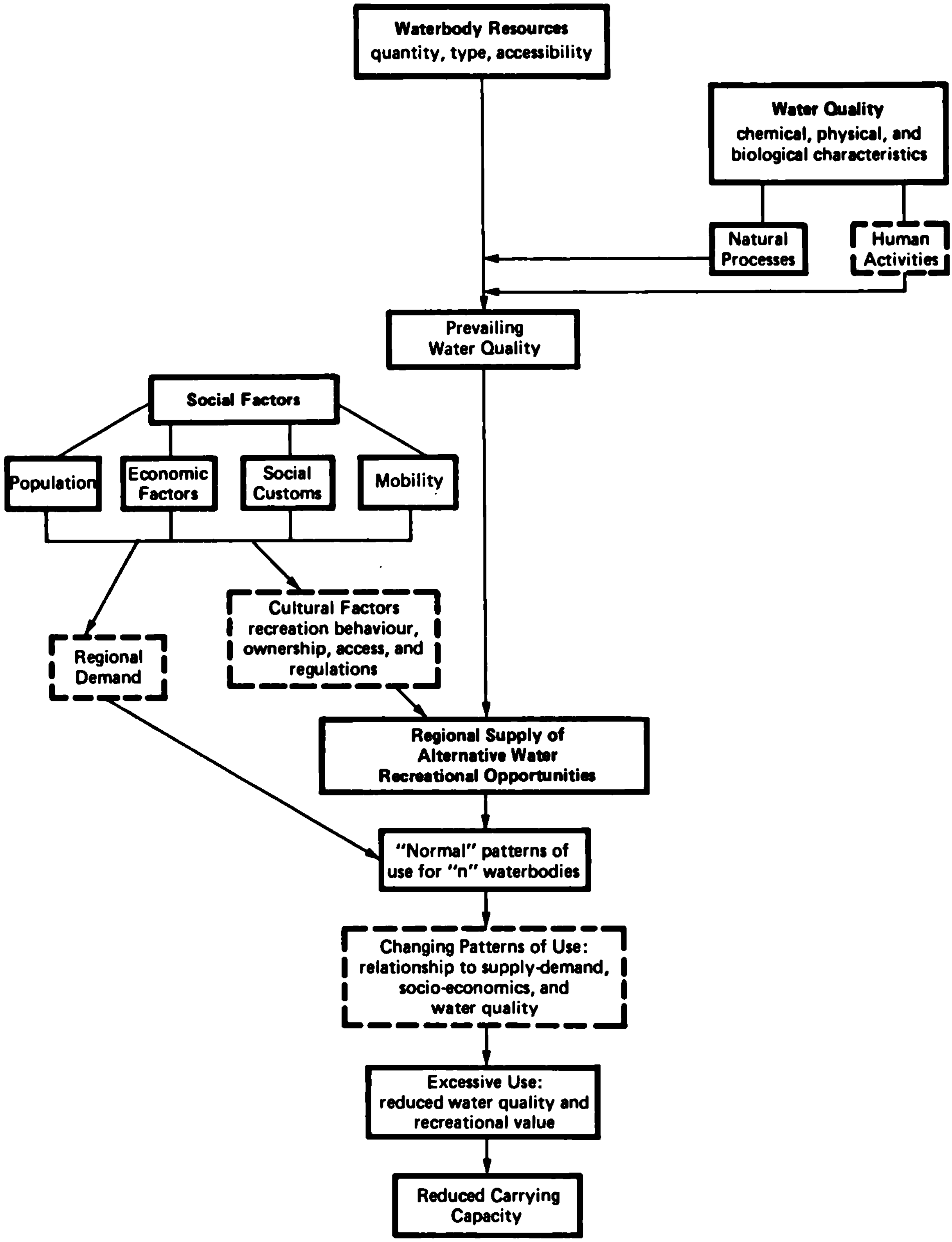

Fig. 3 Relationships involved in a water resource recreation system. /9/

values of water resources are essential descriptive recommendations rather than specific numerical limits because of the varying acuteness of sensory perception and because of the variability of substances and conditions so largely dependent on local conditions. Water quality requirements for bathing are exceptions (Table XXII).

USEPA recommendations /9/ for recreational and aesthetic uses are: surface waters will be aesthetically pleasing if they are virtually free of substances attributable to discharges or waste as follows:

- materials that will settle to form objectionable deposits;
- floating debris, oil, scum, and other matter;
- substances producing objectionable colour, odour, taste, or turbidity;
- substances and conditions or combinations thereof in concentrations which produce undesirable aquatic life.

2.5 Criteria for preserving aquatic life

The natural aquatic ecosystem includes many kinds of plants and animals that vary in their life history and in their chemical and physical requirements. These organisms are interrelated in many ways to form communities. Aquatic environments are protected out of recreational and scientific interest, for aesthetic enjoyment and to maintain certain organisms of special significance as a source of food.

There are two schools of thought as to how this can be accomplished. One is to protect the significant species, the assumption being that by doing so the entire system is protected. The other approach is to protect the aquatic community, the assumption being that the significant species are not protected unless the entire system is maintained.
In Tables XXIII and XXIV water quality criteria are summarized for protection of aquatic life adopted by the European Community, the U.S., EPA, FAO and Inland Waters Directorate (IWD) of Canada. Table XXV reports integrated criteria from previous tables. Numerical values of water quality criteria apply either to running or lacustrine waters, with the exception of total P concentration, the key element in determining trophic level in lakes. Criteria reported in Table XXV have to be considered with reference to imperative limits such as minimum required

concentrations to reach in short periods, while guide levels represent target quality objectives, addressed to the protection of the entire aquatic life. Finally, Table XXVI summarizes environmental quality standards for some List II substances, with reference to hardness, which are required to support fish and other freshwater life.

2.6 Criteria for multiple use of the surface water resource

It is recognized that consideration must be given to the multiple use requirements placed on our water resources, although in this report the uses have been arranged in a certain sequence, but this does not imply any comment on the relative importance of each use. Each water use plays its vital role in the water systems and political, economic and social considerations that vary with historical periods and geographic locations have brought particular water uses to positions of preeminent importance.

In the Western world, the available water is predominantly used for agriculture, industry and production of energy and only a small proportion for domestic purposes. In the developing countries, most of the available water is used for agriculture, but the development of industry is extremely important in the framework of economic self-reliance (Fig. 4). However, domestic water supply, in spite of a small part of the total need, is of equal importance.

The designation of one water use as more vital than another is impossible. There is no balanced priority formula, even if one must realise that man can survive

- 5 minutes without air;
- 5 days without water;
- 50 days without food,

and that perhaps drinking water systems should enjoy priority above agriculture. Furthermore, we must not even restrict our thinking to present concepts and designated uses. Those concerned with water quality must envisage future uses and values that may be assigned to water resources and recognize that man's activities in altering natural aquifers may one day have to be more vigorously controlled.

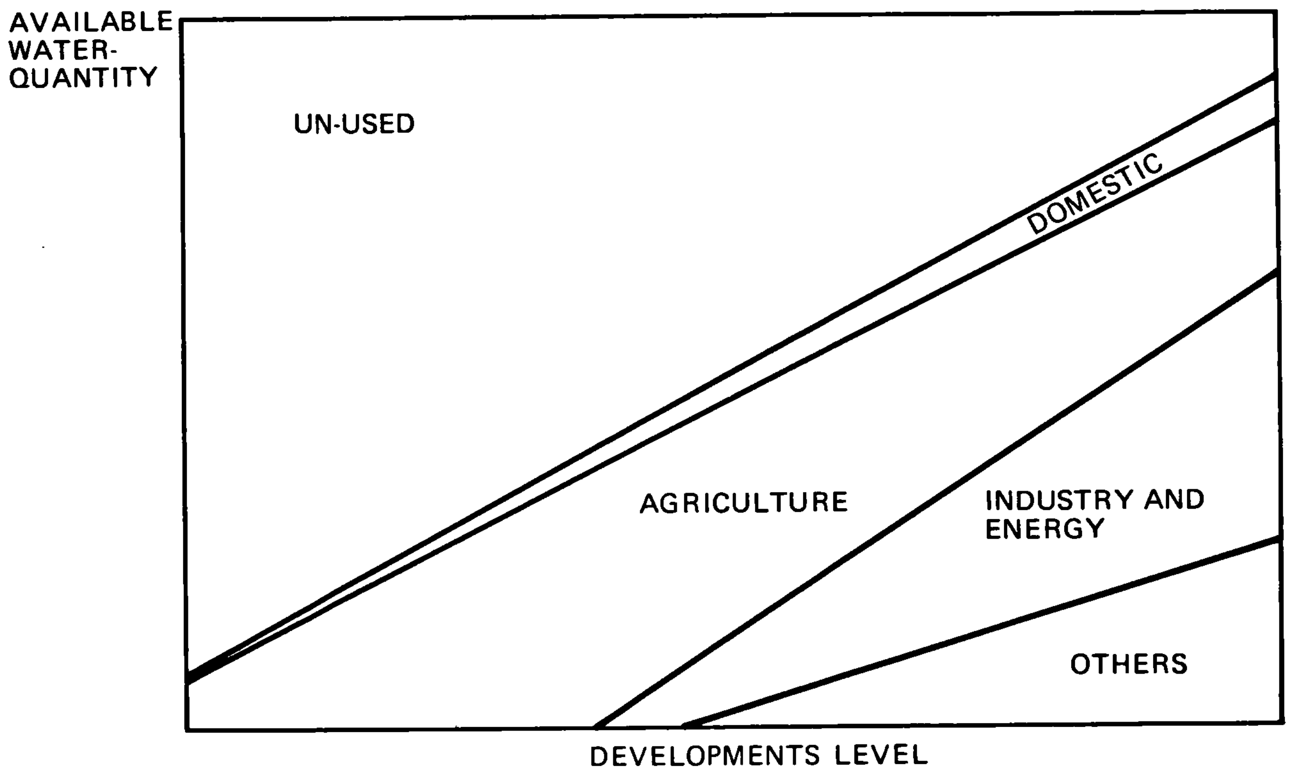

Fig. 4 **Development pattern of water consumption. /31/**

A rank classification of surface resources for multiple uses of water has been recently adopted in water management plan of Lombardia Region /10/, as follows:

Category	Water allowable use
A	drinking water supply, class 1*, conservation of natural environment***, and uses listed in B-D.
B	drinking water supply, class 2*, fishery class 1**, conservation of natural environment***, bathing and uses listed in C-D.
C	drinking water supply, class 3*, fishery class 2**, conservation of natural environment***, and uses listed in D.
D	fishery class 2**, agriculture and industrial uses, absence of acute toxicity with reference to aquatic life****.
I	no use, except navigation (polluted waters).

Explanatory notes:

* - drinking water supply class 1: simple physical treatment and disinfection required (A1/EEC)

- drinking water supply class 2: normal physical treatment, e.g. decantation and filtration (A2/EEC)
- drinking water supply class 3: intensive physical and chemical treatment, extended treatment and disinfection (A3/EEC)

** - fishery class 1: salmonid waters

- fishery class 2: cyprinid waters

*** For conservation of natural enviroment it is understood the preservation of ecological characteristics inherent of the waterbody for natural factors, but that can however require different qualitative characteristics of the water.

**** Raw samples from waterbodies must allow survival (in areating conditions) of at least 90% of animals, used for toxicological tests for 96 hr at 15°C. Test species must be Salmo gairdnerii Rich. as required by Italian law /11/.

Table XXVII presents water quality objectives relating to multiple use of surface resources. Water qualitative characteristics of a given waterbody will pertain to a class of multiple use when in the 90% of cases the values of each parameter will result not higher than or out of the limit values of Table XXVII and in the remaining 10% of cases the values will not be different from the limits more than 20%.

3. OUTLINE OF THE ITALIAN INLAND WATERBODIES

This paragraph summarizes briefly water quality in surface systems, with reference to lentic waterbodies. A lot of investigations, carried out by the Institute of Water Research (IRSA) on natural lakes and reservoirs, representing more than 90% of water resources on volumetric basis, outlined a general framework about the present water quality characteristics in Italy /12/. Seven main Italian lakes (Garda, Maggiore, Como, Bolsena, Iseo, Bracciano, Orta) are included in this description; they count for 97% of the total volume of all lakes considered (166). With the exception of lakes Iseo and Orta, they are subject to purposes of drinking water supplies. The other identified uses of water resource have been energy production (62), irrigation (5) and industrial (2).

3.1 General chemical characteristics

Table XXVIII reports average values of some chemical parameters for the most important lakes. As a general rule, on the basis of their ionic composition, Italian lakes can be classified as calcic-bicarbonate waters, with the exception of vulcanic lakes Bolsena and Bracciano. On the basis of data relative to the sixties and seventies, it has been possible to analyse the variation of hydrochemical characteristics of some Italian lakes. As a general consideration it can be observed that:

i) minimal differences are present in major lakes, while significant changes have been revealed in small lakes;
ii) Na, K and chlorides are increased more than alkalinity and electrical conductivity values;

iii) relevant increase of sulphate concentration has been measured in lake Orta.

3.2 Toxic factors; trace elements (Table XXIX)

High concentrations have been measured for some trace elements in lake Orta (Cd, Cr, Cu). Ni has been only recognized in lake Maggiore (2.6 μg/l). Co and Hg have been always recorded to levels lower than detection limit of the analytical method. Generally, checked values are not such so as to cause accumulation phenomena in food chains, inhibition of algal productivity and deterioration of biological cycles.

It has been recently stated that on the basis of general hydrochemical conditions, the quality of lake waters provides reasonable protection for desired beneficial uses, excluding lake Orta in which Cu concentrations are so high that they exceed the toxicity thresholds for numerous living organisms, in concomittance with acid pH values, extremely critical /13/.

Similar conclusions have been achieved from a recent study using a sedimentological approach to evaluate the potential ecological risk in limnic systems.

The starting point was the possible mobilization of trace elements from lake sediments and its consequences on aquatic life. A summary of the results is shown in Table XXX, from which can be seen that trace metal contamination is reflected by low ecological risk factors in these environments /14/.

With regard to rivers, data for trace elements (Table XXXI) are in general low and not substantially dissimilar from those found in natural waters without any appreciable contamination /15/.

3.3 Toxic factors, organic contaminants

Little is known about the presence and distribution of organics in lakes. Fragmentary studies have been done only in the Western basin of lake Como with respect to phenols, polycyclic aromatic hydrocarbons and pesticides /16/.

3.4 Trophic conditions

The most significant water quality problem in Italian lakes is eutrophication. Such a process, whose causes and consequences are well known and sufficiently described, is considered as an undesirable modification of the aquatic environment that results in the deterioration of water quality and hinders the use of water for virtually all purposes, often producing considerable economic losses.

On the basis of average P concentrations, lentic waters can be classified as follows:

Category	Total P concentration (µg/l)
Oligotrophic	< 10
Oligo-mesotrophic	10 - 20
Mesotrophic, meso-eutrophic	20 - 50
Eutrophic	50 - 100
Hypertrophic	> 100

Table XXXII shows that, with the exception of lakes Garda and Bracciano, the most important lakes either are heavily eutrophicated or not far from eutrophication. As a general consideration it can be stated that more than 80% of natural lakes and reservoirs in Italy are in the mesotrophic and eutrophic categories.

Acting as hydrochemical and trophic characteristics of surface waters, it can outline an exemplifying sight of the present possibilities for multiple use of Italian waters (Table XXXIII). With respect to the lakes, taking into account that eutrophication is a prominent deterioration phenomenon, the assignment to one of different quality classes is fixed on total phosphorus levels. As regards natural running waters, the assignment to different quality classes is established on the basis of the parameters reported in Table XXVII.

4. FUTURE RESEARCH TOPICS

A correct environmental management must evaluate risk amount, intended as probability that some damage happens to human health, to ecological systems, resulting from the introduction of pollutants into the environment. In other words, evaluated the amount of introduced pollutants and the extent of effects, a judgement will have to be expressed on what is unavoidable and what is acceptable with respect to probable damage.

For too long we have been making surveys and resurveys and collecting and recollecting data, simply because it was customary. For too long we have been putting the data we collected into pigeon holes because it was not pertinent, did not give us the needed answers, or we did not know how to use it. We must have a research program designed and conducted to determine the quality specifications for water for all of our various uses. Such a program is basic to efficient use of our water resources and essential if we are to have a sensible, economic, and practical approach to the treatment of wastes and the re-use of our fresh water supplies.

To determine those uses presently attained in an aquatic ecosystem, there are three complementary tasks: the first is to characterize uses in measurable biological and ecological terms. The research approach will be to select key measurable factors that describe important characteristics to determine which of them are linked to particular uses. The second step is to determine what uses are attained. The research approach will be to evaluate available means of assessing the health of an aquatic community based on structural and functional biological procedures. The role of a healthy and balanced ecological life is indeed extremely important for the maintenance of the quality of water itself. This is materialized by many biological processes responsible for waste degradation, water oxygenation, nutrient balance, etc. It may also play an important role as an "alarm" signal. A third step is to determine the environmental factors (e.g. water quality, minimum flow, habitat destruction) that commonly limit uses. This involves evaluating the relationships among physical habitat, water quality and biological variables under field conditions, and developing laboratory and field bioassay techniques for assessing environmental impacts.

Since the experimental approach of a water pollution program can be applied whether in-field or in laboratory, for a more comprehensive analysis we have preferred to subdivide research lines as follows:

- first option: "in situ" research;
- second option: laboratory research.

Furthermore, as a guide for the following considerations, we have taken into account the scientific aspects and more practical ones of environmental problems in Italian waterbodies.

4.1 "In situ" research

Among many pollutants of fresh waters, some are set out in Table XXXIV, of first priority are those considered as producers of eutrophic stress, i.e. nutrients, detergents and fertilizers. As has been mentioned earlier, the eutrophication and its consequences are the most important deterioration phenomena in Italy.

What seems stimulating to us today are researches concerning the recovery times of water resources in relation to a given use. Table XXXV provides very broad estimates of recovery times of several types of ecosystems. Existing uncertainty is related to the little or scanty knowledge that we have about the hydrodynamic aspects of lake waters. For example, in the case of lake Como, the application of the OECD eutrophication model - based on P load/Lake response relationship - gives unreliable results because of underestimation of effective water residence times /17/.

Another field that deserves experimental effort is the evaluation of the consequences on water resources of the introduction of substitutes for sodium tripolyphosphate in detergents, in particular NTA. This provokes great uneasiness mainly in waterbodies intended for human consumption.

Special attention is presently paid to organo-chlorinated compounds. Relatively recent discovery of almost ubiquitary appearance of organochlorinated compounds in drinking waters stirs up a noteworthy worry from Health Authorities for possible effects on health, deriving from continuous exposure of consumers to such substances. Although organo-chlorinated compounds can be already present as contaminants in untreated waters, the quantity and the variety of synthetic organic compounds, which are formed ex novo during treatment processes for the production of potable water, can exceed original quantities coming from direct pollution, whether industrial or agricultural. Particularly, chlorination treatments of waters containing natural and synthetic organic precursors have to be considered as the major source of organo-chlorinated compounds because many surface waters have a great amount of such precursors. Some natural organic substances, such as algae and its extracellular products, can assume an important role as precursors of organo-chlorinated compounds, i.e. trihalomethanes.

As is well known, insubric lakes such as Maggiore, Como, Iseo, Garda, represent strategic water supplies where more or less relevant eutrophication phenomena occur. Because of the fact that water collections from such environments are presently in action for the purpose of creating drinking water, it seems evident that this aspect of environmental research will have, in the future, more and more importance.

Research objectives would consist in formulating management models for multiple use of the water resources. The use of adequate mathematical models on the one hand will allow a better definition of mechanisms responsible for pollution phenomena, and on the other hand will describe the answer of the system to intervention actions and management strategies. From a general point of view it will deal with setting up models able to make previsions of spatial and temporal changes of quantities, characterizing contamination status of the environment. To this purpose a rational choice of parameters must be made, the least possible: such parameters must be representative for the environment, pollutants, possible effects, and must permit at the same time the use of mass balance equations. It is important that mathematical simulations are done with specific reference to real problems and situations, aiming at verifying satisfactorily a proper compromise between scientific strictness of the description and availability of base data.

In what aquatic environments can we do this? The most suitable ecosystems for developing not only specific scientific knowledge and techniques but really to have a "use-based" approach to ensure appropriate management goals, are lakes Varese and Como. Lake Varese because it is at present subjected to external intervention for reducing nutrient loading. So, there is the unique opportunity to evaluate, in terms of recovery time, the most cost-effective waste-water treatment technologies. Lake Como (Western basin) represents a good example of degraded environment where it is urgently required to assess the water quality requirements necessary to define the uses to be made of the water (such as public water supply, propagation of fish and wildlife, recreation, agricultural and industrial purposes).

4.2 Laboratory research

This research would be focused on biological tests for water pollution assessment. Such tests would offer an alternative to the expensive and time-consuming process of dealing with complex waste mixtures on a chemical-by-chemical basis. It is now being recognized that, in order to maintain quality objectives, the water authorities lack an essential instrument, i.e. the possibility of assessing, with sufficient reliability, the level and type of toxicity remaining in treated effluents, before they are discharged into natural waters. Moreover, it is imperative to be able to assess the presence of toxic substances in receiving waters in order to know where effluent controls must be improved.

In the case of complex and mixed effluents, which may contain a large number of pollutants, many at low concentration, it is clear that a chemical analysis approach - even with the aid of advanced and costly techniques (gas chromatography, mass spectroscopy) - will not provide the decision-maker with sufficient information, and is not practical as a routine procedure. This is not only due to the cost and delays involved in chemical analyses, but also to their inability to detect all the toxic chemicals really present in a complex effluent, and even more so to assess the toxicity of all the chemicals which have been identified. As a matter of fact, toxicological effect data will often not be available for all industrial chemicals likely to be found as well as the combined effects of mixtures of chemicals. These difficulties can be overcome satisfactorily by using biological testing methods which can directly evaluate the degree of toxicity of effluents with reliability and at low cost.

Biological testing, therefore, can be used as a new tool to identify the potential ecotoxicity of complex effluents, per se, which cannot be cost-effectively determined by any other method (and which must be detected in order to prevent adverse environmental impact).

The use of biological tests is primarily intended as a tool for the prevention of negative environmental effects. It is generally assumed that most pollutants which cause ecological effects will also pose, directly or indirectly, a human health risk. This is the case in particular for substances which bioaccumulate in aquatic organisms eaten by man or contaminated drinking water supplies. In this context, special attention is presently being paid to organo-chlorinated compounds, and to other proven or suspected carcinogens. Biological testing is very useful in various sectors of water pollution control. These involve identifying environmental problems, setting priorities for pollution control, establishing discharge limits for effluents and monitoring an effluent for compliance with regulatory limits on toxicity. They are generally able to measure inherent short- and long-term ecotoxic effects of pollutants and to present quantitative data on effluent toxicity in order to provide a regulatory basis to control pollution and, in some cases, assess the effects of toxic effluents on ecological life and trophic levels within aquatic ecosystems. Among the advantages of using biological tests, other than those already stated in general terms, are that they provide results to which environmental services and the public and industry can readily relate, thereby making the argument for effluent control more convincing to industry. A further advantage may be that treatment and control of toxic effluents, because their effectiveness depends on the removal of toxic effects rather than upon the removal of specific chemicals, may be less expensive than in the case of "technology based" standards (i.e. effluent limitations that are based upon the best available technology for controlling the release of a specific chemical). This may have greater appeal to industry and to the government because it may free scarce financial resources to be available for other priority issues.

From a practical viewpoint, taking into account the scientific background and familiarity in culturing potential test species, as a first step in the use of biological tests for water pollution assessment, we could refer to algae. The addition to an aquatic ecosystem of nutrients which stimulate the growth of excessive amounts of vegetation in the receiving water (i.e. cause eutrophication), may cause as much or more of an adverse impact than is caused by toxic pollution. In order to protect aquatic ecosystems from the full potential adverse impact of an effluent, therefore, testing of the final effluent on its ability to cause eutrophication should be conducted coincidentally with toxicity testing. This combination of testing and subsequent limitation of toxic substances and eutrophicating substances affords the best protection of aquatic ecosystems and their potential to maintain their value (use).

By using the full spectrum of indiginous phytoplankton, any and all organisms which might be stimulated by nutrient addition, under existing water chemistry conditions, have the opportunity to respond. The advantage of the multispecies approach over a single species test can be implied from the well-known presence of algal antibiotics in water samples. The growth of a single test organism may be inhibited by species-specific antibiotics which often are found in water samples. When present, an antibiotics might suppress the growth of the test organism which otherwise would be stimulated by a nutrient addition. Thus, in a single species test system, the growth-enhancing effect of a limiting nutrient or effluent which is being tested may be masked by the presence of other substances in the water. The point is substantiated by experimental endurance which shows that individual phytoplnakton responds in unique ways to the addition of nutrients or other substances. Therefore, it is reasonable to expect that the growth response of mixed populations would be different from a single arbitrarily chosen test species.

Thus, the use of multispecies environmental models for predicting the effects of effluents has several advantages over the use of single species models, whether the models are used to predict a toxic effect or to predict the potential for eutrophication. Toxicity tests should, therefore, be carried out at population levels, evaluating which members (algal taxa) are subject to the effluent toxicants. With knowledge of the significance and the interactions of the test populations with other members of the community, the work of projecting the overall impact of the effluent on the natural community is greatly assisted.

The second step should be to carry out toxicity tests in a community of organisms in the form of a model ecosystem which imitates the receiving waterbody. This can be done by setting up a balanced microcosm, using organisms from the receiving waters or by using outdoor experimental channels with flow from the receiving water. Although all artificial ecosystems fall short of perfect imitation of the natural environment, their use for testing effluents which are intended for introduction into a receiving body of water, may provide valuable insight into interactive population effects caused by pollutants. They may, therefore, forewarn damage to be caused by the effluent and may also facilitate or contribute to improvements in toxicity testing. Such toxicity testing of an effluent may be used, therefore, to demonstrate the probability of an effluent's toxicity to the biota within an ecosystem. This is based on the assumption that an effluent that is toxic to one or more species in the test system, is likely to be toxic to important components of the ecosystem and, therefore, is likely to cause adverse environmental impact. The alternative to using toxicity tests to judge the environmental impact of an effluent (which has been discharging into a receiving waterbody for a sufficiently long period of time) is to conduct field surveys and analyses of the biota in the receiving waters (costly).

Apart from toxicity testing mentioned above, considered as structural bioassays, functional tests (i.e. the evaluation of toxicant induced physiological, biochemical and cytological changes) can also be used to assess the exposure to an effluent. Exposure to a toxic effluent stresses phytoplankton, and stress produces a variety of gross and subtle effects. Among these are photosynthetic activity, chlorophyll per cell content, and morphological and cytological changes. Evaluation of these functional reactions requires unique measuring systems. Such effects can be detected on the basis of instrument-measured interference with laser induced fluorescence in algae. This technique, developed at JRC-Ispra in the present 4-year environmental program, is now operating and furnishing preliminary results /18,19/. The advantage of functional testing over structural testing is that changes in cell physiology and cell chemistry, which eventually lead to biotic structural changes, may be detected in time to prevent community or population changes in the receiving water.

In addition, functional bioassays may be improved to the point where data collected over the short term could predict the results of long-term chronic toxicity tests and thereby provide a more cost-efficient alternative to these tests.

5. CONCLUSIVE REMARKS

The task of water authorities in industrialized countries consists, to a large extent, of keeping the quality of water resources at a level which is adequate for essential human uses, and in protecting the natural environment. This essential goal requires that careful and continuous pollution control is applied with the best tools available (technical, managerial, regulatory and economic).

Water quality criteria can be of great use in the enforcement of antipollution laws. In the past, pollution control programs have been long drawn out, often due to requests for additional field or laboratory study, or because of delaying tactics and arguments over what concentrations of the wastes in question are significantly toxic or harmful, with the result that many times effective pollution control has not been realized. Delays and difficulties are understandable when the water authority does not definitely know the quality of water required for the use or uses it is seeking to protect. An effective program requires better definition of water quality requirements.

Although much progress has been made in establishing a scientifically sound information base for making water quality management decisions, major information needs to remain. Less expensive, short-term biological tests are needed to facilitate implementation of water quality standards. Such tests are needed to assess water quality and by dischargers to control the toxicity of effluents. Such tests would offer an alternative to the expensive and time-consuming process of dealing with complex waste mixtures on a chemical-by-chemical basis.

The priority given in the last ten years to developing technology-based controls meant that less emphasis was placed on developing the information base and tools needed to support a water quality-based approach.

Figure 5 schematizes the meaning of a water quality-based approach for environmental policy and management. Although minimum technology requirements have improved the overall quality of waters, many waterbodies will require additional controls if water quality standards are to be met. One major water quality research priority is solving the technical and scientific problems associated with translating water quality standards into permit conditions. The remaining water pollution problems will likely be among the most difficult to address, especially if they are caused by toxic substances, non-point sources, or other factors such as low flow which limits the available capacity of the waterbody to assimilate pollutants. Finally, we would like to point out that there are three major aquatic life elements and two human health concerns related to implementation of water quality standards which EPA research is addressing /34/:

- Use attainability: in order to ensure that water quality goals are ecologically attainable, an orderly process is used to classify possible uses and levels of use, determine attainability, set ecological requirements for the use, ensure that these requirements are met and, finally, monitor for results;
- Site-specific criteria and complex effluent toxicity testing: to implement water quality-based controls, state permitting agencies need better information and field validated protocols to establish single pollutant criteria that account for local water quality characteristics and varying sensitivities of local aquatic species, criteria for single pollutants which account for interactions between chemicals in known pollutant mixtures, and criteria for mixture unknown pollutants and toxicity control for complex effluents;
- Wastewater allocation: the wasteload allocation (WLA) process is the basis for permit limitations for individual dischargers, in which margins of safety, distribution of treatment burdens and non-point source controls are considered;
- Human health controls: an association has been shown between infectuous disease incidence in swimmers and water quality as determined by bacterial indicators. However, the identification and origins of the disease agent(s) have not been determined. Recent findings suggest that

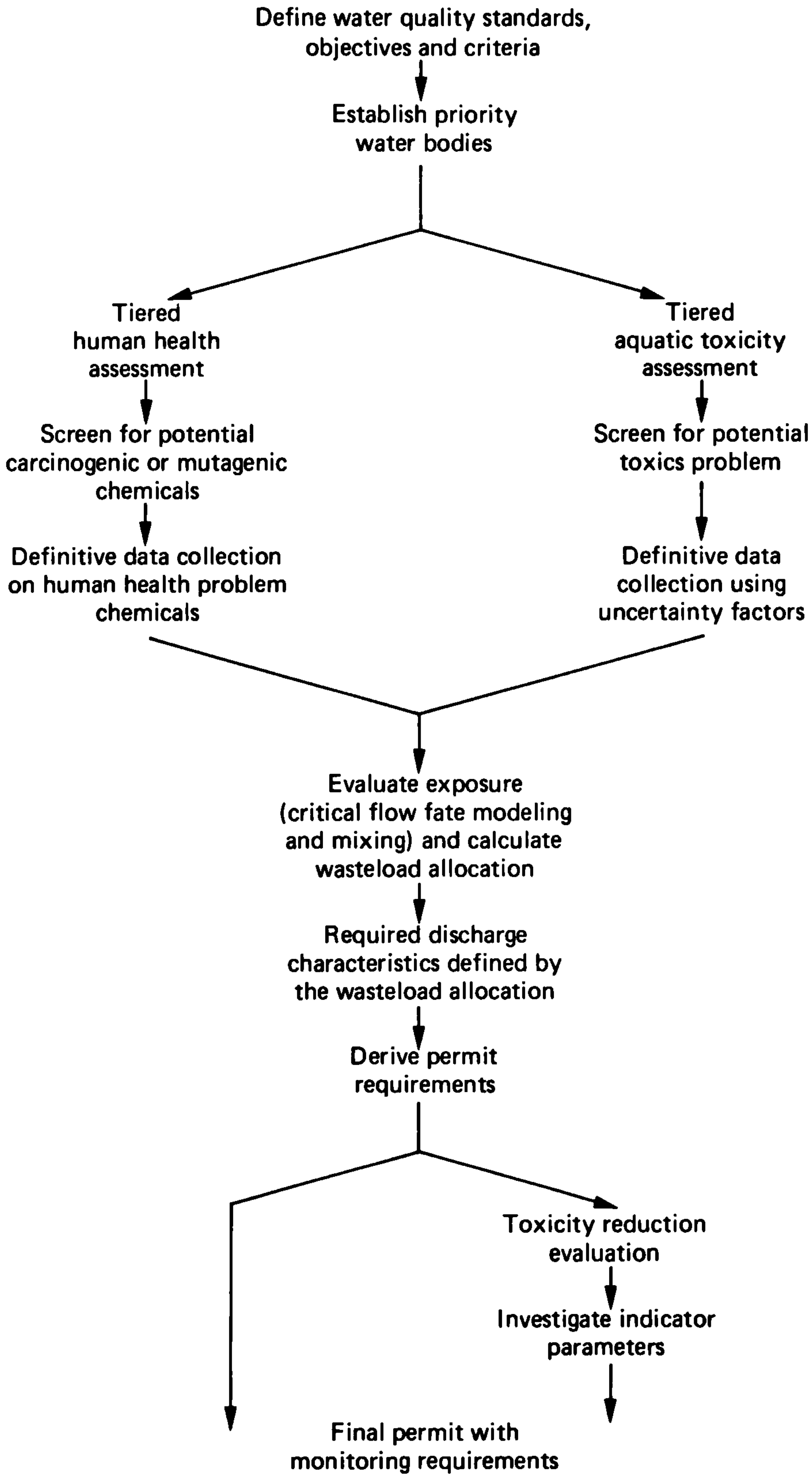

Fig. 5 Overview of the water quality-based approach for the implementation of water pollution control. /32/

the traditionally recognized pathogens may not be responsible for the observed disease. The occurrence of particulate matter, probably derived from wastewater, also influences the exposure patterns of swimmers by allowing infectuous-dose levels of organisms to be ingested at one time;

- Human health criteria: criteria for the protection of human health are important where the designated use for a waterbody includes public water supply, the taking of fish for human consumption, or recreational use. Depending on the nature of a pollutant, human health criteria may be less stringent or more stringent than criteria which protect aquatic life. Because use designations vary, human health criteria also need to be modified on a site-specific basis.

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TABLE I - Ground and surface water abstraction percentages for potable use (present and predicted) /37/

	Present		Predicted*)	
	Groundwater %	Surface water %	Groundwater %	Surface water %
Belgium	85	15	not available	not available
Denmark	98	2	"	"
France	48	52	"	"
Federal Republic of Germany	60	33**)	"	"
Republic of Ireland	unknown	unkown	"	"
Italy	93	7	73	27
Luxembourg	60	40	20	80
Netherlands	70	30	40	60
United Kingdom	34	66	not available	not available
Sweden	46	54	"	"
USA	20	80	"	"

*) Not possible to obtain precise forecasts for the future percentage of water abstraction for potable use.

**) Other sources: 7%.

TABLE II - Percentage of water abstraction for potable use from surface sources in Italy and Federal Republic of Germany /38/

	1966	1980
Northern Italy	9	18
Central Italy	9	18
Southern Italy	0	9
Italy: islands	33	37
Sardinia: maximum	68	76
Nordrhein - Westfalen	--	63
Baden-Württemberg	--	31
Rheinland-Pfalz	--	15
Niedersachsen	--	14

TABLE III - Properties of water intended for human consumption (European Community Directive 80/778) /3/

	Organoleptic parameters				
	Parameters	Expression of the results	Guide level (GL)	Maximum admissible concentration (MAC)	Comments
1	Colour	mg l^{-1} Pt/Co scale	1	20	
2	Turbidity	mg l^{-1} SiO_2	1	10	
		Jackson Units	0.4	4	replaced in certain circumstances by a transparency test, with a Secchi disc reading in meters: GL: 6 m; MAC: 2 m.
3	Odour	dilution number	0	2 at 12°C 3 at 25°C	to be related to the taste tests.
4	Taste	dilution number	0	2 at 12°C 3 at 25°C	to be related to the odour tests.

TABLE IV - Physico-chemical parameters (in relation to the water's natural structure) /3/

	Parameters	Expression of the results	Guide level (GL)	Maximum admissible concentration (MAC)	Comments
5	Temperature	degrees C	12	25	
6	Hydrogen ion concentration	pH unit	6.5 ≤ pH ≤ 8.5		- the water should not be aggressive - the pH values do not apply to water in closed containers - maximum admissible values: 9.5
7	Conductivity	µS cm^{-1} at 20°C	400		- corresponding to the mineralization of the water - corresponding relativity values in ohms cm^{-1}: 2500
7	Chlorides	Cl mg l^{-1}	25		- approximate concentration above which effects might occur: 200 mg l^{-1}
9	Sulphates	SO_4 mg l^{-1}	25	250	
10	Silica	SiO_2 mg l^{-1}			
11	Ca	mg l^{-1}	100		
12	Mg	mg l^{-1}	30	50	
13	Na	mg l^{-1}	20	175 (as from 1984 and with a percentile of 90) 150 (as from 1987 and with a percentile of 80) (these percentiles should be calculated over a reference period of 3 yr)	- The values of this parameter take account of the recommendations of a WHO Working Party (The Hague, May 1978) on the progressive reduction of the current total daily salt intake to 6 g. - As from 1.1.1984 the Commission will submit to the Council reports on trends in the total daily intake of salt per population. - In these reports the Commission will examine to what extent the 120 mg l^{-1} MAC suggested by the WHO Working Party is necessary to achieve a satisfactory total salt intake level, and, if appropriate, will suggest a new salt MAC value to the Council and a deadline for compliance with that value. - Before January 1984 the Commission will submit to the Council a report on whether the reference period of 4 yr for calculating these percentiles is scientifically well founded.
14	K	mg l^{-1}	10	12	
15	Al	mg l^{-1}	0.05	0.2	
16	Total hardness				
17	Dry residues	mg l^{-1} after drying at 180°C			
18	Dissolved oxygen	% O_2 saturation			- saturation value > 75% except for underground water
19	Free carbon dioxide	CO_2 mg l^{-1}			- the water should not be aggressive

TABLE V - Parameters concerning substances undesirable in excessive amounts /3/

	Parameters	Expression of the results	Guide Level (GL)	Maximum admissible concentration (MAC)	Comments
20	Nitrates	NO_3 mg l^{-1}	25	50	
21	Nitrites	NO_2 mg l^{-1}	0.1		
22	Ammonium	NH_4 mg l^{-1}	0.05	0.5	
23	Kjeldahl nitrogen (excluding N in NO_2 and NO_3)	N mg l^{-1}		1	
24	($KMnO_4$) Oxidizability	O_2 mg l^{-1}	2	5	measured when heated in acid medium
25	Total organic carbon (TOC)	C mg l^{-1}			the reason for any increase in the usual concentration must be investigated
26	Hydrogen sulphide	S µg l^{-1}	undetectable organoleptically		
27	Substances extractable in chloroform	mg l^{-1} dry residue	0.1		
28	Dissolved or emulsified hydrocarbons (after extraction by petroleum ether); Mineral oils	µg l^{-1}		10	
29	Phenols (phenol index)	C_6H_5OH µg l^{-1}		0.5	excluding natural phenols which do not react to Cl
30	B	µg l^{-1}	1000		
31	Surfactants (reacting with methylene blue)	µg l^{-1} (lauryl sulphate)		200	
32	Other organochlorine compounds not covered by parameter No.55	µg l^{-1}	1		haloform concentrations must be as low as possible
33	Fe	µg l^{-1}	50	200	
34	Mn	µg l^{-1}	20	50	
35	Cu	µg l^{-1}	100 - at outlets of pumping and/or treatment works and their sub-stations; 3000 - after the water has been standing for 12 h in the piping and at the point where the water is made available to the consumer		above 3000 µg l^{-1} astringent taste, discolouration and corrosion may occur
36	Zn	µg l^{-1}	100 - at outlets of pumping and/or treatment works and their sub-stations; 5000 - after the water has been standing for 12 h in the piping and at the point where the water is made available to the consumer		above 5000 µg l^{-1} astringent taste, opalescence and sand-like deposits may occur
37	Phosphorus	P_2O_5 µg l^{-1}	400	5000	
38	Fluoride	F µg l^{-1} 8 - 12°C; 25 - 30°C		1500; 700	MAC varies according to average temperature in geographical area concerned
39	Co	µg l^{-1}			
40	Suspended solids		none		
41	Residual chlorine	Cl µg l^{-1}			
42	Ba	µg l^{-1}	100		
43	Ag	µg l^{-1}		10	If, exceptionally, Ag is used non-systematically to process the water, a MAC value of 80 µg l^{-1} may be authorized

TABLE VI - Parameters concerning toxic substances /3/

	Parameters	Expression of the results	Guide Level (GL)	Maximum admissible concentration (MAC)	Comments
44	As	$\mu g\ l^{-1}$		50	
45	Be	$\mu g\ l^{-1}$			
46	Cd	$\mu g\ l^{-1}$		5	
47	Cyanides	CN $\mu g\ l^{-1}$		50	
48	Cr	$\mu g\ l^{-1}$		50	
49	Hg	$\mu g\ l^{-1}$		1	
50	Ni	$\mu g\ l^{-1}$		50	
51	Pb	$\mu g\ l^{-1}$		50 (in running water)	Where Pb pipes are present, the Pb content should not exceed 50 $\mu g\ l^{-1}$ in a sample taken after flushing. If the sample is taken either directly or after flushing and the Pb content either frequently or to an appreciable extent exceeds 100 $\mu g\ l^{-1}$, suitable measures must be taken to reduce the exposure to Pb on the part of the consumer.
52	Sb	$\mu g\ l^{-1}$		10	
53	Se	$\mu g\ l^{-1}$		10	
54	V	$\mu g\ l^{-1}$			
55	Pesticides and related products	$\mu g\ l^{-1}$			Pesticides and related products means:
	- substances considered separately			0.1	- insecticides: . persistent organochlorine compounds . organophosphorous compounds . carbamates
	- total			0.5	- herbicides - fungicides - PCBs and PCTs
56	Polycyclic aromatic hydrocarbons	$\mu g\ l^{-1}$		0.2	- reference substances: . fluoranthene . 3,4-benzo-fluoranthene . 11,12 benzfluoranthene . 3,4 benzpyrene . 1,12 benzperylene . indeno [1,2,3-cd]pyrene

TABLE VII - Microbiological parameters /3/

	Parameters	Results: Volume of the sample in ml	Guide Level (GL)	Maximum Admissible Concentration (MAC): Membrane filter method	Maximum Admissible Concentration (MAC): Multiple tube method (MPM)	Comments
57	Total coliforms[a]	100	-	0	MPN < 1	
58	Fecal coliforms	100	-	0	MPN < 1	
59	Fecal streptococci	100	-	0	MPN < 1	
60	Sulphide-reducing clostridia	20	-	-	MPN $\leqq$ 1	
61	Total bacteria counts for water supplied for human consumption	37°C 1	10[ab]	-		
		22°C 1	100[ab]	-		
62	Total bacteria counts for water in closed containers	37°C 1	5	20		On their own responsibility and where parameters 57,58,59 and 60 are complied with, and where the pathogen organisms given above are absent, Member States may process water for their internal use the total bacteria count of which exceeds the MAC values laid down for parameter 62. MAC values should be measured within 12 h of being put into closed containers with the sample water being kept at a constant temperature during that 12 h period.
		22°C 1	20	100		

Water intended for human consumption should not contain pathogenic organisms.
If it is necessary to supplement the microbiological analysis of water intended for human consumption, the samples should be examined not only for the bacteria referred to in Table VII but also for pathogens including: salmonella, pathogenic staphylococci, fecal bacteriophages, entero-viruses. Nor should such water contain: parasites, algae, other organisms such as animalcules.

a For disinfected water the corresponding values should be considerably lower at the point where it leaves the processing plant.

b If, during successive sampling, any of these values is consistently exceeded, a check should be carried out.

TABLE VIII - Minimum required concentration for softened water intended for human consumption/3/

	Parameters	Expression of the results	Minimum required concentration (softened water)	Comments
1	Total hardness	mg l^{-1} Ca	60	Ca or equivalent cations
2	Hydrogen ion concentration	pH		the water should not be aggressive
3	Alkalinity	mg l^{-1} HCO_3	30	
4	Dissolved oxygen			

These provisions also apply to desalinated water.

TABLE IX - Standard pattern analyses/3/

	Standard analyses / Parameters to be considered	Minimum monitoring (C1)	Current monitoring (C2)	Periodic monitoring (C3)	Occasional monitoring in special situations or in case of accidents (C4)
A	Organoleptic parameters	- odour[a] - taste[a]	- odour - taste - turbidity (appearance)	Current monitoring analyses + other parameters as in footnote a	The competent national authorities of the Member States will determine the parameters according to circumstances, taking account of all factors which might have an adverse effect on the quality od drinking water supplied to consumers.
B	Physico-chemical parameters	- conductivity or other physico-chemical parameters - residual chlorine[c]	- temperature[b] - conductivity or other physico-chemical parameters - pH - residual chlorine[c]		
C	Undesirable parameters		- nitrates - nitrites - ammonia		
D	Toxic parameters				
E	Microbiological parameters	- total coliforms or total counts of 33° and 37° - fecal coliforms	- total coliforms - fecal coliforms - total counts of 22° and 37°		

NOTE: An initial analysis, to be carried out before a source is exploited, should be added. The parameters to be considered would be the current monitoring analyses plus, inter alia, various toxic or undesirable substances presumed present. The list would be drawn up by the competent national authorities.

[a] Qualitative assessment.
[b] Except for water supplied in containers.
[c] Or other disinfectants and only in the case of treatment.

TABLE X - Minimum frequency of standard analyses (***) /3/

Volume of water produced or distributed in m^3/day	Population concerned assuming 200 l/day per person	Analysis C1 Number of samples per year	Analysis C2 Number of samples per year	Analysis C3 Number of samples per yeat	Analysis C4
100	500	(*)	(*)	(*)	Frequency to be determined by the competent national authorities as the situation requires
1 000	5 000	(*)	(*)	(*)	
2 000	10 000	12	3	(*)	
10 000	50 000	60	6	1	
20 000	100 000	120	12	2	
30 000	150 000	180	18	3	
60 000	300 000	360(**)	36	6	
100 000	500 000	360(**)	60	10	
200 000	1 000 000	360(**)	120(**)	20(**)	
1 000 000	5 000 000	360(**)	120(**)	20(**)	

(*) Frequency left to the discretion of the competent national authorities. However, water intendef for the food-manufacturing industries must be monitored at least once a year.

(**) The competent health authorities should endeavour to increase this frequency as far as their resources allow.

(***) (a) In the case of water which must be disinfected, microbiological analysis should be twice as frequent.

(b) Where analyses are very frequent, it is advisable to take samples at the most regular intervals possible.

(c) Where the values of the results obtained from samples taken during the preceding years are constant and significantly better than the limits laid down in Annex 1, and where no factor frequencies of the analyses referred to above may be reduced:

- for surface waters, by a factor of 2 with the exception of the frequencies laid down for microbiological analyses;
- for ground waters, by a factor of 4; but without prejudice to the provisions of point (a) above.

TABLE XI - Standards for general chemical and microbiological parameters of surface water intended for abstraction for potable use (concentrations in mg/l, except where stated). EEC DIRECTIVE

		Drinking water		A1 treatment		A2 treatment		A3 treatment	
		G	MAC	G 90P	I 95P	G 90P	I 95P	G 90P	I 95P
		T	T	T	T	T	T	T	T
METALS etc.									
Calcium	as Ca	100							
Magnesium	as Mg	30	50						
Total hardness	as $CaCO_3$	(3)							
Potassium	as K	10	12						
Sodium	as Na	20	175(7) 150(8)						
Dry residues			1500						
ANIONS etc.									
Chloride	as Cl	25	200(9)	200		200		200	
Phosphate(1)	µg/l as P	87	1091	87		153		153	
Silica	as SiO_2	(4)	(4)						
Sulphate	as SO_4	25	250	150	250	150	250(14)	150	250(14)
Salinity	g/kg								
NITROGEN COMPOUNDS									
Ammonia (total)	as N	0.038	0.38	0.038		0.78	1.17	1.56	3.11(17)
Free (unionised) NH_3	µg/l as N								
Nitrite	µg/l as N		30						
Nitrate	as N	5.65	11.3	5.65	11.3(14)		11.3(14)		11.3(14)
Kjeldahl nitrogen	as N	1	1	1		2		3	
OXYGEN DEMAND etc.									
BOD(2)	as O_2			3		5		7	
COD	as O_2							30	
Permanganate value	as O_2	2	5						
TOC	as C	(5)	(5)						
DISSOLVED GASES etc.									
Residual chlorine	µg/l as Cl_2	(4)	(4)						
Dissolved oxygen	% saturated			> 70		> 50		> 30	
MISCELLANEOUS									
Colour	Pt/Co scale	1	20	10	20(14)	50	100(14)	50	200(14)
Conductivity at 20°C	µS/cm	400		1000		1000		1000	
Odour	dilution no.	0	2(10)3(11)	3(11)		10(11)		20(11)	
Taste	dilution no.	0	2(10)3(11)						
pH		6.5-8.5	9.5(9)	6.5-8.5		5.5-9		5.5-9	
Temperature	°C	12	25	22	25(14)	22	25(14)	22	25(14)
Suspended solids		0		25					
	as SiO_2	1	10						
Turbidity	Jackson units	0.4	4						
	Secchi depth, m	6	2						
MICROBIOLOGICAL									
Total bacterial, 37°C	MPN/1ml	10(6)							
Total bacterial, 22°C	MPN/1ml	100(6)							
Faecal coliforms at 44°C	MPN/100ml		< 1(12)	20		2000		2000	
Total coliforms at 37°C	MPN/100ml		< 1(12)	50		5000		5000	
Sulphite-reducing clostridia	MPN/20ml		≤ 1						
Salmonella	MPN/1l		(13)	(15)		(16)			
Faecal streptococci	MPN/100ml		< 1(12)	20		1000		1000	
Entero viruses	MPN/10l		(13)						

Explanatory notes to Table XI

Key to symbols

G guide value, to be observed if possible.

MAC maximum allowable concentration.

I mandatory value.

90P standard defined as a 90 percentile, i.e. 90% of measured values should conform to the standard quoted.

95P standard defined as a 95 percentile, i.e. 95% of measured values should conform to the standard quoted.

AA standard defined as an annual average, i.e. the mean of the measured values over a 12-month period should conform to the standard quoted.

T measured as total, i.e. dissolved plus particulate.

D measured as dissolved, i.e. usually involving filtration of the sample through a 0.45 µm membrane filter before analysis.

Footnotes

1. This parameter was included in the directive concerned with abstraction for drinking water to satisfy the ecological requirement of certain types of environment.

2. Five-day biochemical oxygen demand at 20°C without nitrification (i.e. with the addition of ATU or equivalent) except where stated.

3. The directive stipulates that softened water intended for human consumption should have a minimum hardness of 150 mg/l as $CaCO_3$.

4. Article 8 of the Drinking Water Directive applies, i.e. "Member states shall take all the necessary measures to ensure that any substances used in the preparation of water for human consumption do not remain in concentrations higher than the maximum admissible concentration relating to these substances in water made available to the user, and that they do not, either directly or indirectly, constitute a public health hazard".

5. The reason for any increase in the usual concentration must be investigated.

6. For disinfected water, corresponding values should be considerably lower at the point where water leaves the processing plant. If this guide value is consistently exceeded a check should be carried out. Separate standards apply to water in closed containers: at 37°C G value 5, MAC value 20; at 22°C G value 20, MAC value 100. The MAC values should be measured within 12 hours of bottling, with a constant temperature being kept during that period. The MAC values may be exceeded under certain conditions defined in the Directive.

7. Value applies from 1984 as a 90-percentile over a reference period of three years.

8. Value applies from 1987 as an 80-percentile over a reference period of three years.

9. This is an approximate MAC value. It is given in the comments column in the original Directive and presumably is not intended to have the same force as the other MAC values.

10. At 12°C.

11. At 25°C.

12. The corresponding MAC value if the membrane filter method is in use is 0.

13. Should be absent, as should also pathogenic staphylocci, faecal bacteriophages, parasites, algae and other organisms. However, analysis for these parameters need not necessarily be included.

14. May be waived in the event of exceptional meteorological or geographical conditions.

15. Not present in 5000 ml.

16. Not present in 1000 ml.

17. The Directive states that this value (which is a 75 percentile) applies to shellfish flesh and intervalvular fluid and that pending the adoption of a Directive on the protection of consumers of shellfish products, it is essential that this value be observed in waters in which live shellfish directly edible by man.

TABLE XII - Standards for trace substances (concentrations in μg/l). EEC DIRECTIVE.

		Drinking water(8)		A1 treatment		A2 treatment		A3 treatment	
		G	MAC	G 90P	I 95O	G 90P	I 95P	G 90P	I 95P
		T	T	T	T	T	T	T	T
METALS AND METALLOIDS									
Aluminium	as Al	50	200						
Antimony(1)	as Sb		10						
Arsenic(1)	as As		50	10	50		50	50	100
Barium	as Ba	100			100		1000		1000
Cadmium(1)	as Cd		5	1	5	1	5	1	5
Chromium(1, 2)	as Cr		50		50		50		50
Copper	as Cu	100(9) 3000(10)		20	50(20)	50		1000	
Iron(3)	As Fe	50	200	100	300	1000	2000	1000	
Lead(1)	as Pb		50(12)		50		50		50
Manganese	as Mn	20	50	50		100		1000	
Mercury(1)	as Hg		1	0.5	1	0.5	1	0.5	1
Nickel(1)	as Ni		50						
Silver	as Ag		10(13)						
Zinc	as Zn	100(9) 5000(10)		500	3000	1000	5000	1000	5000
INORGANIC ANIONS									
Boron	as B	1000		1000		1000		1000	
Cyanide(1)	as CN		50		50		50		50
Fluoride	as F		1500(14) 700(15)	1000(14) 700(15)	1500	700(14) 700(15)		700(14) 700(15)	
Hydrogen sulphide	as S		(16)						
Selenium(1)	as Se		10		10		10		10
ORGANIC SUBSTANCES									
Dissolved or emulsified hydrocarbons			10		50	200	200	500	1000
Organochlorines (excluding pesticides)		1(11)							
Pesticides(1, 4, 5)			0.1(17) 0.5(18)		1		25		5
Phenols	as C_6H_5OH		0.5(19)		1	1	5	10	100
Polycyclic aromatic hydrocarbons(1, 6)			0.2		0.2		0.2		1
Substances extractable in chloroform		100		100		200		500	
Surfactants(7)	as lauryl sulphate		200	200		200		500	

Explanatory notes to Table XII

Key to symbols

G guide value, to be observed if possible.

MAC maximum admissible concentration.

I mandatory value.

90P standard defined as a 90 percentile, i.e. 90% of measured values should conform to the standard quoted.

95P standard defined as a 95 percentile, i.e. 95% of measured values should conform to the standard quoted.

AA standard defined as an annual average, i.e. the mean of the measured values over a 12-month period should conform to the standard quoted.

T measured as total, i.e. dissolved plus particulate.

D measured as dissolved, i.e. usually involving filtration of the sample through a 0.45 μm membrane filter before analysis.

Footnotes

1. Under the Water for Human Consumption Directive this parameter is classified as toxic and the standards given in the first two columns (plus those for microbiological parameters and any other parameters chosen by national authorities) apply to water used in food processing.

2. Defines as total chromium (i.e. Cr III and Cr VI) (in the Water for Human Consumption Directive no definition is given, but total chromium is assumed).

3. Defines as dissolved iron in the Directive concerning abstration for drinking water.

4. Defines under the Water for Human Consumption Directive as insecticides (i.e. persistent organochlorine compounds, organophosphorus compounds and carbamates), herbicides, fungicides, PCBs and PCTs.

5. Defines under the Directive concerning abstraction for drinking water as "total pesticides (parathion, BHC, dieldrin)".

6. Reference substances given as: (a) fluoranthene; (b) 3,4-benzofluoranthene; (c) 11,12-benzofluoranthene; (d) 3,4-benzopyrene; (e) 1,12-benzoperylene; and (f) indeno (1,2,3-cd) pyrene. In the Water for Human Consumption Directive (a) and (d) are omitted, (b) is given twice, (c) is as in the foregoing list, (e) is replaced by 1,12-benzopyrene and (f) is replaced by perylene/indeno (1,2,3-cd) pyrene.

7. Substances reacting with methylene blue.

8. The Water for Human Consumption Directive also applies to water used in food processing.

9. In water leaving the water processing plant.

10. In water at the consumer's tap which has been standing for 12 hours in piping.

11. Haloform concentrations must be as low as possible.

12. In running water. Where lead pipes are present, the lead content should not exceed 50 μg/l in a sample taken after flushing. If the sample is taken either directly or after flushing and the lead content either frequently or to an appreciable extent exceeds 100 μg/l, suitable measures must be taken to reduce the exposure to lead on the part of the consumer (this is a direct quotation from the Directive).

13. A MAC value of 80 μg/l is allowed where silver is used non-systematically to process the water.

14. At 8 to 12°C. The Water for Human Consumption Directive gives these temperatures numerically; the abstraction Directive states "low" or "high" temperatures.

15. At 25 to 30°C. The Water for Human Consumption Directive gives these temperatures numerically; the abstraction Directive states "low" or "high" temperatures.

16. Undetectable organoleptically.

17. Individually.

18. In total.

19. Excluding natural phenols which do not react with chlorine.

TABLE XIII - W.H.O. guidelines for drinking water quality: microbiological and biological parameters /4/

Organism	Unit	Guideline value	Remarks
I. Microbiological quality			
A. Piped water supplies			
A.1 Treated water entering the distribution system			
Faecal coliforms	number/100 ml	0	turbidity < 1 NTU; for disinfection with chlorine, pH preferably < 8.0; free chlorine residual 0.2 - 0.5 mg/litre following 30 minutes (minimum) contact.
Coliform organisms	number/100 ml	0	
A.2 Untreated water entering the distribution system			
Faecal coliforms	number/100 ml	0	
Coliform organisms	number/100 ml	0	in 98% of samples examined throughout the year - in the case of large supplies when sufficient samples are examined.
Coliform organisms	number/100 ml	3	in an occasional sample, but not in consecutive samples.
A.3 Water in the distribution system			
Faecal coliforms	number/100 ml	0	
Coliform organisms	number/100 ml	0	in 95% of samples examined throughout the year - in the case of large supplies when sufficient samples are examined.
Coliform organisms	number/100 ml	3	in an occasional sample, but not in consecutive samples.
B. Unpiped water supplies			
Faecal coliforms	number/100 ml	0	
Coliform organisms	number/100 ml	10	should not occur repeatedly; of occurrence is frequent and if sanitary protection cannot be improved, an alternative source must be found, if possible.
C. Bottled drinking-water			
Faecal coliforms	number/100 ml	0	source should be free from faecal contamination.
Coliform organisms	number/100 ml	0	
D. Emergency water supplies			
Faecal coliforms	number/100 ml	0	advise public to boil water in case of failure to meet guideline values.
Coliform organisms	number/100 ml	0	
Enteroviruses	no guideline value set		
II. Biological quality			
Protozoa (pathogenic)	no guideline value set		
Helminths (pathogenic)	no guideline value set		
Free-living organisms (algae, others)	no guidelines set		

TABLE XIV - Inorganic constituents of health significance /4/

Constituent	Unit	Guideline value	Remarks
Arsenic	mg/l	0.05	
Asbestos		no guideline value set	
Barium		no guideline value set	
Beryllium		no guideline value set	
Cadmium	mg/l	0.005	
Chromium	mg/l	0.05	
Cyanide	mg/l	0.1	
Fluoride	mg/l	1.5	natural or delibrately added; local or climatic conditions may necessitate adaptation.
Hardness		no health-related guideline value set	
Lead	mg/l	0.05	
Mercury	mg/l	0.001	
Nickel		no guideline value set	
Nitrate	mg/l (N)	10	
Nitrite		no guideline value set	
Selenium	mg/l	0.01	
Silver		no guideline value set	
Sodium		no guideline value set	

TABLE XV - Organic constituents of health significance /4/

Constituent	Unit	Guideline value	Remarks
Aldrin and dieldrin	µg/l	0.03	
Benzene	µg/l	10[a]	
Benzo [a]pyrene	µg/l	0.01[a]	
Carbon tetrachloride	µg/l	3[a]	tentative guideline value[b]
Chlordane	µg/l	0.3	
Chlorobenzenes	µg/l	no health-related guideline value set	odour threshold concentration between 0.1 and 3 µg/l.
Chloroform	µg/l	30[a]	disinfection efficiency must not be compromised when controlling chloroform content.
Chlorophenols	µg/l	no health-related guideline value set	oudour threshold concentration 0.1 µg/l
2,4-D	µg/l	100[c]	
DDT	µg/l	1	
1,2-dichloroethane	µg/l	10[a]	
1,1-dichloroethene[d]	µg/l	0.3[a]	
Heptachlor and heptachlor epoxide	µg/l	0.1	
Hexachlorobenzene	µg/l	0.01[a]	
Gamma-HCH (lindane)	µg/l	3	
Methoxychlor	µg/l	30	
Pentachlorophenol	µg/l	10	
Tetrachloroethene[d]	µg/l	10[a]	tentative guideline value[b]
Trichloroethene[d]	µg/l	30[a]	tentative guideline value[b]
2,4,6-trichlorophenol	µg/l	10[ac]	odour threshold concentration 0.1 µg/l
Trihalomethanes		no guideline value set	see chloroform

[a] These guideline values were computed from a conservative hypothetical mathematical model which cannot be experimentally verified and values should, therefore, be interpreted differently. Uncertainties involved may amount to two orders of magnitude (i.e. from 0.1 to 10 times the number).

[b] When the available carcinogenicity data did not support a guideline value, but the compounds were judged to be of importance in drinking-water and guidance was considered essential, a tentative guideline value was set on the basis of the available health-related data.

[c] May be detectable by taste and odour at lower concentrations.

[d] These compounds were previously known as 1,1-dichloroethylene, tetrachloroethylene and trichloroethylene, respectively.

TABLE XVI - Aesthetic quality /4/

Constituent or characteristic	Unit	Guideline value	Remarks
Aluminium	mg/l	0.2	
Chloride	mg/l	250	
Chlorobenzenes and chlorophenols		no guideline value set	These compounds may affect taste and odour
Colour	true colour units (TCU)	15	
Copper	mg/l	1.0	
Detergents		no guideline value set	There should not be any foaming or taste and odour problems
Hardness	mg/l (as $CaCO_3$)	500	
Hydrogen sulphide		not detectable by consumers	
Iron	mg/l	0.3	
Manganese	mg/l	0.1	
Oxygen-dissolved		no guideline value set	
pH		6.5 - 8.5	
Sodium	mg/l	200	
Solids - total dissolved	mg/l	1000	
Sulphate	mg/l	400	
Taste and odour		inoffensive to most consumers	
Temperature		no guideline value set	
Turbidity	nephelometric turbidity units (NTU)	5	Preferably < 1 for disinfection efficiency
Zinc	mg/l	5.0	

TABLE XVII - Radioactive constituents /4/

Constituent	Unit	Guideline value	Remarks
Gross alpha activity	Bq/l	0.1	a) If the levels are exceeded more detailed radionuclide analysis may be necessary;
Gross beta activity	Bq/l	1	b) Higher levels do not necessarily imply that the water is unsuitable for human consumption.

TABLE XVIII - U.S.E.P.A. recommended guidelines for salinity in irrigation waters /7/

Classification	TDS mg/l	EC mmhos/cm
Water for which no detrimental effects are usually noticed	500	0.75
Water that can have detrimental effects on sensitive crops	500-1000	0.75-1.50
Water that can have adverse effects on many crops; requires careful management practices	1000-2000	1.50-3.00
Water that can be used for tolerant plants on permeable soils with careful management practices	2000-5000	3.00-7.50

TDS = total dissolved solids
EC = electrical conductivity

Table XIX - U.S.E.P.A. recommended maximum concentrations of trace elements in irrigation waters[a] /7/

Element	For waters used continuously on all soil mg/l	For use up to 20 years on fine textured soils of pH 6.0 to 8.5 mg/l
Aluminium	5.0	20.0
Arsenic	0.10	2.0
Beryllium	0.10	0.50
Boron	0.75	2.0
Cadmium	0.010	0.050
Chromium	0.10	1.0
Cobalt	0.050	5.0
Copper	0.20	5.0
Fluoride	1.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5[b]	2.5[b]
Manganese	0.20	10.0
Molybdenum	0.010	0.050
Nickel	0.20	2.0
Selenium	0.020	0.020
Vanadium	0.10	1.0
Zinc	2.0	10.0

[a] These levels will normally not adversely affect plants or soils.

[b] Recommended maximum concentration for irrigating citrus is 0.075 mg/l.

TABLE XX - Classification of irrigation waters (U.S. Department of Agriculture /8/)

	$\frac{Na \times 100}{Na+K+Ca+Mg}$	TDS mg/l	Electrical conductivity mmhos/cm	Boron mg/l	Chlorides mg/l	Sulphates mg/l
Class 1: from excellent to good; usable in most conditions	60	700	500	0.5	177	960
Class 2: from good to damaging; dangerous to certain cultures under certain conditions	60-75	700-2100	500-3000	0.5-2	177-355	960-1920
Class 3: from damaging to unacceptable; dangerous to most cultures under various conditions	75	2100	3000	2	365	1920

TABLE XXI - Quality criteria of some chemical parameters for major industrial uses of water

Type of industry	Alkalinity mg/l $CaCO_3$	Hardness mg/l $CaCO_3$	TDS mg/l	pH	O_2 mg/l	Cl mg/l	$N-NO_2$ mg/l	$N-NO_3$ mg/l	SO mg/l	Al mg/l	As µg/l	Cd	Cr	Cu	F	Fe	Hg	Mn	Zn
Chemical	500[b] 150[a]	1000[b] 250[a]	2500[b] 750[a]	6.5-8.5[a]	-	250[a]	-	10[a]	250[a]	-	-	-	-	-	-	0.3[a]	-	0.1[a]	-
Primary metals	200[b]	1000[b] 100[a]	1500[b]	6-9[a]	-	150[a]	-	-	-	-	-	-	-	-	-	-	-	-	-
Petroleum refinery	500[b]	900[b] 350[a]	3500[b] 750[a]	6-9[a]	-	200[a]	-	-	-	-	-	-	-	-	-	1[a]	-	-	-
Paper	150[b] 75[a]	475[b] 100[a]	1000[b] 200[a]	-	-	-	-	-	-	-	-	-	-	-	-	0.1[a]	-	0.03[a]	-
Textile	200[b] 50[a]	120[b] 25[a]	150[b] 100[a]	-	-	-	-	-	-	2[a]	-	-	-	10[a,b]	-	0.1[a]	-	0.01[a]	-
Tanning	130[a]	150[a]	100[a]	6.8[a]	-	250[a]	-	-	250[a]	-	-	-	-	-	-	0.3[a]	-	0.2[a]	-
Food	150[a]	150[a]	500[a]	6.5-8.5[a]	-	250[a]	abs.[a]	10[a]	250[a]	-	50[a]	10[a]	100[a]	-	1[a]	0.2[a]	1[a]	0.2[a]	-
Soft drinks	85[b]	250[a]	1500[a]	6.5-7[a]	-	100[a]	-	10[a]	100[a]	-	-	-	-	-	1[a]	0.3[a]	-	0.05[a]	-
Steam generation		1[a]	0.07[a]	6.5[a]	8.8-9.4[a]	abs.[a]	-	-	-	0.01[a]	-	-	-	10[a]	-	0.01[a]	-	0.01[a]	10[a]

[a] I.W.D.Env. Canada /20/

[b] USEPA /21/

TABLE XXII - Quality requirements for bathing water (76/160 EEC Directive) /22/

	Parameters	G	I	Minimum sampling frequency	Method of analysis
	Microbiological				
1	Total coliforms (100 ml)	500	10000	Fortnightly (1)	Fermentation in multiple tubes subculturing of the positive tubes on a confirmation medium.
2	Faecal coliforms (100 ml)	100	2000	Fortnightly (1)	Count according to MPN (most probable number) or membrane filtration and culture on an appropriate medium such as Tergitol lactose agar, endo agar. 0.4% Teepol broth, subculturing and identification of the suspect colonies. In the case of 1 and 2, the incubation temperature is variable according to whether total or faecal coliforms are being investigated.
3	Faecal streptococci (100 ml)	100	-	(2)	Litsky method. Count according to MPN (most probable number) or filtration on membrane. Culture on an appropriate membrane.
4	Salmonella (1 litre)	-	0	(2)	Concentration by membrane filtration. Inoculation on a standard membrane. Enrichment-subculturing on isolating-agar identification.
5	Entero viruses (PFU/10 litres)	-	0	(2)	Concentrating by filtration, flocculation or centrifuging and confirmation.
	Physico-chemical				
6	pH	-	6 to 9 (0)	(2)	Electrometry with calibration at pH 7 & 9.
7	Colour	-	No abnormal change in colour (0)	Fortnightly (1,2)	Visual inspection or photometry with standards on the Pt. Co scale.
8	Mineral oils (mg/litre)	-	No film visible on the surface of the water and no odour	Fortnightly (1)	Visual and olfactory inspection or extraction using an adequate volume and weighing the dry residue.
		< 0.3	-	(2)	
9	Surface-active substances reacting with methylene blue (mg/litre; lauryl-sulfate)	-	No lasting foam	Fortnightly (1)	Visual inspection or absorption spectrophotometry with methylene blue.
		< 0.3		(2)	
10	Phenols (phenol indices (mg/litre; C_6H_5OH)	-	No specific odour	Fortnightly (1)	Verification of the absence of specific odour due to phenol or absorption spectrophotometry 4-aminoantipyrine (4 AAP) method.
		$\leq$ 0.005	$\leq$ 0.05	(2)	
11	Transparency (m)	2	1 (0)	Fortnightly (1)	Secchi's disc.
12	Dissolved oxygen (% saturation; O_2)	80 to 190	-	(2)	Winkler's method or electrometric method (oxygen meter).
13	Tarry residues and floating materials such as wood, plastic articles, bottles, containers of glass, plastic, rubber and any other substance. Waste or splinters.	Absence		Fortnightly (1)	Visual inspection.
14	Ammonia (mg/litre NH_4)			(3)	Absorption spectrophotometry. Nessler's method, or indophenol blue method.
15	Nitrogen Kjeldahl (mg/litre N)			(3)	Kjeldahl method.
16	Pesticides (parathion, HCH, dieldrin) (mg/litre)			(2)	Extraction with appropriate solvents and chromatographic determination.
17	Heavy metals such as: (mg/litre) arsenic (As), cadmium (Cd), chrom VI (CrVI), lead (Pb), mercury (Hg)			(2)	Atomic absorption possible preceded by extraction
18	Cyanides (mg/litre CN)			(2)	Absorption spectrophotometry using a specific reagent.
19	Nitrates and phosphates (mg/litre Nl_1; PO_4)			(2)	Absorption spectrophotometry using a specific reagent.

Notations to Table XXII

G guide

I mandatory

(0) provision exists for exceeding the limits in the event of exceptional geographical or meteorological conditions

(1) when a sampling taken in previous years produced results which are appreciably better than those in this Annex and when no new factor likely to lower the quality of the water has appeared, the competent authorities may reduce the sampling frequency by a factor of 2

(2) concentration to be checked by the competent authorities when an inspection in the bathing area shows that the substance may be present or that the quality of the water has deteriorated

(3) these parameters must be checked by the comptent authorities when there is a tendency towards the eutrophication of the water.

TABLE XXIII - Quality criteria for protection of aquatic life (78/659 EEC Directive) /23/
(G = guide, I = Mandatory)

Parameter	Salmonid waters G	Salmonid waters I	Cyprinid waters G	Cyprinid waters I	Observations
1. Temperature (°C)	Temperature measured downstream of a point of thermal discharge (at the edge of the mixing zone) must not exceed the unaffected temperature by more than: 1.5°C(1)			3°C(1)	(1) Temperature limits may, however, be exceeded for 2% of the time.
2. Dissolved oxygen ($mg/l\ O_2$)	50%≥9 100%≥7	50%≥9(2)	50%≥8 100%≥7	50%≥7(3)	(2) When the oxygen concentration falls below 6 mg/l, Member States shall implement the provisions of Art.7. The competent authority must prove that this situation will have no harmful consequences for the balanced development of the fish population. (3) When the oxygen concentration falls below 4 mg/l, Member states shall implement the provisions of Art.7. The competent authority must prove that this situation will have no harmful consequences for the balanced development of the fish population.
3. pH		6 to 9(4)		6 to 9(4)	(4) Derogations are possible in accordance with Art.11. Artificial pH variations with respect to the unaffected values shall not exceed ± 0.5 of a pH unit within the limits falling between 6.0 and 9.0 provided that these variations do not increase the harmfulness of other substances present in the water.
4. Suspended solids (mg/l)	≤ 25(5)		≤ 25(5)		(5) The values shown are average concentrations and do not apply to suspended solids with harmful chemical properties. Floods are liable to cause particularly high concentrations.
5. BOD_5 ($mg/l\ O_2$)	≤ 3		≤ 6		
6. Total phosphorus (mg/l P)	In the case of lakes of average depth between 18 and 300 m, the following formula could be applied: $L \leq 10\ \bar{Z}/Tw\ (1 + \sqrt{Tw})$, where L = loading expressed as mg P per m^2 lake surface in one year; $\bar{Z}$ = mean depth of lake in metres; Tw = theoretical renewal time of lake water in years. In other cases limit values of 0.2 mg/l for salmonid and of 0.4 mg/l for cyprinid waters, expressed as PO_4, may be regarded as indicative in order to reduce eutrophication.				
7. Nitrites ($mg/l\ NO_2$)	≤0.01		≤0.03		
8. Phenolic compounds ($mg.l\ C_6H_5OH$)		(5)		(5)	(5) An examination by taste shall be made only where the presence of phenolic compounds is presumed. Phenolic compounds must not be present in such concentrations that they adversely affect fish flavour.
9. Petroleum hydrocarbons		(6)		(6)	(6) A visual examination shall be made regularly once a month, with an examination by taste only where the presence of hydrocarbons is presumed. Petroleum products must not be present in water in such quantities that they form a visible film on the surface of the water or form coatings on the beds of water-courses and lakes; impart a detectable "hydrocarbon" taste to fish; or produce harmful effects in fish.
10. Non-ionized ammonia ($mg/l\ NH_3$)	≤ 0.005	≤ 0.025	≤ 0.005	≤ 0.025	Values for non-ionized ammonia may be exceeded in the form of minor peaks in the daytime.
	In order to diminish the risk of toxicity due to non-ionised ammonia, of oxygen consumption due to nitrification and of eutrophication, the concentrations of total ammonium should not exceed the following:				
11. Total ammonium ($mg/l\ NH_4$)	≤ 0.04	≤ 1 (7)	≤ 0.2	≤ 1 (7)	(7) In particular geographical or climatic conditions and particularly in cases of low water temperature and of reduced nitrification or where the competent authority can prove that there are no harmful consequences for the balanced development of the fish population, Member States may fix values higher than 1 mg/l.
12. Total residual chlorine (mg/l HOCl)		≤ 0.005		≤ 0.005	The I-values correspond to pH = 6. Higher concentrations of total chlorine can be accepted if the pH is higher.
13. Total zinc (mg/l Zn)		≤ 0.3		≤ 1.0	The I-values correspond to a water hardness of 100 mg/l $CaCO_3$.
14. Dissolved copper (mg/l Cu)	≤ 0.04		≤ 0.04		The G-values correspond to a water hardness of 100 mg/l $CaCO_3$.

TABLE XXIV - Water quality criteria for protection of aquatic life from other international organizations

	U.S. EPA /35/		FD MAF Netherlands /36/		IWD Canada /20/	FAO /33/	
	Salmonid waters	Cyprinid waters	Intermediate value	Objective		Salmonid waters	Cyprinid waters
Temperature ΔT °C	(2)	(2)				2(1)	2(1)
Dissolved oxygen mg/l	5	5			4	9	5
O_2 saturation			70–130	100			
pH	6.5–9	6.5–9	6–9	6.5–8.7	6.5–9	5–9	5–9
Suspended solids mg/l	25	80	80	25	25	80	80
BOD_5 mg/l		5	3				
Total phosphorus mg/l		0.26	0.05	0.25			
Elemental phosphorus mg/l	0.01	0.01					
Nitrite μg/l	60						
Phenols μg/l	1	1	5	1	1	1000	2000
Mineral oils μg/l	FA = 0.01(7)	FA = 0.01(7)	50	20			
Unionized ammonia μg/l N	20	20	20	20	20	25	25
Total ammonia μg/l N					500		
Residual chlorine (HOCl) μg/l	2	10			2	4	4
Chloride mg/l Cl			200	150			
Fluoride mg/l F			1.5	1			
Alkalinity meq/l	25%(8)	25%(8)			20%(8)		
Sulphate mg/l SO_4			150	150			
Sulphide (H_2S) μg/l					2		
Silicates mg/l Si				10			
Cyanide (HCN) μg/l	5	5	10		5		
Silver μg/l Ag	FA = 0.01(7)	FA = 0.01(7)			0.1		
Arsenic μg/l As	50	50	50	5	50		
Aluminium μg/l Al					100		
Barium μg/l Ba				50			
Beryllium μg/l Be	11(9)			500	11		
Boron μg/l B				50			
Cadmium μg/l Cd	0.4(9) 1.2(10)	4(9)12(10)	3	0.5	0.2	0.6(11)1.5(12)	20(11)50(12)
Dobalt μg/l Co			2	0.5			
Total chromium μg/l Cr	100	100	50	10	40		
Copper μg/l Cu	FA = 0.1(7)	FA = 0.1(7)	20	5	5	5(11)12(12)	20(11)50(12)
Iron μg/l Fe	1000	1000	1000	700	300		
Mercury μg/l Hg	905	905	0.5	0.05	0.1		
Manganese μg/l Mn	100	100	200	50			
Nickel μg/l Ni	FA = 0.01(7)	FA = 0.01(7)	50	5	25		
Lead μg/l Pb	FA = 0.01(7)	FA = 0.01(7)	50	5	30		
Selenium μg/l Se	FA = 0.01(7)	FA = 0.01(7)	10	0.5			
Titanium μg/l Ti				10			
Vanadium μg/l V				10	1		
Zinc μg/l Zn	FA = 0.01(7)	FA = 0.01(7)	100	10	30	30(11)500(12)	300(11)2000(12)
Surfactants μg/l			200		500		
Total organichlorine pesticides μg/l			0.1				
Single organichlorine pesticides μg/l			0.01				
Poly-chloridated biphenyls μg/l			0.1				

Explanatory notes to Table XXIV

1. The temperature measured downstream of a thermal discharge must not exceed the values upstream by more than the values indicated.

2. A limit is not indicated, but rather a criterion which can be applied to each water body. In general it is suggested that the temperature upstream should not be exceeded by more than 2°C.

3. Value which must be exceeded in at least 50% of measurements.

4. Value which must be exceeded in at least 100% of measurements.

5. Must not be present in concentrations which give a taste to the flesh of the fish.

6. The hydrocarbons of petroliferous origin must not be present in quantities such as to:
   - form a visible film on the water surface or on the bottom of lakes or rivers;
   - give a taste to the flesh of fish;
   - produce damaging effects in fish.

7. FA = application factor. The concentration must not exceed the value of the LC_{50} at 96 hours, evaluated on sensitive autochthonous species, multiplied by the application factor.

8. The alkalinity of the water body must not be reduced or increased by more than the value indicated.

9. Limits for water with low hardness (75 mm/l $CaCO_3$).

10. Limits for hard water (150 mg/l $CaCO_3$).

11. Limits for water with low hardness (100 mg/l $CaCO_3$).

12. Limits for hard water (300 mg/l $CaCO_3$).

G = guideline; I = obligatory value.

TABLE XXV - Criteria for protection of aquatic life, derived from synthesis and integration of the criteria reported in Tablex XXIII and XXIV

		Salmonid waters		Cyprinid waters	
		Mandatory	Guide	Mandatory	Guide
Temperature	ΔT °C	1.5 (1)	1.5 (1)	3 (1)	3 (1)
Dissolved O_2	mg/l	50%>9(2) 100%>6 (3)	50%>9(2) 100%>7(3)	50%>7(2) 100%>4(3)	50%>8(2) 100%>5(3)
Dissolved O_2 sat.	%	50%>100(2) 100%>65(3)	50%>100(2) 100%>75(3)	50%>85(2) 100%>50(3)	50%>100(2) 100%>60(3)
pH		6 - 9	6.5 - 8.7	6 - 9	6.5 - 8.7
Alkalinity	meq/l	25% (5)	20% (5)	25% (5)	20% (5)
Suspended solids	mg/l	<80 (6)	<25 (6)	<80 (6)	<25 (6)
BOD_5	mg/l	<5	<3	<10	<7
Chlorides	mg/l Cl	<200	<150	<200	<200
Residual chlorine(HOCl)	µg/l	<5	<2	<5	<2
Sulphates	mg/l SO_4	<250	<150	<250	<150
Total phosphorus	µg/l P	<100-40 (7)	<100-50 (7)	<100-50 (7)	<100-50 (7)
Non-ionized ammonia	µg/l	<20	<4	<20	<4
Total ammonia	µg/l NH_4	<200	<40	<800	<400
Nitrites	µg/l N	<10	<5	<50	<10
Fluorides	µg/l F	<1.5	<1	<1.5	<1
Silver	µg/l Ag	<0.4 (8)	<0.1 (9)	<0.4 (8)	<0.1 (9)
Aluminium	µg/l Al	<100	<100	<100	<100
Arsenic	µg/l As	<25	<10	<50	<25
Boron	µg/l B	<200	<100	<200	<100
Barium	µg/l Ba	<100	<50	<100	<50
Beryllium	µg/l Be	<10	<10	<10	<10
Cadmium	µg/l Cd	<0.5(10) - <1.5(11)	<0.5(10) - <1.5(11)	<4(10 - <12(11)	<0.5(10) - <1.5(11)
Cobalt	µg/l Co	<2	<0.5	<2	<0.5
Total chromium	µg/l Cr	<50	<10	<100	<50
Copper	µg/l Cu	<10	<5	<20	<10
Iron	µg/l Fe	<1000	<300	<1000	<300
Mercury	µg/l Hg	<0.5	<0.1	<0.5	<0.1
Silicates	mg/l Si	<10	<5	<20	<10
Manganese	µg/l Mn	<200	<50	<200	<50
Nickel	µg/l Ni	<25	<5	<25	<5
Lead	µg/l Pb	<25	<5	<25	<5
Selenium	µg/l Se	<10	<5	<10	<5
Tin	µg/l Sn	<25 (12)	<5 (12)	<25 (12)	<5 (12)
Zinc	µg/l Zn	<100	<50	<100	<50
Phenols	µg/l	<5 (13)	<1 (13)	<5 (13)	<1 (13)
Mineral oils	µg/l	<50 (14)	<20 (14)	<100 (14)	<20 (14)
Total surfactants	mg/l	<0.5	<0.2	<0.5	<0.2
Pesticides, total organochlorine	µg/l	<0.1	<0.1	<0.1	<0.1
Pesticides, single organochlorine	µg/l	<0.01	<0.01	<0.01	<0.01
PCB and PCT	µg/l	<0.1	<0.01	<0.1	<0.01
Pesticides, total organophosphorus	µg/l	<0.2	<0.2	<0.2	<0.2
Pesticides, single organophosphorus	µg/l	<0.1	<0.1	<0.1	<0.1

Explanatory notes to Table XXV

1. For water courses the temperature measured downstream of a discharge, within 50 m of the immission point, must not exceed the values upstream by more than the values indicated. For lakes the comparison must be made with the temperature measured in three points on an arc 250 metres from the immission point.

2. Value that must be exceeded in more than 50% of cases.

3. Value that must be exceeded in all cases.

4. The values indicated for the saturation percentage (3) have been determined from values of mg/l O_2 considering a limiting temperature of 20°C for salmonid waters and 25°C for cyprinic waters.

5. The natural alkalinity of the water body must not be reduced or increased by more than the value indicated.

6. This limit may be departed from in water courses with particular hydrological conditions in which there are natural enrichments without effects caused by man.

7. The limits indicated refer exclusively to flowing waters. For water courses which are lake tributaries they must not exceed 50 µg/l P in the closure section. For lakes, as an obligatory limit, they must not exceed 50 µg/l P as average over the water column in the period of circulation; the objective limit is that which corresponds to the natural phosphorus concentration which can be derived as a function of the morphoedaphic index according to the following equation: $\log P = 0.87 + 0.3 \log IME_{cond}$, increased by 25%.

8. Deduced from the 96 h LC_{50} values for sensitive species, multiplied by the application factor equal to 0.01.

9. Because of the extreme long-term toxicity of silver the Great Lakes Water Quality Board recommends a limit of 0.1 µg/l (1978).

10. In waters at a hardness lower than 150 mg/l as $CaCO_3$.

11. In waters at a hardness in excess of 150 mg/l as $CaCO_3$.

12. Damaging effects for aquatic life mainly due to the presence of organotin compounds.

13. Criterion of quality for the chlorophenols.

14. Measured by IR spectrometry after extraction with carbon tetrachloride.

TABLE XXVI - Standards for trace substances-dependence on hardness of standards for protection of freshwater fish and other freshwater life /24/. (All concentrations in µg/l. Standards expressed as dissolved concentration, relative to annual average, except where stated).

		< 50	50-100	100-150	150-200	200-250	> 250
Protection of salmonid freshwater fish at hardness (mg/l $CaCO_3$)							
Arsenic	as As	50	50	50	50	50	50
Cadmium	as Cd	5*(2)*	5*(2)*	5*(2)*	5*(2)*	5*(2)*	5*(2)*
Chromium	as Cr	5	10	20	20	50	50
Copper	as Cu	1*(3)* 5*(4)*	6*(3)* 22*(4)*	10*(3)* 40*(4)*	10*(3)* 40*(4)*	10*(3)* 40*(4)*	28*(3)* 112*(4)*
Lead	as Pb	4	10	10	20	20	20
Mercury	as Hg	1*(5)*	1*(5)*	1*(5)*	1*(5)*	1*(5)*	1*(5)*
Nickel	as Ni	50	100	150	150	200	200
Zinc	as Zn	10*(6)* 30*(7)*	50*(6)* 200*(7)*	75*(6)* 300*(7)*	75*(6)* 300*(7)*	75*(6)* 300*(7)*	125*(6)* 500*(7)*
Protection of coarse freshwater fish at hardness (mg/l $CaCO_3$)							
Arsenic	as As	50	50	50	50	50	50
Cadmium	As Cd	5*(2)*	5*(2)*	5*(2)*	5*(2)*	5*(2)*	5*(2)*
Chromium	as Cr	150	175	200	200	250	250
Copper	as Cu	1*(3)* 5*(4)*	6*(3)* 22*(4)*	10*(3)* 40*(4)*	10*(3)* 40*(4)*	10*(3)* 40*(4)*	28*(3)* 112*(4)*
Lead	as Pb	50	125	125	250	250	250
Mercury	as Hg	1*(5)*	1*(5)*	1*(5)*	1*(5)*	1*(5)*	1*(5)*
Nickel	as Ni	50	100	150	150	200	200
Zinc	as Zn	75*(6)* 300*(7)*	175*(6)* 700*(7)*	250*(6)* 1000*(7)*	250*(6)* 1000*(7)*	250*(6)* 1000*(7)*	500*(6)* 2000*(7)*
Protection of other freshwater life at hardness (mg/l $CaCO_3$)							
Arsenic	as As	130	150	150	150	150	150
Cadmium	as Cd	5*(2)*	5*(2)*	5*(2)*	5*(2)*	5*(2)*	5*(2)*
Chromium	as Cr	5	10	20	20	50	50
Copper	as Cu	1*(8)*	6*(8)*	10*(8)*	10*(8)*	10*(8)*	28*(8)*
Lead	as Pb	5	60	60	60	60	60
Mercury	as Hg	1*(5)*	1*(5)*	1*(5)*	1*(5)*	1*(5)*	1*(5)*
Nickel	as Ni	8	20	50	50	100	100
Zinc	as Zn	100	100	100	100	100	100

Explanatory notes to Table XXVI

1. Defines as total chromium (i.e. Cr III + Cr VI).

2. Total concentration (i.e. dissolved plus particulate).

3. Applies in waters not specifically designated under the appropriate Directive (i.e. the Directive concerning the quality of water required to support fish life). A higher value may be acceptable where acclimation is expected or copper is present in organic complexes.

4. Applies only in waters specifically designated under the appropriate Directive (i.e. the Directive concerning the quality of water required to support fish life). This is a guide value, defined as a 95 percentile. The 112 µg/l standard only applies at a hardness in excess of 300 mg/l as $CaCO_3$.

5. Applies to all waters affected by discharges likely to contain mercury. Refers to the total concentration (dissolved plus particulate) defined as an annual average.

6. Applies in waters not specifically designated under the appropriate Directive (i.e. the Directive concerning the quality of water required to support freshwater fish life).

7. Applies only in waters specifically designated under the appropriate Directive (i.e. the Directive concerning the quality of water required to support freshwater fish life). This is a mandatory value, referring to the total zinc concentration (dissolved plus particulate) defined as a 95 percentile. The 500 and 2000 µg/l standards, for salmonid and coarse fish waters, respectively, only apply at a hardness in excess of 500 mg/l as $CaCO_3$.

8. A higher value may be acceptable where acclimation is expected or copper is present in organic complexes.

TABLE XXVII- Quality objectives for multiple use of surface resources with regard to its classification /10/

		Category A	Category B	Category C	Category D
Temperature	ΔT °C	1.5 (1)	1.5 (1)	3 (1)	3 (1)
Dissolved O_2	mg/l	50%>9(2) 100%>7(3)	50%>9(2) 100%>7(3)	50%>8(2) 100%>5(3)	50%>7(2) 100%>4(3)
Dissolved O_2, sat.	%	50%>100(2) 100%>75(3)	50%>100(2) 100%>75(3)	50%>100(2) 100%>60(3)	100%>45(3)
pH		6.5 - 8.5	6.5 - 8.5	6 - 9	6 - 9
Alkalinity	meq/l	20% (4)	25% (4)	25% (4)	25% (4)
Colour Pt scale	mg/l	<10	<50	<50	<100
Taste (dil. factor at 25°C)		<3	<10	<20	<20
Transparency	m	<1	<1	<1	<0.5
Conductability	µS	<1000	<1000	<1000	<1000
Suspended solids	mg/l	<25 (5)	<25 (5)	<25 (5)	<80 (5)
BOD_5	mg/l	<3	<5	<7	<10
COD	mg/l	<10	<15	<20	<30
Chlorides	mg/l Cl	<150	<150	<150	<150
Residual chlorine (HOCl)	µg/l	<5	<5	<5	<5
Sulphates	mg/l SO_4	<150	<150	<150	<250
Total phosphorus:	µg/l P				
running waters		<50 (6)	<50 (6)	<50-100 (6)	<50-100 (6)
lake waters		<10 (6)	<20 (6)	<50 (6)	<100 (6)
Non-ionized ammonia	µg/l N	<4	<10	<20	<20
Total ammonium	µg/l NH4	<40	<200	<400	<800
Nitrites	µg/l N	<5	<10	<20	<40
Nitrates	mg/l N	<5	<10	<10	<20
Fluorides	µg/l F	<1	<1.5	<1.5	<1.5
Silver	µg/l Ag	<0.1	<0.1	<0.1	<0.4
Aluminium	µg/l Al	<100	<100	<100	<100
Arsenic	µg/l As	<10	<25	<50	<50
Boron	µg/l B	<100	<200	<200	<200
Barium	µg/l Ba	<50	<100	<100	<100
Beryllium	µg/l Be	<10	<10	<10	<10
Cadmium	µg/l Cd	<0.5	<1	<2	<5
Cobalt	µg/l Co	<0.5	<2	<2	<2
Total chromium	µg/l Cr	<10	<50	<50	<100
Copper	µg/l Cu	<5	<10	<10	<20
Iron	µg/l Fe	<100	<300	<1000	<1000
Mercury	µg/l Hg	<0.1	<0.1	<0.5	<0.5
Silicates	mg/l Si	<10	<10	<20	<20
Manganese	µg/l Mn	<50	<100	<100	<200
Nickel	µg/l Ni	<5	<10	<25	<25
Lead	µg/l Pb	<5	<10	<25	<25
Selenium	µg/l Se	<5	<5	<5	<10
Tin	µg/l Sn	<5 (7)	<5 (7)	<25 (7)	<25 (7)
Total zinc	µg/l Zn	<50	<50	<100	<100
Cyanides	µg/l	<5	<5	<10	<10
Phenols (C_6H_5OH)	µg/l	<1 (8)	<4 (8)	<5 (8)	<5 (8)
Mineral oils	µg/l	<20 (9)	<20 (9)	<50 (9)	<100 (9)
Total surfactants	µg/l	<200	<200	<500	<500
Pesticides, total organochlorine	µg/l	<0.1	<0.1	<0.1	<0.1
Pesticides, single organochlorine	µg/l	<0.01	<0.01	<0.01	<0.01
PCB and PCT	µg/l	<0.01	<0.01	<0.01	<0.1
Pesticides, total organophosphorus	µg/l	<0.2	<0.2	<0.2	<0.2
Pesticides, single organophosphorus	µg/l	<0.1	<0.1	<0.1	<0.1
Total dissolved or emulsionized hydrocarbons (petroleum ethers)	µg/l	<50	<200	<500	<1000
PAH	µg/l	<0.2	<0.2	<1	<1
Total coliforms	/100 ml	<50	<2000	<5000	<5000
Faecal coliforms	/100 ml	<20	<100	<1000	<1000
Faecal streptococci	/100 ml	<20	<100	<1000	<1000
Salmonella		abs. in 5 l	abs. in 1 l	abs. in 1 l	abs. in 1 l
SAR index		<10	<10	<10	<18

Explanatory notes to Table XXVII

Key to symbols

Category A	drinking water supply, class 1 (see page 12)
Category B	drinking water supply, class 2
Category C	drinking water supply, class 3
Category D	fishery class 2

Footnotes

1. The temperature measured downstream of a thermal discharge, within 50 m from the point of immission, must not exceed the levels upstream by more than the values indicated. For lakes the comparison must be made with the temperature measured in three points on an arc 250 m from the immission point.
2. Value which must be exceeded in at least 50% of measurements.
3. Value which must be exceeded in 100% of measurements.
4. The natural alkalinity of the water body must not be reduced or increased by more than the value indicated.
5. This limit may be departed from in water courses with particular hydrological conditions in which there are natural enrichments without effects caused by man.
6. For running waters in classes C and D, the limit of 50 µg/l can be applied to lake tributary waters in the closure section, while the value of 100 µg/l is applicable to all the other waters. For lake waters the values reported are purely indicative, in that the limit value for each environment in general is evaluated as a function of the concentration of natural phosphorus which can be derived from the values of the morphoedaphic index according to the formula: $\log P = 0.87 + 0.3 \log IME_{cond}$. The final objective quality criterion must correspond to the natural phosphorus value increased by 25% for all the environments.

7. Damaging effects for aquatic life caused mainly by the presence of organotin compounds.

8. Criterion of quality for the chlorophenols.

9. Measured by IR spectrometry after extraction with carbon tetrachloride.

TABLE XXVIII-Average values of some chemical parameters for major Italian lakes (IRSA)/13/

Lakes	Σ ions meq/l	Alkalinity meq/l	Sulphates meq/l	Chlorides meq/l	Conducibility μS	Calcium meq/l	Magnesium meq/l	Na+K meq/l
Como	3.65	1.21	0.51	0.03	182	1.29	0.44	0.11
Garda	4.86	2.10	0.21	0.06	202	1.61	0.68	0.13
Iseo	6.46	1.77	1.30	0.10	256	2.30	0.68	0.13
Lugano	4.80	2.22	0.26	0.08	178	1.70	0.71	0.19
Maggiore	2.96	0.78	0.59	0.06	136	1.07	0.30	0.12
Orta	2.80	0.10	0.72	0.09	147	0.22	0.26	0.32
Varese	7.14	2.61	0.70	0.28	296	2.31	0.62	0.45

TABLE XXIX - Average concentrations for trace elements in some Italian lakes (IRSA) /13/
For comparison, data for other environments are also given

Lake	Cd µg/l	Co µg/l	Cr µg/l	Cu µg/l	Hg µg/l	Ni µg/l	Pb µg/l
Annone Est	x	x	x	x	x	x	x
Annone Ovest	x	x	x	x	x	x	x
Alserio	x	x	x	x	x	x	x
Garda	-	x	-	-	x	-	-
Iseo	x	x	x	1.0	x	x	0.9
Maggiore	-	-	1.2	2.3	-	2.6	-
Montorfano	x	x	x	x	x	x	x
Pusiano	x	x	x	x	x	x	x
Segrino	x	x	x	x	x	x	x
Varese	0.15	x	5.2	4.1	x	x	1.9
Bodensee /25/	0.006-0.02	-	-	0.3-0.8	-	-	0.05-0.1
Michigan /25/	0.3	0.18	1.7	5	0.027	3.0	1.5
Swedish acidified lakes (pH = 4.1) /25/	0.3	Zn=30	AL=600				1
Natural levels /26/	-	0.9	0.18	0.10	0.08	10	5

x = value lower than minimum detectable concentration with the method, respectively:
Cd = 0.06 µg/l, Co = 2 µg/l, Cr = 0.8 µg/l, Cu = 0.2 µg/l, Hg = 0.09 µg/l,
Ni = 2 µg/l, Pb = 0.5 µg/l.

TABLE XXX - The potential ecological risk factors (E_r^i-values) and risk indices (Ri-values) of 12 Italian lakes (Premazzi et al.,) /14/

Risk index (RI)	Lake/basin	RI	Ecological risk factor (E_r^i): very high $E_r^i \geq 400$	high $400 > E_r^i \geq 200$	considerable $200 > E_r^i \geq 100$	moderate $100 > E_r^i \geq 50$	low $E_r^i \geq 50$
very high $RI \geq 320$	Orta/Pettenasco	700	Cr	-	Hg	-	Cd > Cu > Zn > Pb
	Garda/Peschiera	519	-	Hg*)	Cd	-	Cr > Zn > Cu > Pb
	Monate	431	-	Hg*)	-	Cd	Zn > Pb > Cr > Cu
	Segrino	410	-	Hg	-	-	Pb > Cr > Cd = Zn > Cu
considerable $160 \leq RI < 320$	Garda/Desenzano	316	-	Hg*)	-	-	Cd > Zn > Cr > Cu > Pb
	Como/Lecco	312	-	-	Hg*) Cd	-	Cr = Zn > Cu = Pb
	Mergozzo	258	-	-	Hg	Cd	Zn > Pb > Cr > Cu
	Caldonazzo	258	-	Hg	-	-	Cd > Zn = Pb > Cr = Cu
	Orta/Omegna	249	-	-	Cr	Hg	Cd > Cu > Zn > Pb
	Pusiano	196	-	-	Hg	-	Cr > Cd > Pb > Zn > Cu
	Lugano/Agno	185	-	-	Hg*)	-	Cd > Cr > Zn = Pb > Cu
moderate $80 \leq RI < 160$	Como/Como	126	-	-	-	Hg*)	Cd > Cr > Zn = Cu = Pb
	Annone Est	117	-	-	-	-	Hg > Pb > Cr = Zn > Cd > Cu
	Comabbio	116	-	-	-	Cd	Hg > Cr > Zn > Cu = Pb
	Alserio	100	-	-	-	Hg	Cd > Pb > Cr > Zn > Cu

*) hypothetical: no data available on terrestrial compartment of the ecosystem.

TABLE XXXI - Trace elements in major Italian rivers. The levels are expressed in µg/l and refer to the filtered sample at 0.45 µm /15/

River	Fe	Mn	Zn	Cu	Pb	Cd	Cr	As	Se	V
Adige	21	3	3.2	0.50	0.18	0.065	0.55	0.300	0.008	0.2
Arno	10	8	5.8	0.5	0.16	0.080	1.20	0.050	0.008	0.4
Biferno	36	37	4.1	0.6	0.25	0.060	0.12	0.080	0.080	0.2
Garigliano	27	19	1.7	0.3	0.20	0.050	0.10	0.075	0.015	0.2
Isonzo	11	0.4	1.0	0.22	0.07	0.030	0.28	0.015	0.009	0.2
Magra	11	8	2.0	0.4	0.08	0.040	0.22	0.020	0.006	0.2
Ofanto	16	18	2.0	0.8	0.30	0.060	0.10	0.080	0.055	0.2
Pescara	35	13	4.1	1	0.4	0.085	0.35	0.280	0.015	0.2
Piave	20	6	1.6	0.25	0.07	0.065	0.18	0.015	0.002	0.2
Po (Lagoscuro)	5	13	2.5	0.45	0.15	0.055	0.90	0.380	0.015	0.2
Po (Pavia)	21	514	4.0	0.6	0.21	0.055	1.00	0.650	0.025	0.2
Reno	14	69	1.8	0.4	0.18	0.080	0.18	0.280	0.035	0.2
Sele	26	32	1.2	0.3	0.20	0.055	0.11	0.080	0.030	0.2
Tagliamento	10	4	1.5	0.25	0.08	0.055	0.10	0.055	0.009	0.2
Tevere	41	28	2.8	0.30	0.12	0.070	0.10	0.075	0.060	0.35
Ticino	7	9	1.5	0.3	0.08	0.070	0.80	0.620	0.020	0.8
Volturno	7	24	1.9	0.5	0.18	0.070	0.12	0.090	0.018	0.35

TABLE XXXII - Average values of total P concentration for the most important Italian lakes

Lake	Total P concentration $mg.m^{-3}$
Garda	10
Bracciano	10
Maggiore	25
Bolsena	25
Iseo	32
Como	67
Lugano	175
Varese	408

TABLE XXXIII - Classification of major Italian lakes and rivers for multiple uses[1]

Lakes	present category	natural category
Bolsena	C	A
Bracciano	B	A
Comabbio	I	C
Como	D	A
Garda	B	A
Iseo	C	A
Lugano	I	A
Maggiore	C	A
Varese	I	B
Rivers		
Adda	I (a)	B
Adige	D (a)	B
Arno	I (a)	C
Po	I (a)	C
Tevere	I (a)	C
Ticino	I/D (a)	B

(1) Numerical values of water quality objectives for different categories are reported in Table XXVII.

(a) This class is mainly attributed on the basis of microbiological considerations.

TABLE XXXIV - Common pollutants of freshwaters /27/

Medium	Physical state	Substances and sources			
		Domestic			
		Primary	Secondary	Industrial	Agricultural
Fresh waters	Dissolved	Organic body wastes → Detergents → Pharmaceuticals Cosmetics Pesticides Metal salts	Nitrates Phosphates Carbonates Phosphates	Very wide range of organic substances: detergents pharmaceuticals oils pesticides metal salts	Concentrated organic livestock wastes: phosphates nitrates Pesticides
	Suspended	Organic and inorganic particles		Organic and inorganic particles	Organic and soil particles

TABLE XXXV - Ecosystem recovery times /28/

Freshwater	
a) Lotic systems	
- fast flowing streams	3 - 5 years
- slow flowing rivers	5 - 10 years
b) Lentic systems	
- small ponds	10 years
- large lakes never recover their original state without human intervention	
Marine	
a) Intertidal shore	
- sand beach	1 - 2 years
- rocky shore	5 - 10 years
- tidal flats	5 - 10 years
b) Intertidal wetlands	
- marshes	10 - 20 years
- mangrove swamps	20 - 80 years
c) Subtidal systems	
- seagrass systems	50 years
- coral reefs	10 - 20 years
- soft bottom benthos	10 years minimum