PARAMETERS OF WATER QUALITY

INTERPRETATION AND STANDARDS

ENVIRONMENTAL PROTECTION AGENCY
An Ghníomhaireacht um Chaomhnú Comhshaoil

Environmental Protection Agency

Establishment
The Environmental Protection Agency Act, 1992, was enacted on 23 April, 1992, and under this legislation the Agency was formally established on 26 July, 1993.

Responsibilities
The Agency has a wide range of statutory duties and powers under the Act. The main responsibilities of the Agency include the following:

- the licensing and regulation of large/complex industrial and other processes with significant polluting potential, on the basis of integrated pollution control (IPC) and the application of best available technologies for this purpose;

- the monitoring of environmental quality, including the establishment of databases to which the public will have access, and the publication of periodic reports on the state of the environment;

- advising public authorities in respect of environmental functions and assisting local authorities in the performance of their environmental protection functions;

- the promotion of environmentally sound practices through, for example, the encouragement of the use of environmental audits, the setting of environmental quality objectives and the issuing of codes of practice on matters affecting the environment;

- the promotion and co-ordination of environmental research;

- the licensing and regulation of all significant waste disposal and recovery activities, including landfills and the preparation and periodic updating of a national hazardous waste management plan for implementation by other bodies;

- implementing a system of permitting for the control of VOC emissions resulting from the storage of significant quantities of petrol at terminals;

- implementing and enforcing the GMO Regulations for the contained use and deliberate release of GMOs into the environment;

- preparation and implementation of a national hydrometric programme for the collection, analysis and publication of information on the levels, volumes and flows of water in rivers, lakes and groundwaters; and

- generally overseeing the performance by local authorities of their statutory environmental protection functions.

Status
The Agency is an independent public body. Its sponsor in Government is the Department of the Environment and Local Government. Independence is assured through the selection procedures for the Director General and Directors and the freedom, as provided in the legislation, to act on its own initiative. The assignment, under the legislation, of direct responsibility for a wide range of functions underpins this independence. Under the legislation, it is a specific offence to attempt to influence the Agency, or anyone acting on its behalf, in an improper manner.

Organisation
The Agency's headquarters is located in Wexford and it operates five regional inspectorates, located in Dublin, Cork, Kilkenny, Castlebar and Monaghan.

Management
The Agency is managed by a full-time Executive Board consisting of a Director General and four Directors. The Executive Board is appointed by the Government following detailed procedures laid down in the Act.

Advisory Committee
The Agency is assisted by an Advisory Committee of twelve members. The members are appointed by the Minister for the Environment and Local Government and are selected mainly from those nominated by organisations with an interest in environmental and developmental matters. The Committee has been given a wide range of advisory functions under the Act, both in relation to the Agency and to the Minister.

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PARAMETERS OF WATER QUALITY
Interpretation and Standards

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The definitive sources of the water quality standards quoted in this publication are the relevant European Union Directives and the national Statutory Instruments which contain the corresponding Regulations.

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LIST OF ABBREVIATIONS

[A] / [B] / [C] / [D]	Indicate (in increasing order) four *arbitrary* classifications of complexity of analytical techniques. Thus, [A] indicates a basic technique which is found in virtually any laboratory; [D] denotes a technique of high sophistication which will be available in only specialised laboratories. Further, the use of more than one classification - e.g. [B]/[C] - indicates that there are two techniques commonly used for the particular determination, one more complex than the other.
(S)	Salmonid waters - Freshwater Fish Directive/Salmonid Water Regulations
(C)	Cyprinid waters - Freshwater Fish Directive
G [value]	Guide [advisory] value in EU Directives
I [value]	Mandatory [imperative] value in EU Directives
MAC	Maximum admissible concentration - 1980 Drinking Water Directive/ 1988 Regulations
MRC	Minimum required concentration - 1980 Drinking Water Directive/1988 Regulations
NLV	National Limit Value - fixed in accordance with Directives/corresponding Regulations
n/a	Not applicable

GLOSSARY OF TERMS

A1 waters | A2 waters | A3 waters	The water categories in the 1975 Surface Water Directive/1989 Regulations.
Cyprinid waters	Waters of a quality sufficient to support coarse but not game fish.
Salmonid waters	Waters of a quality sufficient to support game fish.
96-hour LC_{50}	The concentration of a toxic material which will bring about the death of 50 per cent of the species under test in 96 hours.
Organoleptic tests/ properties	Tests for and characteristics of parameters which depend on or affect the senses of smell and taste.

UNITS OF EXPRESSION

µg/l x	micrograms per litre of substance x, expressed as x
mg/l x	milligrams per litre of substance x, expressed as x
ng/l x	nanograms per litre of substance x, expressed as x.

PRINCIPAL RELEVANT ATOMIC WEIGHTS

Calcium (Ca)	40	Nitrogen (N)	14
Carbon (C)	12	Oxygen (O)	16
Chlorine (Cl)	35.5	Phosphorus (P)	31
Hydrogen (H)	1	Sulphur (S)	32.

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IMPORTANT NOTICE

Readers are advised that this document, as posted on the Environmental Protection Agency website, is a slightly reformatted version of the published volume of the same name, which was issued by the E.P.A. in 2001. The content of this present version is identical to that of the latter and has not been updated or revised. Therefore, readers should be aware that additional Regulations may now be in force and, if so, they should be taken into account when considering the subject matter of this document.

A Note on Sources

The most relevant sources for the present volume are unquestionably the various Directives relating to water which have been adopted by the Council of the European Union over a period of some 25 years. All the standards which are cited herein originate in the respective Directives, although in many cases successive Ministers for the Environment (and Local Government) have made national Regulations which transpose the provisions of the corresponding Directives into Irish law. In making the Regulations, the respective Ministers have generally adopted the same limit values for the individual parameters as are given in the original Directives. However, there are some important exceptions where a Minister has fixed a standard which is stricter than in the Directive.

In this volume, Regulations (where they have been made) are cited as they have precedence over the underlying Directive, the latter being quoted only where necessary. This scheme is necessary in the case of the Freshwater Fish Directive (78/659/EEC) which specifies parallel standards for salmonid and cyprinid waters, respectively. There are Ministerial Regulations covering the former only, and, accordingly, the coverage of the latter below is based on the Directive. The EU Directives which are quoted extensively in this handbook are listed in detail in the text below. The texts of the respective Directives have been published in the *Official Journal of the European Communities* and the appropriate references are cited. A supplementary list of Directives is set out in Appendix 5, again with *Journal* references.

The reader of previous editions of this book will note that in the present version the tables containing the standards cover EU-related legislation only, and that references to American EPA or World Health Organisation [WHO] sources have been omitted. This change has been made for two reasons. Firstly, the information presented was advisory or for guidance and had no legal force and, further, some of it was either out of date or of little current relevance. Secondly, with the future adoption by the EU of the Framework Directive in the Field of Water Policy, systems will be put in place for the incorporation of standards for any substances for which it is considered they are required. It is the intention of the EU Commission that a list of priority dangerous substances will be drawn up, with appropriate environmental quality standards [EQSs], and incorporated in the Framework Directive, and, further, that there will be future additions to the Directive as circumstances warrant.

It is important to stress, however, that one of the most important sources of all is the invaluable WHO publication *Guidelines for drinking-water quality*.[1] This is an essential reference work which should be in the hands of all concerned with the quality of drinking water. The reader should note that the only definitive sources of water quality standards in Ireland are the respective EU Directives and/or the corresponding National Regulations made in connection therewith. This volume is not a legal document.

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[1] The WHO *Guidelines for Drinking-water quality* at present comprises four volumes, as under. Of these, the first two are essential for those concerned with drinking water quality, the remaining two being strongly recommended. [1] *Guidelines for Drinking-water Quality Volume I : Recommendations*, Second Edition, Paperback 188 pages (1993), ISBN 92 4 154460 0; [2] *Guidelines for Drinking-water Quality Addendum to Volume I : Recommendations.* Paperback - 36 pages (1998), ISBN 92 4 154514 3; [3*] Guidelines for Drinking-water Quality Volume 2: Health Criteria and Other Supporting Information*, Second Edition, Hardcover - 973 pages (1996), ISBN 92 4 154480 5; [4] *Guidelines for Drinking-water Quality Volume 3: Surveillance and Control of Community Water Supplies,* Second Edition, Paperback -238 pages (1997), ISBN 92 4 154503 8.

INTRODUCTION

The present volume is a completely new edition of the handbook originally published by the Environmental Research Unit in early 1989. The latter, in turn, was based on a manual produced in October 1986 as the sixth in a series of publications for the Water Supply Distribution Training Programme of An Foras Forbartha. As with its predecessors, the present aim is to present in an immediately accessible, compact form all the relevant data and informative comment useful to the environmentalist faced with problems caused by a wide variety of water pollutants, and who may be called upon to take immediate remedial action.

In this context, the term environmentalist is used bearing in mind particularly those personnel - administrators, chemists, engineers or technicians - who are immediately charged with the implementation of national and EU legislation concerning water pollution. The present book is therefore addressed to monitoring agencies, in particular, but it is the hope that others with an active concern for or professional involvement in the field of water pollution control will find it of some value.

The aim of the handbook is to distil the principal facts and figures on a total of some 100 individual or group pollutants - information which is otherwise available, but in a wide variety of sources - into a single volume, in which the parameters are treated individually, in a generally uniform format. While there is a very large (and growing) body of scientific and technical literature in the field of water and wastewater analyses and their interpretation and significance, many publications, because of the thoroughness with which they deal with perhaps a very specialised aspect, do not contain in succinct "capsule" form those facts which are of most practical value.

Among the most relevant facts concerning each parameter are, of course, the limits (advisory or mandatory) which either scientific or medical opinion or legislative bodies consider applicable. Hence, there is a comprehensive presentation of all concentration levels specified either nationally or in the legislation of the EU. It is considered that the present compendium of guide and mandatory levels as set out in the relevant EU Directives, and the associated national Regulations made by the respective Ministers for the Environment (and Local Government) - and which is as comprehensive as possible at the time of writing - should prove a convenient reference source.

One major reason for the publication of the present handbook is the fact that the variety of analytical techniques and their complexity is growing, necessitating the presence of an increasingly high degree of specialisation in the laboratory. There is often an accordingly wide gap between those who perform a set of analyses and those who will be responsible for the interpretation of the results and the taking of any consequent action. It is the intention that this manual will help to bridge this gap.

STANDARDS OF WATER QUALITY

There are many sources of water quality criteria and standards - they may originate in the Member States of the European Union, or may be adopted by the Council or Parliament of the EU, or by individual countries, or they may be issued by international bodies.

Further, these various levels specified will take cognisance of the differing uses for which water quality must be maintained. The requirements, as regards suitability, of water for industrial use, for drinking, for boilers and so on, may differ widely and each may be quite demanding. The ultimate objective of the imposition of standards (which may necessitate extensive treatment prior to use) is the protection of the end uses, be these by humans, animals, agriculture or industry. In the present context, however, the main considerations are in regard to safeguarding public health and the protection of the whole aquatic environment. Both have very high quality requirements which complement each other to a great extent. For example, in general terms, if a river or lake water meets the most stringent fishery requirements it will meet all or virtually all other environmental quality objectives [EQOs). In fact, the EU Framework Directive in the field of Water Policy[1] defines a single EQO - achieving and maintaining "good ecological status." [2]

In Ireland the origins of the vast majority of water quality standards imposed to date are the various EU Directives which since 1975 have specified the quality required of waters for different uses. Under the most important Directives, however, the actual standards which are in legal force are enshrined in the corresponding Ministerial Regulations. These give effect in Irish law to the quality and other requirements of the Directives. It is important to bear in mind that the Minister for the Environment and Local Government has (and exercises) the power to require that national standards may be more strict than the levels laid down in the Directives. It should also be understood that, in cases where Regulations have been made in connection with a Directive, it is the Regulations which must be adhered to.

Both Directives and Regulations are aimed primarily at the safeguarding of human health by protecting both waters and fish (as part of the food chain), as well, of course, as the aquatic environment at large. Because of the importance of these Directives and Regulations and their complexity (including the interrelationship between different Directives) their main provisions are for convenience summarised below insofar as they deal with quality standards. However, sampling and analytical aspects of the Directives are not covered here. The adoption of the Framework Directive will mean that the standards enshrined in the individual water Directives will (over a period of time) be subsumed into the former and that the latter enactments will be repealed.

EU WATER QUALITY DIRECTIVES AND ASSOCIATED REGULATIONS

In the period since 1975 a total of eight "primary" Directives,[3] which are particularly relevant to the quality of water for various uses, have been adopted by the EU. Further, National Regulations have been made in connection virtually all these Directives. In the table below and, where appropriate, throughout this volume the Directives are listed in chronological order of adoption. Each Directive has an official reference number and also an official title which is in some cases quite lengthy. Familiar usage in this country and elsewhere has resulted in informal short titles being given to the Directives and it is by these designations that the Directives (and the corresponding Regulations) are generally known.

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[1] This is referred to from now on simply as the Framework Directive.

[2] This is defined in very great detail in the Directive.

[3] The total of eight includes Directive 98/83/EC of 3 November 1998 - a new Drinking Water Directive - which will replace the original Directive 80/778/EEC by 01 January 2004, at the latest.

For convenience Table 1 below sets out the reference numbers and the full and short titles. The respective dates of publication of these Directives are given in footnotes to Table 1.

A supplementary list of Directives appears in Appendix 5. These are aimed mainly at the prohibition of discharges of specific compounds or compound classes, often from particular industries. Their provisions are most important in their implications and the inclusion of these Directives in an Appendix to the main text of the present volume is not intended to diminish in any way their relevance. It simply reflects the fact that the bulk of the principal water quality standards and limit values are dealt with by Directives other than these.

Table 1

EU WATER QUALITY DIRECTIVES

No	Official Ref No	Full Title Of Directive	Short Title
1	75/440/EEC*	Council Directive of 16 June 1975 concerning the quality required of surface water intended for the abstraction of drinking water in the Member States. [4]	Surface Water
2	76/160/EEC*	Council Directive of 8 December 1975 concerning the quality of bathing water. [5]	Bathing Water
3	76/464/EEC	Council Directive of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community .[6]	Dangerous Substances
4	78/659/EEC*	Council Directive of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life.[7]	Freshwater Fish
5	79/923/EEC*	Council Directive of 30 October 1979 on the quality required of shellfish waters. [8]	Shellfish
6	80/68/EEC*	Council Directive of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances. [9]	Ground Water
7	80/778/EEC*	Council Directive of 15 July 1980 relating to the quality of water intended for human consumption. [10]	Drinking Water
8	98/83/EC	Council Directive of 3 November 1998 relating to the quality of water intended for human consumption. [11]	Drinking Water

* *The Minister for the Environment has made Regulations incorporating the requirements of the Directive; these are discussed in detail below insofar as they deal with water quality standards.*

Official Journal of the European Communities No L 194, pp 26-31, 25 July 1975.
Official Journal of the European Communities No L 31, pp 1-7, 05 February 1976
Official Journal of the European Communities No L 129, pp 23-29, 18 May 1976.
Official Journal of the European Communities No L 222, pp 1-10, 14 August 1978.
Official Journal of the European Communities No L 281, pp 47-52, 10 October 1979.
Official Journal of the European Communities No L 20, pp 43-48, 26 January 1980.
Official Journal of the European Communities No L 229, pp 11-29, 30 August 1980.
Official Journal of the European Communities No L 330, pp 32-54, 05 December 1998.

PROVISIONS OF THE MAIN DIRECTIVES AND REGULATIONS

The principal provisions of the listed Directives and/or the associated Regulations are summarised below for convenience. It is most important to bear in mind when considering the Directives and Regulations, *and when examining the standards and limits set out in the main body of this volume,* that **in many** (but not all) **cases there is a required percentage compliance in terms of numbers of samples analysed.** That is, there is a degree of flexibility so that a single excessive value obtained in a sampling programme of adequate intensity would not mean that the water in question was in breach of the requirements. The individual required compliance percentages are specified below for the respective Directives or Regulations.

It must be emphasised that the interpretation of the Directives is a complex matter requiring .no little concentration, and it may be noted that, in addition to defining national quality standards, the Regulations also seek to clarify the general requirements of the Directives. It is therefore considered useful to give only a very broad outline of the provisions of this highly important body of legislation in the following paragraphs. The reader is accordingly urged to refer to the original texts of the Directives or, more importantly, where they have been made, to the associated Regulations.

Another important factor to be remembered in the consideration of levels and standards is that in several Directives/Regulations departures from the stated limits may be granted by the Minister for the Environment and Local Government where the parameters concerned are likely to be influenced by exceptional climatological or geological conditions. It must be understood that such departures constitute approved waivers of the relevant Directive(s) *for the individual parameters referred to. There are no blanket waivers of Directive provisions, nor are there waivers in the case of any parameter which has any connotation for the health of the public.*

Surface Water (75/440/EEC)

This Directive - adopted on 16 June 1976 - was the first of the series relating principally to water quality to come into force. It must be remembered that the informal title given almost universally to the Directive - the "Surface Water Directive" - is actually a misnomer in that it can convey the impression that it covers the quality of surface waters in general. In fact, as is quite unambiguous in the full title (cf Table 1), it covers the quality only of surface water which is used as a source of water for human consumption - drinking water - with appropriate treatment following abstraction. The Directive really deals with so-called "raw water" (i.e. water intended for distribution after the appropriate treatment processes).

The important topics of the extent and frequency of sampling and analysis required for implementation were not covered by the Directive, and the EU subsequently adopted a separate Directive on sampling and analysis in connection with the Surface Water Directive. It may be noted for completeness that the so-called "Methods of Analysis and Frequency of Sampling" [12] Directive (which is not dealt with in the present volume because of its detailed, operational content) was adopted on 9 October 1979, with reference number 79/869/EEC.

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[12] *Official Journal of the European Communities* No L271, pp 44-53, 29 October 1979.

The European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989, were signed by the Minister for the Environment on 10 November 1989 and took effect from 1 December 1989. These Regulations,[13] though concise, incorporate the requirements of both the Surface Water and Methods of Analysis Directives, thereby simplifying very considerably the task of interpretation. In the discussion of the individual parameters of water quality below, the limit values specified are those laid down by the Regulations.

The Regulations categorise surface waters from which water for public supply will be taken as Al, A2 or A3, depending on the (increasing) degree of treatment which will be applied, and they set out quality standards for a total of 39 parameters. There is a requirement that 95% of samples taken comply with the standards and, further, that, in the case of the 5% of samples not complying, (i) the water does not deviate from the standards in question by more than 50%, with the exception of the standards for temperature, pH, dissolved oxygen and the microbiological parameters, (ii) there is no resultant danger to public health, and (iii) no two consecutive samples deviate from the quality standards. The topic of analytical methods is covered in depth by the Regulations, but is not discussed in the present volume.

Bathing Water (76/160/EEC)

The Bathing Water Directive has been given effect in Irish law by the European Communities (Quality of Bathing Water) Regulations, 1988, signed by the Minister for the Environment on 4 May 1988.[14] These Regulations laid down quality requirements for all fresh and sea waters which were defined as bathing areas. Specific bathing areas were designated for monitoring in accordance with the provisions of the Directive, and monitoring has been carried out on a regular basis since 1978-79 by the sanitary authorities concerned.

The Bathing Water Regulations specified quality standards for the various relevant parameters and they also dealt in detail with the matter of percentage compliance of samples with the prescribed limit values. This was done both in the Regulations on a parameter by parameter basis. The principal point of note is that the national limit values for total and faecal coliforms were 50% lower than the mandatory values in the Directive, although at a lower compliance percentage.

The European Communities (Quality of Bathing Water) (Revocation) Regulations, 1992,[15] formally revoked both the 1988 and 1989[16] Regulations and made way for the adoption of the Quality of Bathing Waters Regulations, 1992.[17] The latter, which are not considered comprehensively in the present context (and which should be referred to), re-enact all the provisions of the 1988 and 1989 Regulations and expand their coverage. The change most relevant to the present volume was the addition of the total and faecal coliform standards in the original Directive to those adopted in the 1988 Regulations. As a result, there is now a more comprehensive coliform standard in the current Regulations than is contained in either of the original sources on its own.

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13 Statutory Instrument S.I. No 294 of 1989.
14 Statutory Instrument S.I. No 84 of 1988.
15 Statutory Instrument S.I. No 154 of 1992.
16 These Regulations [Statutory Instrument S.I. No 99 of 1989] had designated further bathing areas only.
17 Statutory Instrument S.I. No 155 of 1992.

Dangerous Substances (76/464/EEC)

This framework[18] Directive is potentially very wide-ranging in its scope. In its original coverage the Directive applied to inland surface water, territorial waters, internal coastal waters and groundwater. However, the last-mentioned category has subsequently been dealt with by another Directive (see below). The Dangerous Substances Directive requires Member States to take:

appropriate steps to eliminate pollution of [these waters] by the dangerous substances in the families and groups of substances in List I of the Annex and to reduce pollution of the said waters by the dangerous substances in the families and groups of substances in List II of the Annex.

It notes that the provisions "represent only a first step towards this goal." Details of the contents of Lists I and II are given in Appendix 6. The substances specified by the Directive in List I (the "black list") and in List II (the "grey list") represent a very wide range of materials and the thrust of the Directive is towards emission control rather than environmental monitoring. The main provisions of the Directive are as under:-

- List I discharges must be authorised, such authorisation laying down emission standards for discharges to waters and, where necessary, to sewers [see Directive for further details}.
- The Council of the European Communities, on a proposal from the Commission, may lay down limit values for said emission standards, and may also lay down quality objectives.
- List II discharges shall also be subject to authorisation, again with emission standards based on quality objectives (where the latter have been defined).
- Member States are required to establish programmes in order to reduce pollution by List II substances, such programmes to include quality objectives and so on.
- "The competent authority shall draw up an inventory of the discharges ... which may contain substances within List I to which emission standards are applicable."

It will be noted from reference to the Lists that the coverage of the Directive is, as mentioned, very wide indeed, and that it is accordingly totally impractical to approach the implementation of the provisions from a general monitoring point of view. As stated, the emphasis is on control of emissions but, of course, it follows that where such controls are imposed specific monitoring for the pollutants under restriction is both feasible and necessary. Such monitoring may be very complex and demanding on resources.

Among the further Directives listed in Appendix 5 are so-called "daughter" Directives based on the Dangerous Substances Directive; these relate to discharges of cadmium and mercury, for example, as well as selected pesticides. Ministerial Regulations have been made in connection with some of these further Directives and in certain circumstances water quality standards which must be observed are laid down. However, because of the specific nature of the quality standards and monitoring requirements and the rather intricate way in which they are related to the quantities being discharged of the pollutants in question, neither the daughter Directives nor the associated Regulations are commented upon in the present context. The reader is therefore recommended to consult the original sources.

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[18] It is important that Directive 76/464/EEC not be confused with the year 2000 Water Framework Directive. Although described often as a "framework" Directive, perhaps a better term for the former would have been "umbrella" Directive as it was envisaged that 76/464/EEC would form the blanket under which further, "daughter" Directives (dealing separately or in groups with specific dangerous substances) would be adopted.
In fact, several such subsidiary Directives were adopted, as shown in Appendix 5. The new Framework Directive in contrast establishes a complex structure within which much environmental protection activity may be developed without further legislation.

Freshwater Fish (78/659/EEC)

The Freshwater Fish Directive is, in practical terms, one of the most important of all the earlier Directives in that its quality requirements have been applied widely in various contexts, notably in Water Quality Management Plans. This was because, effectively, if the quality standards for fish (especially salmonid fish) are met by a water, then that water will be of sufficiently high quality for a variety of EQOs including that of serving as a source of raw water for public supply. Because of this wide use of its quality standards there is great familiarity with this Directive so that its provisions are only briefly summarised here.

The Directive classifies fresh waters as either *salmonid* (S) or *cyprinid* (C), the former being of such quality as to support game fish and the latter being of a lesser quality but satisfactory for coarse fish. Accordingly, there is a dual range of standards, those for salmonid waters obviously being rather stricter than the quality requirements for cyprinid waters. The standards apply "to those waters designated by the Member States as needing protection or improvement in order to support fish life." A range of Irish waters has been designated under the terms of the Directive and in each case the waters have been classified as salmonid, requiring the higher quality standards. On 18 November 1988, in order to incorporate fully in Irish law the requirements of the Directive for salmonid waters and the designations of waters thus far made, the then Minister for the Environment signed the European Communities (Quality of Salmonid Waters) Regulations.[19]

Article 6 of the Directive specifies that 95% of samples for key parameters (e.g. pH and non-ionised ammonia), based on an effective monthly sampling frequency, shall conform to the specified values. Because of the wording used, in which conformity with both G (guide) and I (mandatory) values is referred to (necessitating careful interpretation) it is important to consult the text of the Directive if cyprinid waters are under consideration. In the case of salmonid waters the Regulations are comprehensive, giving details of compliance required on an individual parameter basis, where appropriate.

Shellfish (79/923/EEC)

The Directive "concerns the quality of shellfish waters and applies to those coastal and brackish waters designated by Member States as needing protection or improvement in order to support shellfish.. .life and growth..." Both G and I values are set out in the Directive. In cases of discharges containing the parameters metals and organohalogenated substances, in addition to the quality objectives specified by the present Directive any emission standards laid down by Member States under the Dangerous Substances Directive (76/464/EEC, q.v.) shall also be applied. [20]

Under the Shellfish Directive, Member States are required to make initial designations of shellfish waters within two years following the notification of the Directive and also to establish programmes "in order to reduce pollution and to ensure that designated waters conform, within six years of designation, [with the values specified]."

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[19] Statutory Instrument S.I. No 293 of 1988. Note that to date there are no corresponding Regulations for cyprinid waters.

[20] In fact, emission standards exist in "daughter" Directives of Directive (76/464/EEC) and not in the latter itself. More importantly, such standards will be enshrined in the Framework Directive, in due course.

Minimum sampling frequencies are laid down in the Annex but, as is the case with other Directives, monitoring may be reduced or suspended in the absence of pollution. The required compliances vary from 100% for organohalogenated substances and metals to 95% for salinity and dissolved oxygen to 75% for remaining parameters (cf original source). The Quality of Shellfish Waters Regulations were made in 1994 [21]; they designated specific shellfishery waters.

Groundwater (80/68/EEC)

The Groundwater Directive is a follow-up ("daughter") Directive within the framework of the Dangerous Substances Directive (76/464/EEC, q.v.) and its formulation was envisaged in the latter. Its principal provisions are as follows:

- *Its purpose is to prevent the pollution of ground water by substances belonging to "substances in Lists I or II."* [cf Annexes to this Directive and Directive (76/464/EEC), and Appendices 6 and 7 below; these are not quite identical but are very similar in their scope],
- The provisions do not apply to the following:- (a) discharges of domestic effluents from isolated dwellings not connected to a sewerage system and situated outside areas protected for the abstraction of water for human consumption; (b) discharges which are found by the competent authority of the Member State concerned to contain substances in Lists I or II in a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of receiving ground water; and (c) discharges of matter containing radioactive substances.
- Member States are required to prevent the introduction into ground water of substances in List I and limit the introduction into ground water of substances in List II so as to avoid pollution of this water by these substances. The general prohibition on direct discharges containing List I substances does not apply in the case of ground, waters which are found on investigation to be permanently unsuitable for other uses, especially domestic or agricultural. Authorisations are required for any such discharges to these waters.
- Accordingly. Member States shall prohibit all direct discharge of substances in List I, shall "subject to prior investigation any disposal or tipping for the purpose of disposal of these substances which might lead to indirect discharge" and shall "take all appropriate measures they deem necessary to prevent any indirect discharge of substances in list I due to activities on or in the ground other than those mentioned just [above]."
- Member States must also "make subject to prior investigation all discharges of substances in list II, so as to limit such discharges" and similarly "the disposal or tipping for the purpose of disposal of these substances which might lead to indirect discharge." In addition, they are required to "take the appropriate measures they shall deem necessary to limit ail indirect discharge of substances in list II, due to activities on or in the ground other than those mentioned [above]. "

For further essential detail about the requirements of this Directive (especially as regards the "prior investigations" mentioned, the authorisation of discharges and the content of such authorisations) it is most important that the original text be referred to. Finally, it should be noted that the Local Government (Water Pollution) Regulations, 1992,[22] set a limit of zero for discharges of List I substances to ground water.

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[21] Statutory Instrument S.I. No 200 of 1994.
[22] Statutory Instrument S.I. No 271 of 1992.

Drinking Water (80/778/EEC)

According to the 1988 Regulations which give effect in Irish law to the requirements of the Directive, all water used for human consumption, whether "in its original state or after treatment, regardless of origin," is covered, as is water used in the food industry. However, natural mineral waters and medicinal waters do not fall under its provisions. The Regulations [European Communities (Quality of Water Intended for Human Consumption) Regulations, 1988][23] were signed by the Minister for the Environment on 29 April 1988 and took effect on 1 June 1988. Maximum admissible concentrations (MAC values) are fixed for over fifty parameters. In some cases - as was also the case in some of the other Directives commented upon earlier - departures from the values specified may be granted by the Minister because of climatological or geological factors which may make the standards impossible to attain.

A handbook on the implementation of the Drinking Water Regulations was prepared by the Environmental Research Unit and issued in autumn 1989. Although intended primarily for the information and guidance of those responsible for the implementation of the Regulations - the sanitary authorities - the handbook proved to be of interest to a wider readership. A new edition will be published on the formal introduction of the provisions of the new Drinking Water Directive 98/83/EC.

Drinking Water (98/83/EC)

The new Drinking Water Directive was adopted by the EU Council on 3 November 1998 and came into force on 25 December 1998 (after the passing of the specified 20 days from its publication in the Official Journal). Accordingly, the final deadline for the technical adoption[24] by the Member States of this Directive (and for the simultaneous repeal of Directive 80/778/EEC) is 25 December 2003. However, any necessary administrative or legislative provisions must be in place by 25 December 2000.

The corollary of the new Directive is that the provisions of both the 1980 and the 1988 Regulations will be rescinded and replaced by the markedly different requirements enshrined in the 1998 Directive. The Minister for the Environment and Local Government will make Regulations in due course, and these will be the applicable legislation in Ireland. Because the content of a new edition of the 1989 handbook for sanitary authorities will depend very much on the provisions made by the Minister for the Environment and Local Government in any new Regulations, some time must necessarily elapse before the publication is available. Likewise, it would, of course, be impossible to anticipate the provisions of such Regulations in this present volume, which, in any event, is not an appropriate context. Nonetheless, it may be noted that the new Directive differs very greatly from its predecessor and a wholly new approach to sampling and analysis will be required on the part of the sanitary authorities. What are appropriate and particularly relevant to the present publication, are the list of parameters and the applicable limit values contained in Directive 98/83/EC which will constitute a key element of new Regulations.

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[23] Statutory Instrument S.I. No 81 of 1988.

[24] The application of the limit values, termed "parametric values" in the Directive.

One prominent change in terminology concerns the limit values - the old term MAC ("maximum admissible concentration") has been abolished and the standard term for limit value in Directive 98/83/EC is "parametric value" [PV]. [25] Other major changes concern the old C1-C4 and A-E parameter classifications which have been replaced by a new scheme. Further, the actual limit values for several parameters have been revised (downwards) for some key parameters. All these matters, which are of prime concern to the sanitary authorities, will demand detailed consideration in the new handbook.

A BRIEF OVERVIEW OF THE ABOVE DIRECTIVES

It is noteworthy that most of the above Directives (all except the Dangerous Substances and Ground Water Directives) are based on the so-called "Environmental Quality Objective" [EQO] approach, in which standards [EQSs] are laid down for various types of water in which contaminants may be found, and the concentrations of which are more or less strictly limited. Monitoring under these Directives/Regulations will detect and, if adequate in its scope, quantify the extent to which any pollutants are present. (These observations are more appropriate, however, to Directives other than the Drinking Water Directive, where the extensive range of limits is naturally aimed at the protection of public health.) The two exceptions are emission control Directives, under which pollution of the aquatic environment and/or ground water in particular should be limited by the issue of and policing of discharge authorisations.

As mentioned above, most of these individual Directives will give way to the Water Framework Directive (over several years), but the latter will straightaway incorporate Article 6 of the Dangerous Substances Directive 76/464/EEC which provides that the EU Council (on a proposal from the Commission) may specify EQSs for specified substances on a list which will form one of its Annexes. The key aim of the Framework Directive is, as stated, to achieve and maintain good ecological status throughout the aquatic environment. One of the principal means of reaching this goal is the strict control of dangerous substances using procedures which originated in the Dangerous Substances Directive 76/464/EEC.

[25] The very rarely referred to MRC ("minimum required concentration") does not appear in Directive (98/83/EC).

PARAMETERS COVERED IN THE PRESENT VOLUME

The list of parameters in the first edition of the present publication has been revised thoroughly, with some parameters of minor significance being omitted, and a range of additional determinands (largely organic micropollutants) added. In the present volume, the following approach has been adopted.

Firstly, all parameters which appeared in previous editions have been retained, as they may well be of practical (if not statutory) interest to readers. Secondly, all "new" parameters - those listed in Directive 98/83/EC and in "daughter" Directives to Directive 76/464/EEC - have been included and are treated in the standard format used throughout.

Thirdly, the MAC values specified in Directive 80/778/EEC have been excluded from the list of standards as they are being replaced by the PVs [parametric values] of Directive 98/83/EC. Fourthly, these PVs are presented throughout the present text, although it must be remembered that the Minister for the Environment and Local Government, when making Regulations in connection with Directive 98/83/EC, may decide to set stricter limits than the Directive for certain parameters.

PRESENTATION OF THE DATA

For convenience in reference each parameter included in this volume is covered in a standard format consisting of a numbered template in which important explanatory and background information is summarised. This is followed by a standardised tabular format in which the limit figures specified by the various sources are quoted clearly. The parameters are dealt with in one alphabetical series and, in general, the text and tables relating to a given parameter are complete in themselves. However, because of the close relationship between some parameters full cross-references are provided. The elements of the template are as follows, in the order in which they appear:

- **Chemical Symbol or Formula:** These are in the conventional chemical notation, e.g. Antimony is Sb, Silver is Ag, Silica is SiO_2, and so on. In many cases the entry is "Not Applicable" as there is either no chemical formula at all, as for microbiological parameters, or else the parameter, although chemical, is a bulk one, e.g. Pesticides, so that the use of formulae is precluded on practical grounds.
- **Units used for Analytical Results:** The complex subject of units of analysis is dealt with in detail in Appendix 2 of this volume. It may simply be noted here that for several key parameters the results of analysis may be reported in terms other than those of the chemical formulae of the entities being determined. Examples are nitrate, NO_3^-, reported often as N, and phosphate, PO_4^{---} commonly reported as P.
- **Normal Methods of Analysis:** Although analytical methodology is not covered by the present volume, brief mention is made of the methods most commonly employed for the determination of the various parameters. It must be stressed, however, that in many cases there are additional or alternative techniques which may be used satisfactorily. As a guide, letters [A], [B], [C] and [D] have been used throughout to indicate, respectively, an increasing degree of sophistication of the technique and/or of the equipment used. Thus, [A] indicates a method suitable for use in a more basic water laboratory, [B] implies a method more demanding of staff expertise or equipment, [C] implies an elaborate laboratory set-up, with advanced instrumentation, and [D] denotes a specialist laboratory with state-of-the-art equipment. A dual designation, e.g. [B/C], is used for those methods which may be practicable at different levels of instrumentation or expertise. It may be noted that these designations are quite in for mat and are offered for guidance only. In reality, there may often be no clear gradations between the capabilities of different laboratories.
- **Occurrence/Origin:** A brief indication is given as to whether substances covered by the parameter occur in rock, are constituents of sewage or industrial wastes, or are synthetic materials. It is assumed throughout that substances attributed to industrial wastes could equally well arise from tiphead leachates, this is not always specified.
- **Health/Sanitary Significance:** Brief reference is made to known toxic or physiological effects - or the lack of them - of each parameter. It must be stressed that such references are not in any way exhaustive, but are merely indicative. This volume does not purport in any way to deal with medical matters or with any material connection between a given parameter and the health of the user/consumer of a water containing it.

- **Background Information:** This section contains adequate detail to set the significance of each parameter in perspective. In some important cases, notably "Oxygen Demand, Biochemical," "Hardness" and "Oxygen, Dissolved," the entries are fairly lengthy, but this is in line with one of the primary aims of this volume, namely to act as a "free-standing" reference for the engineer, environmentalist or scientist.
- **Comments:** Where appropriate, further amplifying information on the parameter is given under this heading.

Important Note As regards analytical methods, it may be added that it is assumed throughout this treatment of the results of analysis *that such results are the end product of a properly designed and competently executed programme of sampling and analysis in which all precautions necessary to ensure meaningful data have been taken.* While the present volume does not deal with such operational matters, it is important that the opportunity be taken to stress that the taking of samples, which might at first glance appear to be a fairly simple procedure, may in fact be anything but, depending on the parameters to be determined. *Unless the proper procedures are followed strictly the validity of the sample may be compromised, and the resulting analytical data of little value.*

Layout of the Tables In the tabular format mentioned, the "Recommended or Mandatory Limit Values" for the respective parameters are presented as follows. The table first gives the values contained in the EU Directives summarised above. However, where Regulations have been made by the Minister for the Environment which contain national quality standards, the values quoted are generally those *in the Regulations, not the Directive* corresponding to such Regulations. National values are, clearly, mandatory standards which must be complied with to the extent laid down in the appropriate Regulations.

This is in contrast to the Directives (whose values are quoted here if no Regulations have been made to date) which contain either recommended or "guide" values, designated as G values, or mandatory figures, designated I values (*imperatif*). The latter are standards which must be adhered to; they are legal requirements of the EU. References under the Surface Water Regulations to "A1, A2 and A3" waters indicate the different water categories specified in the Regulations. As mentioned above, under the Freshwater Fish Directive, "(S)" and "(C)" denote salmonid and cyprinid waters, respectively.

To avoid unnecessary blank spaces, references to Directives or other sources containing no data on a given parameter have been omitted from the respective 'tables as appropriate. It follows, therefore, that if a Directive or the corresponding Regulations are not referred to under a given heading then neither the Directive nor the Regulations expressly refer to the parameter in question. However, the term *"No reference/recommendation"* in a table does not imply that the parameter is not or may not be of relevance to the intended readership. Where necessary, notes are used to present detail which cannot be summarised in a table or to explain some of the complexities which arise in certain cases. To simplify presentation the notes are numbered separately for each parameter rather than in one large overall series.

Analytical Units The potential for confusion arising from the multiplicity of units employed (in particular in the different Directives) is unfortunately rather great and, accordingly, it is essential that in studying standards attention be paid both to the limit value and to the units in which such value is expressed. A detailed note on units forms Appendix 2.

The
Principal Parameters
of
Water Quality

[in alphabetical order]

1. ACIDITY

Chemical Symbol or Formula: Not Applicable [Bulk parameter]

Units Used for Analytical Results: mg/l $CaCO_3$.

Normal Method(s) of Analysis: Titration with Sodium Hydroxide [A]

Occurrence/Origin: Arises from the presence of weak or strong acids and/or certain inorganic salts. The presence of dissolved carbon dioxide is usually the main acidity factor in unpolluted surface waters (it forms the weak acid H_2CO_3 - carbonic acid).

Health/Sanitary Significance: No particular implications apart from palatability considerations in excessively acid waters.

Background Information: The determination is arbitrary to a degree in that the end-point pH values [colour changes] will depend on the choice of indicator reagents made by the analyst. Commonly, methyl orange or bromophenol blue are used in the first stage as indicator (colour change around pH 4.5), with phenolphthalein in the second stage (colour change around pH 8.3). Hence the various terms *methyl orange acidity* (alternatively, *mineral acidity*), and *phenolphthalein acidity* (or *total acidity*).

Comments: The acidity of a water will affect its corrosiveness and also the speciation[1] of some of its other constituents.

Acidity : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

2. ACRYLAMIDE

Chemical Symbol or Formula: C_3H_5NO.

Units Used for Analytical Results: µg/l compound.

Normal Method(s) of Analysis: Chromatography [C/D]

Occurrence/Origin: Synthetic chemical which is the monomer from which polyacrylamide is derived.

Health/Sanitary Significance: Highly toxic, acrylamide is a carcinogenic substance. It can also be absorbed readily through unbroken skin and it affects the central nervous system.

Background Information: Polyacrylamide is used as a flocculant aid in water treatment and the polymeric substance inevitably contains traces of acrylamide monomer.

Comments: The WHO Guidelines note that "the most important source of drinking-water contamination by acrylamide is the use of polyacrylamide flocculants that contain residual, acrylamide monomer" and adds that "concentrations in drinking-water can be controlled by product and dose specification."

[1] i.e. The precise form in which the parameter will exist in the water [cf "Ammonia"].

Acrylamide : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l compound	n/a	0.10	[1]

Notes

[1] The Directive states that "The parametric value refers to the residual monomer concentration in the water as calculated according to specifications of the maximum release from the corresponding polymer in contact with the water."

3. ALKALINITY

Chemical Symbol or Formula: Not Applicable [Bulk parameter]

Units Used for Analytical Results: mg/l $CaCO_3$.

Normal Method(s) of Analysis: Titration with Sulphuric Acid [A]

Occurrence/Origin: The alkalinity of a natural water is generally due to the presence of bicarbonates formed in reactions in the soils through which the water percolates. It is a measure of the capacity of the water to neutralise acids and it reflects its so-called *buffer capacity* (its inherent resistance to pH change). A poorly-buffered water will have a low or very low alkalinity and will be susceptible to pH reduction by, for example, "acid rain." At times, however, river alkalinity values of up to 400 mg/l $CaCO_3$ may be found; they are without significance in the context of the quality of the water.

Health/Sanitary Significance: There is little known sanitary significance attaching to alkalinity (even up to 400 mg/l $CaCO_3$), though unpalatability may result in highly alkaline waters.

Background Information: Alkalinity in natural waters may also be attributable to carbonates and hydroxides. Sometimes analysis is carried out to distinguish between the alkalinity elements and this is done by using different indicators in the titration procedure and by making appropriate calculations. The indicators most commonly employed are phenolphthalein (colour change around pH8.3) and methyl orange (colour change around pH4.5), resulting in the additional terms *phenolphthalein alkalinity* and *methyl orange alkalinity*; the latter is synonymous with *total alkalinity*.

Alkalinity is involved in the consequential effects of eutrophication [over-enrichment] of waters. Where a high degree of photosynthesis occurs, as discussed below under "Oxygen, Dissolved" (q.v.), there is a high consumption of carbon dioxide by algae. As any free carbon dioxide initially available is consumed, more is produced in a series of related chemical equilibrium reactions, as follows:

1. $H^+ + HCO_3^- \Leftrightarrow H_2CO_3$ [$H_2O + CO_2$]
2. $H^+ + CO_3^{--} \Leftrightarrow HCO_3^-$
3. $H_2O \Leftrightarrow H^+ + OH^-$.

As the carbon dioxide is consumed by photosynthesis, more is produced (reaction 1, left to right) by the action of bicarbonate ions, present as alkalinity, and hydrogen ions to give undissociated carbonic acid (carbon dioxide and water). Any carbonate ions present will then react with more hydrogen ions to replace the bicarbonate consumed (reaction 2, again left to right). Both these reactions consume hydrogen ions, more of which are produced as in reaction 3 (equilibrium again to the right). A net overall effect is the production of hydroxyl ions and an increase in the pH. It is not uncommon for extreme photosynthetic activity to produce pH levels high enough to cause serious damage (even death) to fish.

Comments: The parameter is of interest to water engineers in that it is a factor concerned in the computation of the so-called Langelier "Saturation Index" which relates to the corrosion of or deposition of scale in distribution networks (see Appendix 4). Alkalinity is sometimes designated *alkali level*.

Alkalinity : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

4. ALUMINIUM

Chemical Symbol or Formula: Al.

Units Used for Analytical Results: mg/l Al.

Normal Method(s) of Analysis: Colorimetry [B]; Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Aluminium is one of the most abundant elements in the earth's crust. A salt, aluminium sulphate, is very widely used for colour- and colloid-removal in the treatment of waters for drinking.

Health/Sanitary Significance: Not originally considered to be a significant health hazard in drinking waters, aluminium has more recently been shown to pose a danger to persons suffering from kidney disorders. It causes neurological problems and has been cited as a contributory factor to Alzheimer disease. However, the WHO Guidelines for Drinking-Water Quality[2] states that:

> There is a need for further studies, but the balance of epidemiological and physiological evidence at present does not support a causal role for aluminium in Alzheimer disease. Therefore, no health-based guideline value is recommended.

Background Information: The compound aluminium sulphate ("alum") is very widely used in water treatment to remove colour and non-filtrable matter in raw waters. The alum is hydrolysed and is converted to a flocculent hydroxide which, being dense and insoluble, precipitates bringing with it the offending colour and turbidity particles. With careful plant control it is possible to ensure that residual aluminium levels are acceptable (i.e. 0.2 mg/l Al or less, above which discoloration may occur).

Comments: Aluminium levels are limited under the Drinking Water Directive 198/83/EC].

Aluminium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l Al	n/a	200	

[2] Second Edition. 1993.

5. AMMONIA

Chemical Symbol or Formula: NH_3.

Units Used for Analytical Results: mg/l N.

Normal Method(s) of Analysis: Colorimetric (Manual; Nessler's Reagent) [A/B]; Colorimetric (Automated; Berthelot Reaction) [B/C].

Occurrence/Origin: Ammonia is generally present in natural waters, though in very small amounts, as a result of microbiological activity which causes the reduction of nitrogen-containing compounds. When present in levels above 0.1 mg/l N, sewage or industrial contamination may be indicated.

Health/Sanitary Significance: From the viewpoint of human health the significance of ammonia is marked because it indicates the possibility of sewage pollution and the consequent possible presence of pathogenic micro-organisms.

Background Information: The form of the ammonia - whether it is "free" (as NH_3) or "saline" (as NH_4^+) in slightly acid waters - depends on the pH and these forms are not distinguished from one another during analysis. The different terms commonly applied to the forms of ammonia are as follows: *total ammonia (NH_3 & NH_4^+)* *total ammonium (NH_3 & NH_4^+)* *free ammonia (NH_3)* *free and saline ammonia (NH_3 & NH_4^+)* *ionised ammonia (NH_4^+)* *and* *un-ionised ammonia (NH_3).*

The different forms arise from the pH/temperature related equilibrium reactions:

1. $NH_3 + H_2O \Leftrightarrow NH_3.H_2O$
2. $NH_3.H_2O \Leftrightarrow NH_4^+ + OH^-$.

The ammonia tolerances for fishery waters are narrow and have been considered and reported on by the European Inland Fisheries Advisory Commission. Research has shown that it is the un-ionised species of ammonia which is most harmful to freshwater aquatic life and to game fish, in particular. Arising from the complex relationship between total ammonia concentration, pH and temperature there emerges a level for total ammonia of around 0.3 mg/l NH_3 which is considered to be that which would contain the limiting amount of un-ionised ammonia (see Appendix 3 for full details). Because of the ease of natural interconversion from one form to another - this could be brought about by pH changes caused by algal activity, for example - the total ammonia levels should be very low.

Comments: Before the advent of microbiological techniques for assessing the potability of a water the analysis for ammonia was used as an indication of sewage contamination, often in conjunction with chloride, because both are present in significant quantities in sewage. High ammonia levels interfere with chlorination processes in water treatment, an aspect which is discussed in detail below (see "Chlorine"). The formation of chloramine compounds (which are much less potent disinfectants than free chlorine) by reaction between the added chlorine and the ammonia present in the water necessitates an increased use of chlorine if disinfection efficiencies are to be maintained.

Ammonia : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l NH_4	n/a	0.2	[1]
	A2 waters	mg/l NH_4	n/a	1.5	[1]
	A3 waters	mg/l NH_4	n/a	4	[1,2]

Ammonia : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]		-	-	-	[3]
Dangerous Substances Directive [76/464/EEC]			List II substance		[4]
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l NH_3	$\leq$ 0.005	$\leq$ 0.025	[5]
	(C)	mg/l NH_3	$\leq$ 0.005	$\leq$ 0.025	[5]
	(S)	mg/l NH_4	$\leq$ 0.04	< 1	[6]
	(C)	mg/l NH_4	$\leq$ 0.2	$\leq$ 1	[6]
Salmonid Waters Regulations [1988]		mg/l NH_3	n/a	$\leq$ .02	[5,7]
		mg/l NH_3	n/a	$\leq$ 1	[6,8]
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		mg/l NH_4	n/a	0.5	[9]

Notes

[1] Designation is "Ammonia."
[2] Departure from standard may be granted by Minister "where exceptional meteorological or geographical conditions have arisen."
[3] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters ... or, in the case of... ammonia, that there is a tendency towards eutrophication."
[4] List II specifies "Substances which have an adverse effect on the oxygen balance, particularly ammonia, nitrites."
[5] Limits are for "Non-ionised Ammonia."
[6] Limits are for "Total Ammonium."
[7] Standard may be exceeded in the form of minor peaks in daytime and, subject to this, be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples.
[8] Standard is $\leq$ 1 "subject to conforming with. the standard for non-ionised ammonia." Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples.
[9] Parameter designated "Ammonium."

6. ANTIMONY

Chemical Symbol or Formula: Sb.

Units Used for Analytical Results: mg/l Sb.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: Naturally occurring trace element used in metal industry and in flame retardant materials. Antimony can occur naturally in water from weathering of rocks but is more likely to arise from effluents.

Health/Sanitary Significance: Although the health effects of antimony have not been established definitively, there is evidence of actual or potential carcinogenicity of some antimony compounds. Accordingly, concentrations are limited in drinking water.

Background Information: Antimony levels in freshwater streams in the US can be around 1 µg/l.

Comments: Antimony levels are limited under Drinking Water Directive [98/83/EC].

Antimony : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]		List II substance		
Ground Water Directive [80/68/EEC]		List II substance		
Drinking Water Directive [98/83/EC]	µg/l Sb	n/a	5	

7. ARSENIC

Chemical Symbol or Formula: As.

Units Used for Analytical Results: mg/l As.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [C/D]

Occurrence/Origin: This element is very widely distributed throughout the earth's crust, according to the WHO Guidelines, which state that "it is introduced into water through the dissolution of minerals and ores, from industrial effluents, and from atmospheric deposition: concentrations in ground water in some areas are sometimes elevated as a result of erosion from natural sources. The average daily intake of inorganic arsenic in water is estimated to be similar to that from food; intake from air is negligible." Arsenic is used in the glass and semiconductor industries and as a fungicide in timber processing. A major US emission source is coal-fired power plant.

Health/Sanitary Significance: Very toxic to humans, some arsenical compounds are carcinogens, hence much of the concern regarding them, but there are a variety of other effects on health. The WHO states that inorganic arsenic is a documented human carcinogen, and that a relatively high incidence of skin and possibly other cancers that increase with dose and age has been observed in populations ingesting water containing high concentrations of arsenic.

Background Information: Found in air and in all living organisms.

Comments: Parameter is extensively covered by Directives and Regulations (see below).

Arsenic : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l As	n/a	0.05	
	A2 waters	mg/l As	n/a	0.05	
	A3 waters	mg/l As	n/a	0.10	

Arsenic : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	mg/l As	-	-	[1]
Dangerous Substances Directive [76/464/EEC]		List II substance		
Shellfish Directive [79/923/EEC]	mg/l As	[2]	[3]	
Ground Water Directive [80/68/EEC]		List II substance		
Drinking Water Directive [98/83/EC]	µg/l As	n/a	10	

Notes

[1] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..."
[3] "The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with .article 1 [of the Directive], to the high quality of shellfish products."
[3] "The concentration of [this] substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of [this and other specified] metals must be taken into consideration."

8. BARIUM

Chemical Symbol or Formula: Ba.

Units Used for Analytical Results: mg/l Ba.

Normal Method(s) of Analysis: Turbidimetric [A/B]; Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Naturally occurring mineral (e.g. in barytes), which has in the past been mined in several places in Ireland, including Benbulben in County Sligo. According to the WHO Guidelines, while food is the main source of barium intake by humans, where barium occurs in drinking water supplies the latter can contribute a significant proportion of total intake.

Health/Sanitary Significance: Excessive amounts of barium can cause muscular, cardiovascular and renal damage. Although not markedly toxic, barium in excess quantities is clearly undesirable.

Background Information: In normal surface waters levels are likely to be low as traces of barium will react with sulphate present to form the highly insoluble barium sulphate.

Comments: The WHO 1993 Guidelines set a guideline value of 0.7 mg/l but Directive [98/83/EC] neither sets a parametric value nor refers to the metal, in contrast to Directive [80/778/EEC].

Barium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Ba	n/a	0.10	
	A2 waters	mg/l Ba	n/a	1.0	
	A3 waters	mg/l Ba	n/a	1.0	

Barium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]	List II substance			
Ground Water Directive [80/68/EEC]	List II substance			
Drinking Water Directive [98/83/EC]	No reference/parametric value			

9. BENZENE

Chemical Symbol or Formula: C_6H_6.

Units Used for Analytical Results: µg/l compound.

Normal Method(s) of Analysis: Gas Chromatography [C].

Occurrence/Origin: Constituent of some petroleum products; industrial raw material; solvent.

Health/Sanitary Significance: Carcinogenic substance which also affects the central nervous system adversely.

Background Information: Emissions from motor vehicles account for most of the benzene in the air, which can in due course reach the aquatic environment. Pollution from industrial sources can also introduce benzene to water.

Comments: Benzene is not a naturally-occurring constituent of water.

Benzene : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l compound	n/a	1.0	

BENZO(b)FLUORANTHENE

(See Poly cyclic Aromatic Hydrocarbons)

BENZO(k)FLUORANTHENE

(See Polycyclic Aromatic Hydrocarbons)

BENZO(ghi)PERYLENE

(See Polycyclic Aromatic Hydrocarbons)

10. BENZO(a)PYRENE [3]

Chemical Symbol or Formula: $C_{20}H_{12}$.

Units Used for Analytical Results: µg/l compound

Normal Method(s) of Analysis: High-Pressure Liquid Chromatography [C]

Occurrence/Origin: Synthetic complex aromatic organic compound formed by pyrolysis or combustion of organic materials. See discussion of "Polycychc Aromatic Hydrocarbons" below.

Health/Sanitary Significance: Benzo(a)pyrene is a carcinogenic and mutagenic substance which is considered to be highly undesirable in drinking water, even though the WHO *Guidelines* indicate that food is the main source of human exposure to this type of substance.

Background Information: See "Polycyclic Aromatic Hydrocarbons" below.

Comments: The undesirability of the presence of, and the need to restrict the concentrations of, benzo(a)pyrene is indicated clearly by its designation as a discrete parameter in Drinking Water Directive [98/83/EC], in contrast to its former inclusion as a constituent of the group parameter "Polycyclic Aromatic Hydrocarbons" (q.v.).

Benzo(a)pyrene : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l compound	n/a	0.010	

11. BERYLLIUM

Chemical Symbol or Formula: Be.

Units Used for Analytical Results: mg/I Be.

Normal Method(s) of Analysis: Colorimetric (Aluminon) [B]; Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: The major source is combustion of fossil fuels, the metal reaching waterthrough atmospheric fall- or wash-out. Weathering of rocks and soils, as well as discharges, also contributes.

Health/Sanitary Significance: The metal and its compounds, if inhaled for example, are very toxic and can lead to a variety of respiratory and other diseases. The picture regarding the toxicity of beryllium and compounds in water and food is, however, very unclear and there is no compelling evidence in favour of restriction, hence the lack of standards.

Background Information: It is used in brass and other alloys and also in the aircraft and space industries.

Comments: It is significant that WHO refers to the low level of exposure risk. The parameter is listed in both the Surface Water and Drinking Water Directives - though without any limit values being quoted, hence its omission from the corresponding Regulations.

[3] Alternatively named 3,4-Benzopyrene.

Beryllium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]		List II substance		
Ground Water Directive [80/68/EEC]		List II substance		

BIOCHEMICAL OXYGEN DEMAND

(See "Oxygen Demand, Biochemical")

BOD

(See "Oxygen Demand, Biochemical")

12. BORON

Chemical Symbol or Formula: B.

Units Used for Analytical Results: mg/l B.

Normal Method(s) of Analysis: Colorimetric (Curcumin) [B]; Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: Naturally occurring trace element. Used in cleaning compounds and in alloys.

Health/Sanitary Significance: Although excessive amounts of boron can cause nervous problems, the element is not considered a problem in drinking water. It has been identified as a danger to crops when present in irrigation water at the 1 - 2 mg/l concentration range.

Background Information: Present in seawater around 5 mg/l.

Comments: The Surface Water and Drinking Water Regulations specify limits.

Boron : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l B	n/a	2.0	
	A2 waters	mg/l B	n/a	2.0	
	A3 waters	mg/l B	n/a	2.0	
Dangerous Substances Directive [76/464/EEC]			List II substance		
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		mg/l B	n/a	1.0	

13. BROMATE

Chemical Symbol or Formula: BrO_3^-.

Units Used for Analytical Results: µg/l BrO_3^-.

Normal Method(s) of Analysis: Ion Chromatography [C]

Occurrence/Origin: Occurs when bromide ions [Br^-] present in water are oxidised by ozone and some other oxidising agents (including, it is believed, chlorine).

Health/Sanitary Significance: Both carcinogenic and mutagenic.

Background Information: Has come into prominence along with trihalomethanes [THM; q.v.], both being formed by the action of chlorine on constituents in water before it is distributed.

Comments: Bromate was not a determinand in the earlier Drinking Water Directive [80/778/EEC].

Bromate : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l BrO_3^-	n/a	10	[1]

Notes

[1] The Directive states that "Where possible, without compromising disinfection, Member States should strive for a lower value.

For the water referred to in Article 6(1)(a), (b) and (d), the value must be met, at. the latest, 10 calendar years after the entry into force of the Directive. The parametric value for bromate from five years after the entry into force of this Directive until 10 years after its entry into force is 25 µg/l."

BROMODICHLOROMETHANE

(See "Trihalomethanes")

BROMOFORM

(See "Trihalomethanes")

14. CADMIUM

Chemical Symbol or Formula: Cd.

Units Used for Analytical Results: µg/l Cd.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: In ores, including those of zinc. Cadmium in water is due nearly exclusively to industrial discharges (e.g. from electroplating, paint-making, manufacture of plastics etc) and landfill leachates.

Health/Sanitary Significance: Very highly toxic, hence severe restrictions on its concentrations in waters.

Background Information: The metal is very strongly adsorbed on muds, humus and organic matter, leading to the possibility 'of entry to the food chain via fish and fish food, and subsequent accumulation in tissue.

Comments: The principal physiological effects of cadmium are bone damage, chronic kidney disease, cancer and hypertension. The metal is also highly toxic to aquatic life.

Cadmium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Cd	n/a	0.005	
	A2 waters	mg/l Cd	n/a	0.005	
	A3 waters	mg/l Cd	n/a	0.005	
Bathing Water Regulations [1989-1998]		mg/l Cd	-	-	[1]
Dangerous Substances Directive [76/464/EEC]			List I substance		[2]
Shellfish Directive [79/923/EEC]		mg/l Cd	[3]	[4]	
Ground Water Directive [80/68/EEC]			List I substance		
Drinking Water Directive [98/83/EC]		µg/l Cd	n/a	5.0	[2]

Notes

[1] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing that there has been: a deterioration, in the quality of waters..."
[2] Designation is "Cadmium and its compounds."
f3] "The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."
[4] "The concentration of [this] substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of [this and other specified] metals must be taken into consideration."

CAE

(See "Substances Extractable in Chloroform")

15. CALCIUM

Chemical Symbol or Formula: Ca.

Units Used for Analytical Results: mg/l Ca.

Normal Method(s) of Analysis: Titration (Calcium Hardness) [A]; Atomic Absorption Spectrometry [B].

Occurrence/Origin: Occurs in rocks, bones, shells etc. Very abundant.

Health/Sanitary Significance: High levels may be beneficial (see below) and waters which are rich in calcium (and hence are very hard) are very palatable.

Background Information: This element is the most important and abundant in the human body and an adequate intake is essential for normal growth and health. The maximum daily requirement is of the order of 1 - 2 grams and comes especially from dairy products. There is some evidence to show that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary constituent of which is calcium, so that the presence of the element in a water supply is beneficial to health.

Comments: Despite the potential health benefits of calcium abundance there are problems associated with hardness, as discussed below (q.v.).

Calcium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	*No reference/parametric value*			

CARBON-ALCOHOL EXTRACT

(See "Substances Extractable in Chloroform")

CARBON-CHLOROFORM EXTRACT

(See "Substances Extractable in Chloroform")

16. CARBON DIOXIDE (FREE)

Chemical Symbol or Formula: CO_2

Units Used for Analytical Results: mg/l CO_2.

Normal Method(s) of Analysis: Titration with Sodium Carbonate [A; *field test*]; Nomograph [Alkalinity/Total Dissolved Solids] [B]

Occurrence/Origin: From air, algal respiration, organic breakdown.

Health/Sanitary Significance: None.

Background Information: The chemical equations given for "Alkalinity" (q.v.) show the interrelationship between carbon dioxide, bicarbonate and carbonate. The primary interest in free carbon dioxide concentrations arises in connection with the behaviour of waters in distribution systems - whether they will be corrosive or whether they will tend to deposit insoluble calcium carbonate as scale. The Langelier Index was devised to characterise waters on the basis of such tendencies (see Appendix 4).

Comments: High levels of free carbon dioxide may also enhance the effects of deoxygenation and of high ammonia concentrations. Excessive levels of carbon dioxide may have adverse effects on aquatic life.

Carbon Dioxide (Free) : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

CCE

(See "Substances Extractable in Chloroform")

CHEMICAL OXYGEN DEMAND

(See "Oxygen Demand, Chemical")

17. CHLORIDE

Chemical Symbol or Formula: Cl^-

Units Used for Analytical Results: mg/l Cl.

Normal Method (s) of Analysis: Titration (Mohr Method: Silver Nitrate) [A]

Occurrence/Origin: Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl). In fresh waters the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents.

Health/Sanitary Significance: Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability.

Background Information: At levels above 250 mg/l Cl water will begin to taste salty and will become increasingly objectionable as the concentration rises further. However, external circumstances govern acceptability and in some arid areas waters containing up to 2,000 mg/l Cl are consumed, though not by people unfamiliar with such concentrations. High chloride levels may similarly render freshwater unsuitable for agricultural irrigation.

Comments: Because sewage is such a rich source of chloride, a high result may indicate pollution of a water by a sewage effluent. Natural levels in rivers and other fresh waters are usually in the range 15-35 mg/l Cl - much below drinking water standards. What is normally important to note in a series of results from a river, for example, is not the absolute level, but rather the relative levels from one sampling point to another.

An increase of even 5 mg/l at one station may give rise to suspicions of a sewage discharge, especially if the free ammonia levels (q.v.) are also elevated. In coastal areas, however, elevated chloride values may be due to sea spray, or sea water infiltration, and not necessarily to discharges. Normal raw water treatment processes do not remove chloride.

Chloride : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Cl	n/a	250	
	A2 waters	mg/l Cl	n/a	250	
	A3 waters	mg/l Cl	n/a	250	
Drinking Water Directive [98/83/EC]		mg/l Cl	n/a	250	

18. CHLORINE, RESIDUAL

Chemical Symbol or Formula: Cl_2.

Units Used for Analytical Results: mg/l Cl.

Normal Method(s) of Analysis: Colorimetric (DPD) [A; *in-situ test*].

Occurrence/Origin: Water treatment processes, industrial effluents, chlorinated sewage and other effluents.

Health/Sanitary Significance: No direct significance at the relatively tiny levels used in water treatment processes.

Background Information: Water supplies are disinfected to destroy or deactivate microorganisms which can produce diseases such as cholera, typhoid and so on, and the process is the most important in water treatment. Disinfection maybe achieved in various ways but the vast majority of supplies are treated with chlorine which is a powerful oxidising agent and an extremely efficient disinfectant. It is relatively easy to handle and is also cost-effective, hence its almost universal use. Chlorine is very reactive and will only remain, as discussed below, in treated waters of high quality. It is not a constituent of unpolluted natural waters.

The primary effects of chlorination are extremely beneficial and for many minor water supplies the process may be the only treatment deemed necessary. Quite low levels are effective for disinfection in normal circumstances, but should the ammonia or organic content of the water be high then the water may have an appreciable "chlorine demand" and a higher chlorine input may be needed to achieve a given degree of protection.

As in many cases the treatment works for a public water supply may be a considerable distance from the ultimate consumers, it is essential that continuing protection be afforded along the distribution system, particularly if it is old and prone to leaks and/ or infiltration of extraneous matter. The philosophy underlying chlorination is therefore to ensure that there is a chlorine *residual* which will protect against recontamination. Dosage, contact time and other factors in the chlorinattion process will be adjusted so that a concentration of 0.1-0.3 mg/l Cl remains after 30 minutes' contact.

Chlorine reacts with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl). The former is a weak acid which dissociates to give hypochlorite ions (OCl^-) and there is a chemical equilibrium between the dissociated and the undissociated forms (the latter actually effects the disinfection) but it is very common to add the chlorine as hypochlorite solution. The *free chlorine residual* is taken to include chlorine, hypochlorous acid and hypochlorite, irrespective of form.

Because of the reactivity with reducing agents and organic matter these free residual forms may not persist and there may not therefore be continuing protection. Ammonia will also react with chlorine forms to give mono-chloramine (NH_2Cl), di-chloramine ($NHCl_2$) and tri-chloramine (NCl_3), depending on relative concentrations and pH. The mono- and di-chloramines have significant disinfection power which persists. Because of this it is sometimes the practice to add ammonia in the chlorination stage to give a *combined residual* rather than a free residual. The results of a complete analysis will therefore show from the relative proportions of free and combined residuals the extent to which disinfection can be maintained during distribution of a supply. Free chlorine is a more efficient disinfection agent than the chloramines but, being more reactive, it is more likely to disappear fairly quickly from solution; the combined chlorine, on the other hand, gives longer-lasting protection.

Two further points should be noted about the use of chlorine. First, if a water is polluted by phenols or by trace organic compounds released from decaying algal growths, chlorination can give rise to very severe taste and odour problems, rendering the water unfit to drink. Second, it should also be noted about chlorination that where a water contains even small amounts of organic (humic) colouring matter, the reaction between it and the added chlorine will give rise to undesirable chlorinated by-products [e.g. trihalomethanes; q.v.] which are also subject to restriction.

Comments: Although chlorine is a poisonous gas, its toxicity to humans is not a consideration in drinking water supplies as a water would be unacceptable on organoleptic grounds long before the onset of directly toxic effects. There are, however, strict limits on its concentration in fishery waters as its toxicity to aquatic life forms is much more marked.

Chlorine : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l HOCl	-	$\leq$ .005	[1]
	(C)	mg/l HOCl	-	$\leq$ .005	[1]
Salmonid Waters Regulations [1988]		mg/l HOCl	n/a	< .005	[2]
Drinking Water Directive [98/83/EC]		-	-	-	[3]

Notes

[1] Designation is "Total residual chlorine." "The I values correspond to pH = 6. Higher concentrations of total chlorine can. be accepted if the pH is higher." Most Irish rivers would be covered by the latter provision; however, no further values are quoted.

[2] Standard to be conformed with by 95 % of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples.

[3] According to Article 7 of the Directive, "Member States shall take all measures necessary to ensure that, where disinfection forms part of the preparation or distribution of water intended for human consumption, the efficiency of the disinfection treatment applied is verified, and that any contamination from disinfection by-products is kept as low as possible without compromising the disinfection." However, residual chlorine *per se* is not mentioned as a parameter.

CHLORODIBROMOMETHANE

(See "Trihalomethanes")

CHLOROFORM

(See "Trihalomethanes")

19. CHLOROPHYLL

Chemical Symbol or Formula: [Complex chemical structure; rarely used]

Units Used for Analytical Results: µg/l or mg/m^3 chlorophyll (total) [4]

Normal Method(s) of Analysis: Solvent extraction/Colorimetry [B]

Occurrence/Origin: Naturally-occurring green pigment in algae, cyanobacteria, plants, vegetation.

Health/Sanitary Significance: No direct implications for health or sanitation.

Background Information: Chlorophyll is perhaps the single most important parameter in the assessment of the water quality of lakes, particularly in regard to their trophic quality (i.e. whether or not, or to what degree, they are enriched due to the presence of nutrients such as phosphorus and - to a much lesser extent - nitrogen in the form of nitrate}. Excessive nutrient presence in lakes promotes the growth of algae which in overabundance cause serious environmental problems.

In over-enriched - eutrophic - lakes "algal blooms" can occur. These are surface accumulations of cyanobacteria (formerly classified as blue-green algae), i.e. dense masses of algae which can be swept by the winds into bays or along the lake shore (where they can decay, causing further problems), and which can seriously disrupt the dissolved oxygen regime. In day time, when conditions are bright or sunny, the algae will carry out photosynthesis, consuming carbon dioxide and releasing oxygen to the waterbody (see "Oxygen, Dissolved"). In darkness, however, the algae respire, consuming dissolved oxygen the levels of which may become critically low - low enough, infact, to cause fish mortality.

Cyanobacterial and algal material can release trace organic components which can cause severe problems on two main accounts. Firstly, the compounds released by cyanobacteria can prove toxic to animals ingesting the water in which they are present. It has been necessary in some instances for local authorities to warn the public not to walk dogs along affected lakeshores or to allow them access to the water. Secondly, in cases where algae are present they can give rise to taste and odour problems if the water is used as drinking water source. One characteristic of waters affected by algal presence is a musty taste or odour. The tastes and odours are much more pronounced if the water is chlorinated prior to distribution as drinking water. In some instances the severity of the taste and odour has been such that temporary closure of the supply was needed.

There are no mandatory standards for chlorophyll concentrations in water, nor are there references to the parameter in the various EU Directives relating to water quality. However, the Organisation for Economic Cooperation and Development [OECD] in 1982 proposed a trophic classification scheme for lake waters which has been adopted (with modifications) in Ireland by the EPA, and which forms the basis for the reporting of quality status in lakes. This scheme is shown in the table below and alongside it is a summation of the corresponding environmental characteristics.

LAKE CLASSIFICATION SCHEME	
Trophic category of Lake water	*Annual Maximum Chlorophyll mg/m^3*
Oligotrophic [O]	< 8
Mesotrophic [M]	8 - 25
Eutrophic - Moderately [m-E]	25 - 35
Eutrophic - Strongly [s-E]	35 - 55
Eutrophic-Highly [h-E]	55 - 75
Hypertrophic [H]	> 75

CATEGORY DESCRIPTORS			
Alga Growth	*Deoxygen. in Hypolimnion*	*Level of Pollution*	*Impairment of Use of Lake*
Low	Low	Very low	Prob. none
Moderate	Moderate	Low	Very little
Substantial	May be high	Significant	May be appr.
High	High	Strong	Appreciable
High	Prob. total	High	High
Very high	Prob. total	Very high	Very high

[4] Results are the same numerically as the units quoted are exact equivalents.

Comments: While not mandatory, the modified OECD classification is an invaluable tool in the categorisation of Irish lake waters.

Chlorophyll : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

20. CHROMIUM

Chemical Symbol or Formula: Cr.

Units Used for Analytical Results: mg/l Cr.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Natural occurrence is in ore, but chromium arises in surface waters from discharges from electroplating, tanning, textile, paint and dyeing plants.

Health/Sanitary Significance: Chromium is toxic, to a degree which varies with the form in which it occurs, whether as the trivalent Cr^{III} or the hexavalent Cr^{VI} form. The latter is considered the more hazardous but because it is difficult to distinguish by analysis the figures quoted below refer mainly to the total chromium concentrations.

Background Information: The element is an essential dietary requirement - in limited amounts - and a deficiency can lead to disruption of glucose metabolism. Indeed, it has been reported that chromium deficiency is of greater nutritional concern than overexposure. However, it is considered that the element is carcinogenic (at high concentrations), though much more evidence of this is needed, and it can act as a skin irritant. Hence its limitation in domestic water supplies. The deaths of livestock resulting from watering in chromium-contaminated water have been reported from time to time.

Comments: There is an extensive list of criteria/standards/recommendations for this element.

Chromium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Cr	n/a	0.05	[1]
	A2 waters	mg/l Cr	n/a	0.05	[1]
	A3 waters	mg/l Cr	n/a	0.05	[1]
Bathing Water Regulations [1989-1998]		mg/l Cr^{VI}	-	-	[2]
Dangerous Substances Directive [76/464/EEC]			List II substance		
Shellfish Directive [79/923/EEC]			[3]	[4]	
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		µg/l Cr	n/a	50	

Chromium: Notes

[1] Total chromium.
[2] Parameter is "Heavy metals such as ... chrome VI..." Sampling to be earned out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..."
[3] "The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."
[4] "The concentration of [this] substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of [this and other specified] metals must be taken into consideration."

21. CLOSTRIDIUM PERFRINGENS (Including Spores)

Chemical Symbol or Formula: Not Applicable [Microbiological Parameter].

Units Used for Analytical Results: Number of organisms/100 ml sample.

Normal Method(s) of Analysis: Most Probable Number (MPN; Multiple Tube Method) [B]; Membrane Filtration Method [B].

Occurrence/Origin: Human and animal wastes and/or soil.

Health/Sanitary Significance: Some species are pathogenic, but health effects - as in the case of the disease of botulism - are also caused by toxins from Clostridium species instead of direct infection.

Background Information; Some Clostridium species have the property of reducing sulphite to sulphide, this characteristic forming the basis of test procedures. They may be used as indicators of faecal pollution and this likely to become a widespread practice. *Clostridium perfringens* is a specific and characteristic member of the group.

Comments: Clostridia are anaerobic, spore-forming organisms, largely but not solely of intestinal origin. They exist in much smaller numbers than E. Coli. Their spores can survive in water much longer than organisms of the coliform group and they are more resistant to disinfection. The WHO *Guidelines* note that "Their presence in disinfected waters may ... indicate deficiencies in treatment and that disinfection-resistant pathogens could have survived treatment," and adds the observation that they are indicative of intermittent or remote contamination, with the caution that "Because they tend to survive and accumulate, they may be detected long after and far from the pollution and thus give rise to false alarms." A limit appears in Drinking Water Directive [98/83/EC] only.

Clostridium perfringens : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	no/100 ml	n/a	0	[1]

Notes

[1] This parameter need not be measured unless the water originates from or is influenced by surface water. In the event of non-compliance with this parametric value, the Member State concerned must investigate the supply to ensure that there is no potential danger to human health arising from the presence of pathogenic micro-organisms, e.g. cryptosporidium. Member States must include the results of all such investigations in the reports they must submit under Article 13(2).

CLOSTRIDIA, SULPHITE-REDUCING

(See "Clostridium Perfringens (Including Spores")

22. COBALT

Chemical Symbol or Formula: Co.

Units Used for Analytical Results: mg/l Co.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Occurs in ores. Presence in water due to discharges.

Health/Sanitary Significance: Little significance in water due to low level of occurrence. The metal and its compounds are hazardous as solids or strong solutions.

Background Information: Cobalt is contained in the Vitamin B_{12} molecule and as such is an important dietary requirement, being provided by green vegetables, in particular. It is rarely found in natural waters and, accordingly, there are few recommendations as to its limitation.

Comments: The lack of standards for drinking water reflects the minimal risk.

Cobalt : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance	
Ground Water Directive [80/68/EEC]			List II substance	

COD

(See "Oxygen Demand, Chemical")

23. COLIFORMS, FAECAL & TOTAL

Chemical Symbol or Formula: Not Applicable [Microbiological parameter].

Units Used for Analytical Results: Number of organisms/100 ml sample.

Normal Method (s) of Analysis: Most Probable Number (MPN: Multiple Tube Method) [B]; Membrane Filtration Method [B].

Occurrence/Origin: Faecal coliforms originate in human and animal waste. Total coliforms include faecal and also other bacteria with similar properties which originate in soil and are non-faecal.

Health/Sanitary Significance: Indicators of possible presence of pathogenic micro-organisms [see detailed discussion below].

Background Information: The risk to consumers of infection from drinking polluted waters will vary very widely from instance to instance because the numbers of pathogenic organisms (i.e. the actual disease-causing organisms) in contaminated waters will show great variations. The number of pathogens in a sewage contaminated water is a function of the number of persons (so-

called "carriers") who excrete such organisms. As the latter is an unknown quantity, and as the positive identification of specific bacteria may be a very difficult task (and not one suited to the routine bacteriological screening of a water on public health grounds) an indirect approach is universally adopted.

To ensure a high factor of safety, the practice has been to monitor *indicator organisms* which, by definition, should be (i) easily detected and identified, (ii) of the same origin as the pathogens (i.e. from the human or animal intestine), (iii) present in far greater numbers than the pathogens, and (iv) present whenever the pathogens are likely to be present. In addition, they should show the same or better survival characteristics than the pathogens and, of course, *they must not be in themselves pathogenic.* To date the universal indicator organisms have been the coliforms, specifically *Escherichia coli*.[5] These bacteria are of definite faecal origin (human and animal) and they are excreted in vast numbers. Their presence in a water supply is proof that faecal contamination has occurred and it is therefore a definite indication of the risk that pathogens may be present. The absence of these faecal coliforms indicates strongly the probability that pathogens are absent.

Because not all coliform organisms (or organisms which show the same test behaviour as coliforms) are of faecal origin, some types being able to grow in soil, a second analysis is carried out for the presence of total coliforms, giving an indication of the general level of microbiological contamination of a water. Each microbiological test procedure is designed around some distinctive, characteristic property of the group of organisms under study. In the case of the coliforms this is the ability to grow aerobically on an agar/bile-salt medium and to ferment lactose, producing acid and gas, within 48 hours at 37°C. *E. coli* are distinguished by further individual properties.

As indicated above, two distinct analytical procedures are used routinely. The first is a multiple tube technique in which several replicates of each of three different dilutions of sample are incubated in test-tubes containing the appropriate medium. After incubation the number of positive results is noted, i.e. the number of tubes at each dilution in which the production of gas etc. is observed, and the result - the Most Probable Number of organisms in 100 ml of sample, commonly known as the MPN - is obtained from probability tables. It is presumed that each "positive" indication is due to the presence of coliforms and the test is known as the "presumptive coliform test." [Confirmatory tests may then be carried out as required.] Concurrent Most Probable Number determinations are made for faecal and total coliforms (at different incubation temperatures) and the results reported separately.

In the MPN technique actual numbers of coliforms are not being determined, as they are in the second commonly used procedure - Membrane Filtration. Here, measured amounts of sample are passed through sterilised filter membranes. The micro-organisms present are retained on the membranes which are transferred to a suitable medium for culturing separately at the appropriate temperatures. The numbers of resulting colonies are counted to give presumptive *E. coli* and total coliform counts. The term presumptive is applied as additional tests would be required to verify that the organisms showed all the reactions characteristic of the coliform group. However, if these extra tests are omitted and waters assessed on the basis of presumptive tests only there is an even greater margin of safety, as a "worst-case" situation is assumed to apply.

The philosophy which has been adopted universally is to use the coliforms as definite indicators of sewage (faecal) pollution and to apply strict limits on their presence in water sources and supplies. The interpretation of the results of analysis may be summarised as follows:

> Where *E. coli* are present in large numbers the inference is that heavy, recent pollution by human or animal wastes has occurred; if the B. coli numbers are low it is inferred that pollution from the same source(s) is either less recent or less severe. If coliforms not including *E. coli* are observed the indication is that either the pollution is recent and non-faecal in origin or of remote, faecal origin such that the intestinal conforms have not survived.

[5] This part of the discussion deals specifically with the organisms E. coli Type I (classified on the basis of test responses) which are the classic indicators of faecal contamination. The quite distinct - and in particular circumstances - highly toxic E. coli Type 0.157 is not germane to the present discussion.

However, if any coliforms at all are found in a treated drinking water supply, following chlorination, it should be concluded that either inadequate treatment is being applied or else that contamination has been introduced during distribution of the water, or in the sampling or handling of the sample(s). Any indication at all of contamination, however apparently mild, must be regarded as a matter of gravity and the circumstances investigated promptly.

Comments: The whole philosophy behind the use of the coliforms as indicators is to give a very high margin of safety. While the exact safety factor would, of course, depend on the ratio of coliforms to pathogens, in practice this is never quantified. Experience has shown this approach to be satisfactory.

Recommended or Mandatory Limit Values

FAECAL COLIFORMS

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	no/100 ml	n/a	1,000	
	A2 waters	no/100 ml	n/a	5,000	
	A3 waters	no/100 ml	n/a	40,000	
Bathing Water Regulations [1989-1998]		no/100 ml	n/a	< 1,000	[1]
		no/100 ml	n/a	< 2,000	[2]
Shellfish Directive [79/923/EEC]		no/100 ml	< 300	-	[3]
Drinking Water Directive [98/83/EC]		no/100 ml	n/a	0	[4,5,6]
		no/250 ml	n/a	0	[4,5,7]

Notes

[1] To be conformed with by 80% or more of samples and not to be exceeded by any two consecutive samples in any case.

[2] To be conformed with by 95% or more of samples and not to be exceeded by any two consecutive samples in any case.

[3] Value applies "in the shellfish flesh and intervalvular liquid," but, pending the adoption of another Directive on the protection of the consumers of shellfish products, "it is essential that this value be observed in waters in which live shell fish directly edible by man."

[4] The parameter is designated “Escherichia coli (E. coli)” and not as faecal coliforms (which it is, in fact).

[5] Analysis by membrane filtration procedure.

[6] This parametric value applies to all drinking water other than that offered for sale in bottles or containers.

[7] This parametric value applies to water offered for sale in bottles or containers.

TOTAL COLIFORMS

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	no/100 ml	n/a	5,000	[1]
	A2 waters	no/100 ml	n/a	25,000	[1]
	A3 waters	no/100 ml	n/a	100,000	[1]
Bathing Water Regulations [1989-1998]		no/100 ml	n/a	$\leq$ 5,000	[2]
		no/100 ml	n/a	$\leq$ 10,000	[3]
Drinking Water Directive [98/83/EC]		no/100 ml	n/a	0	[4,5,]

Total Coliforms : Notes

[1] Incubation temperature 37 "C.
[2] To be conformed with by 80% or more of samples and not to be exceeded by any two consecutive samples in any case.
[3] To be conformed with by 95% or more of samples and not to be exceeded by any two consecutive samples in any case.
[4] The parameter is designated "Coliform bacteria" and not as total coliforms (which it is, in fact).
[5] Analysis by membrane filtration procedure.

24. COLONY COUNT(S)

Chemical Symbol or Formula: Not Applicable [Microbiological parameter].

Units Used for Analytical Results: Number of organisms/ml sample at the stated temperature of incubation [22ºC and 37°C].

Normal Method(s) of Analysis: Incubation on appropriate media plates [B/C].

Occurrence/Origin: Natural or artificial colonisation of water.

Health/Sanitary Significance: None specific - general indicator of the microbiological purity.

Background Information: This is an empirical measurement of aerobic and facultative anaerobic bacteria as a group which is made to assess the overall microbiological quality of a water for human consumption. EU Drinking Water Directive [98/83/EC] uses the parameter designation *Colony Count* (at stated temperature); alternative designations *Standard Plate Count*, *Total Bacteria (Count)* and *Total Plate Count* (at a stated temperature) are also used.

Comments: Because bacteria will have differing properties and hence will not all respond in like manner to the conditions chosen in the test procedure it is clear that the parameter is a rather arbitrary one which nonetheless is useful as a general purity indicator.

Colony Counts: Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	-	n/a	No abnormal change	[1]
	no/1 ml	n/a	100	[2]
	no/1 ml	n/a	20	[3]

Notes

[1] Indicator parameter. Incubation temperature 22°C. Applies to water other than that offered for sale in bottles or containers.
[2] Microbiological parameter. Incubation temperature 22°C. Applies to water offered for sale in bottles or containers.
[3] Microbiological parameter. Incubation temperature 37°C. Applies to water offered for sale in bottles or containers.

25. COLOUR

Chemical Symbol or Formula: Not Applicable [Bulk parameter].

Units Used for Analytical Results: mg/l Pt/Co [mg/l Hazen].

Normal Method(s) of Analysis: Colorimetric [A/C]

Occurrence/Origin: Natural colour reflects the presence of complex organic molecules derived from vegetable (humic) matter such as peat, leaves, branches and soon. Its effect can be enhanced by the presence of suspended matter but this is normally eliminated in the analysis by filtration. Obviously, the more vegetable matter in the water the greater is the colour. Exceptionally, natural colour may arise from the presence of colloidal iron/manganese in a water but organic matter is almost always the cause.

Health/Sanitary Significance: Objections to high colour are generally on aesthetic grounds rather than on the basis of a health hazard. Consumers are reluctant to drink water, however safe, which has a yellowish-brown colour not unlike that of urine, and because of this revulsion any marked colour is very undesirable. So strong may be the objection to colour in water that occasional cases have been noted of people turning from coloured but otherwise safe waters to alternative supplies without coloration, and of a much lower bacteriological quality. However, the 1998 EU Drinking Water Directive - in contrast to its 1980 predecessor - does not set a quantitative standard for colour, effectively leaving the matter to the reactions of consumers.

Nonetheless, it must be noted that the presence of colour on a persistent basis (i.e. with short-term seasonal peak values discounted) in a water which is then disinfected by chlorination is highly undesirable. This because of the readiness with which the colour-causing substances reacted with the added chlorine giving rise to the presence of trihalomethanes (THM; q.v.). The latter compounds are a potential hazard to public health.

Background Information: Because of its origins in vegetable matter the degree of colour in a water will vary very widely in space and in time. The highest colour levels in rivers occur in floods, especially the first flood after a dry season when accumulated deposits of decaying leaves and debris are swept up into the heavy flow releasing highly colouring matter. Because of this variability (which could perhaps be ten-fold) it is essential that many determinations are made to establish the true range of colour in a river, particularly if the water is to be used after treatment for public supply.

Comments: In the present context - and, indeed, in general usage - the term "colour" refers to the natural coloration occurring in waters and not to any induced colouring resulting from wastes.

Colour : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Pt/Co	n/a	20	[1,2]
	A2 waters	mg/l Pt/Co	n/a	100	[1,2]
	A3 waters	mg/l Pt/Co	n/a	150	[1,2]
Bathing Water Regulations [1989-1998]		mg/l Pt/Co	n/a	-	[3]
Shellfish Directive [79/923/EEC]		mg/l Pt/Co	-	-	[4]
Drinking Water Directive [98/83/EC]		-	-	Acceptable to consumers and no abnormal change	

Notes

[1] Parameter is "Colouration (sic) [after simple filtration]."

[2] Departure may be granted by the Minister "where exceptional climatic or geographical conditions have arisen."

Colour : Notes (continued)

[3] The standard in the Regulations is "No abnormal change in colour." It is specified that the standard "be conformed with in 95% of inspections of bathing water. No two consecutive inspections to fail standard."
[4] Parameter is "Coloration [after Filtration]" [through a 0.45µm membrane]. "A discharge affecting shellfish waters must not cause the colour of the waters after filtration to deviate by more than 10 mg Pt/l (sic) from the colour of the waters not so affected."

26. CONDUCTIVITY

Chemical Symbol or Formula: Not Applicable [Physical parameter].

Units Used for Analytical Results: µS/cm.[6]

Normal Method(s) of Analysis: Electrometric [A].

Occurrence/Origin: Reflects mineral salt content of water.

Health/Sanitary Significance: No direct significance.

Background Information: Also referred to as *electrical conductivity* and, not wholly accurately, as *specific conductance*, the conductivity of a water is an expression of its ability to conduct an electric current. As this property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration, the relevance of easily performed conductivity measurements is apparent. In itself conductivity is a property of little interest to a water analyst but it is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall, and also of the order of the dissolved solids content of the water. While a certain proportion of the dissolved solids (for example, those which are of vegetable origin) will not be ionised (and hence will not be reflected in the conductivity figures) for many surface waters the following *approximation* will apply: Conductivity (µS/cm) x 2/3 = Total Dissolved Solids (mg/l).

In samples from a source which is regularly tested a rapid conductivity analysis may be an adequate replacement for other, longer determinations.

Comments: It is important to note that there is an interrelationship between conductivity and temperature, the former increasing with temperature at a rate of some 2 per cent per degree C rise. There is a regrettable lack of uniformity in the terms in which conductivity is reported. Some UK methods manuals report the results at 20°C while the standard US reference manual uses 25°C. A difference of 10 percent can therefore arise depending on how the results are quoted. An error of this magnitude could not be tolerated, especially where conductivity readings are being used to estimate salinity.

Conductivity : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	µS/cm	n/a	1,000	[1]
	A2 waters	µS/cm	n/a	1,000	[1]
	A3 waters	µS/cm	n/a	1,000	[1]
Drinking Water Directive [98/83/EC]		µS/cm	n/a	2,500	[1,2]

Notes

[1] Measured at 20 °C.
[2] "The water should not be aggressive."

[6] The unit is micro-Siemens/centimetre.

27. COPPER

Chemical Symbol or Formula: Cu.

Units Used for Analytical Results: mg/l Cu.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: Ores; industrial wastes.

Health/Sanitary Significance: Copper is not particularly toxic to humans (indeed, it is an essential dietary requirement) and medicinal doses up to 20 mg/l are not unknown. However, astringent tastes in water can be caused by levels above 1 mg/l Cu.

Background Information: This element is present naturally in metalliferous areas but more often its presence in waters is due to attack on copper piping. Rarely, its occurrence may be due to its use as an algicide. Unless used with great care for algal control there is a grave risk of fish kills, as it is as a toxicant to fish that copper is of greatest interest. In recent years there has been at least one major fish kill attributed to the improper use of copper as an algal toxicant. Copper is an element the toxicity of which to fish varies widely with the hardness of the water.

Comments: A problem associated with high levels of copper in water is galvanic corrosion of tanks.

Copper : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Cu	n/a	0.05	[1]
	A2 waters	mg/l Cu	n/a	0.1	[1]
	A3 waters	mg/l Cu	n/a	1.0	[1]
Dangerous Substances Directive [76/464/EEC]			List II substance		
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l Cu	$\leq$ 0.04	-	[2]
	(C)	mg/l Cu	$\leq$ 0.04	-	[2]
Salmonid Waters Regulations [1988]		mg/l Cu	n/a	$\leq$ 0.005	[3,7]
		mg/l Cu	n/a	$\leq$ 0.022	[4,7]
		mg/l Cu	n/a	$\leq$ 0.04	[5,7]
		mg/l Cu	n/a	$\leq$ 0.112	[6,7]
Shellfish Directive [79/923/EEC]		mg/l Cu	[8]	[9]	
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		mg/l Cu	n/a	2.0	[10]

Notes

[1] Departure may be granted "where exceptional climatic or geographical conditions have arisen."

[2] Parameter is "Dissolved copper." The G values given are with reference to a hardness value of 100 mg/ $CaCO_3$. Relevant values for other hardness levels are as follows:

Hardness		10	50	100	500	mg/ $CaCO_3$
Copper	(S)	0.005	0.022	0.04	0.112	mg/l Cu
	(C)	0.005	0.022	0.04	0.112	mg/l Cu

Copper : Notes (Continued)

[3] Standard applies to water of hardness 10 mg/l $CaCO_3$.
[4] Standard applies to water of hardness 50 mg/l $CaCO_3$.
[5] Standard applies to water of hardness 100 mg/l $CaCO_3$.
[6] Standard applies to water of hardness 300 mg/l $CaCO_3$.
[7] Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples.
[8] "The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."
[9] "The concentration of [this] substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of this and other specified] metals must be taken into consideration."
[10] "The value applies to a sample of water intended for human consumption obtained by an adequate sampling method ..... at the tap and taken so as to be representative of a weekly average value ingested by consumers. Where appropriate the sampling and monitoring methods must be applied in a harmonised fashion to be drawn up in accordance with Article 7(4). Member States must take account of the occurrence of peak levels that may cause adverse effects on human health."

28. CRYPTOSPORIDIUM

Chemical Symbol or Formula: Not Applicable [Microbiological parameter]

Units Used for Analytical Results: Number of cysts/100 litres.

Normal Method(s) of Analysis: Advanced Microbiological Techniques [C/D]

Occurrence/Origin: Present in human and animal wastes.

Health/Sanitary Significance: *Cryptosporidium* is a small (microscopic) parasite present in faecal material. It has pathogenic effects in both children and adults, when it enters the gastrointestinal tract and causes an infection termed *cryptosporidiosis*. The effects of the latter include fever, stomach upsets, weight loss and diarrhoea. While healthy adults will normally recover within three days, the effects on both old and young, and those with weakened immune systems, are much more serious and can lead to death.

The *Cryptosporidium* organism - a protozoan - is protected by an outer shell (termed a cyst) which affords it protection and permits it to survive for long periods outside the body. It can occur in drinking water supplies which are contaminated by human or animal waste and is considered by the WHO to be a pathogen of high health significance.

Background Information: A problem associated with *Cryptosporidium* is that it is very resistant to destruction by chlorine and other disinfectants. It may survive the disinfection process unless specific additional treatment is applied.

Comments: If the quality of a drinking water is suspect, the water should be brought to the boil before consumption. This will destroy the micro-organisms present.

Cryptosporidium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	-	-	-	[1]

Cryptosporidium: Notes

[1] While the Directive does not include Cryptosporidium in. any of its lists of parameters, Article 4 stipulates that: "For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be clean and wholesome if it: ...is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to public health."

29. CYANIDE

Chemical Symbol or Formula: CN^-

Units Used for Analytical Results: mg/l CN.

Normal Method(s) of Analysis: Colorimetric (after distillation) (B]; Specific Ion Electrode (after distillation) [B].

Occurrence/Origin: Industrial effluents (principally electroplating).

Health/Sanitary Significance: Cyanide is a reactive, highly toxic entity which in excessive amount will cause mortality rapidly to humans and to fish.

Background Information: It is a common constituent of industrial wastes, especially from metal plating processes and electronic components manufacture.

Comments: Due to its reactivity cyanide does not persist in the environment.

Cyanide : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l CN	n/a	0.05	
	A2 waters	mg/l CN	n/a	0.05	
	A3 waters	mg/l CN	n/a	0.05	
Bathing Water Regulations [1989-1998]		mg/l CN	-	-	[1]
Dangerous Substances Directive [76/464/EEC]			List II substance		
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		µg/l CN	n/a	50	

Notes

[1] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..."

30. 1,2-DICHLOROETHANE

Chemical Symbol or Formula: $C_2H_4Cl_2$.

Units Used for Analytical Results: µg/l $C_2H_4Cl_2$.

Normal Method(s) of Analysis: Gas Chromatography [C].

Occurrence/Origin: Synthetic organic solvent used in various industries.

Health/Sanitary Significance: Toxic substance which causes a variety of ill-effects in humans, including eye damage, dermatitis, narcotic effects etc.

Background Information: The compound is alternatively known as ethylene dichloride. It is used as a solvent for a variety of materials, especially rubber.

Comments: This only limit for this substance occurs in Drinking Water Directive [98/83/EC].

1,2-Dichloroethane : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l	n/a	3.0	

E. coli

(See "Coliforms, Faecal and Total")

31. ENTEROCOCCI

Chemical Symbol or Formula: Not Applicable [Microbiological parameter].

Units Used for Analytical Results: Number of organisms/100 ml sample.

Normal Method(s) of Analysis: Most Probable Number (MPN) technique [B]; Membrane Filtration procedure [B].

Occurrence/Origin: Sewage and similar wastes.

Health/Sanitary Significance: Some members of the group "enterococci" have pathogenic properties.

Background Information: These organisms originate in faeces, both animal and human. Despite their having some pathogenic properties, their main use is as an indicator of faecal pollution and, as they can be reliably and easily determined, their estimation is useful in clarifying the position in waters which show no *E. coli* but large numbers of coliform bacteria as a group. In the earlier Drinking Water Directive [80/778/EEC] the relevant parameter was "Faecal Streptococci" but this has been replaced by the present broader term. One of the more relevant members of this group is *Streptococcus faecalis*.

Comments: While the measurement of faecal streptococci has been recommended as a source of valuable supplementary information on surface water quality, particularly in combination with data from faecal coliform assays, it should be remembered that a limitation on the use of faecal streptococci is their shorter survival time in the aquatic environment.

Enterococci : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	no./100 ml	n/a	200	
	A2 waters	no./100 ml	n/a	2,000	
	A3 waters	no./100 ml	n/a	10,000	

Enterococci : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	no./100 ml	n/a	≤ 300	[1]
Drinking Water Directive [98/83/EC]	no./100 ml	n/a	0	[2,3]
	no./250 ml	n/a	0	[2,4]

Notes

[1] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..." Standard to be conformed with by 95% of samples and not to be exceeded by any two consecutive samples,
[2] Parameter is designated "Enterococci."
[3] This parametric value applies to drinking water other than that offered for sale in bottles or containers.
[4] This parametric value applies to "water offered for sale in bottles or containers,"

32. ENTEROPATHOGENIC VIRUSES

Chemical Symbol or Formula: Not Applicable [Microbiological parameter].

Units Used for Analytical Results: PFU / 10 litres.

Normal Method(s) of Analysis: [Specialised microbiological techniques] [D]

Occurrence/Origin: Human and animal wastes.

Health/Sanitary Significance: Viruses are pathogens with highly specific reactions, causing several well-known major diseases in man, as discussed below.

Background Information: Those viruses of concern in water supply can pass through the stomach and into the intestine where they multiply and from which they are excreted. Among the diseases which are viral in origin and are water-borne are poliomyelitis, gastro-enteritis and infectious hepatitis. Because the detection of viruses is a complicated analytical procedure and cannot be done quickly, the analysis is not carried out as a routine and reliance is placed instead on the coliforms as indicators of faecal pollution (see "Coliforms, Faecal & Total" above).

However, caution must be exercised as the viruses are not as susceptible to chlorination as bacteria and it does not necessarily follow that a complete bacterial kill will be matched by the absence of all viruses. It is critically important, therefore, that adequate care is taken in chlorination and that proper chlorine residuals are maintained in water supplies.

Comments: Deficiencies in analytical and epidemiological techniques mean that it is not possible to assert that a water is free of viruses, hence the absence of limit values or guideline levels in most of the sources cited, including the 1993 WHO *Guidelines*. However, this invaluable WHO publication contains a table of recommended treatments for different sources aimed at producing water with a negligible virus risk. Details are quoted in Appendix 9 below. The relevance of the low turbidity requirement mentioned in the Appendix (which must be met before the water is disinfected) arises because the colloidal solid matter giving rise to turbidity may otherwise act as a shield for any viruses present, possibly preventing fully efficient disinfection.

Enteropathogenic Viruses : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	PFU/10 litres	-	0	[1,2]
Drinking Water Directive [98/83/EC]	-	-	-	[3]

Notes

[1] Units are plaque-forming units [PFU]/10 litres.

[2] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..." A 95% compliance is required.

[3] Article 4(1) of the Directive states, *inter alia*, that: "For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be wholesome and clean if it... is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health......"; Article 7(6) requires that "Member States shall ensure that additional monitoring is carried out on a case-by-case basis of substances and micro-organisms for which no parametric value has been set in accordance with Article 5, if there is reason to suspect that they may be present in amounts or numbers which constitute a potential danger to human health."

33. EPICHLOROHYDRIN

Chemical Symbol or Formula: C_3H_5ClO.

Units Used for Analytical Results: µg/l C_3H_5ClO.

Normal Method(s) of Analysis: Gas Chromatography [C].

Occurrence/Origin: Synthetic chlorinated solvent.

Health/Sanitary Significance: Toxic substance which is a strong skin irritant and which can cause kidney and other damage.

Background Information: Solvent for resins, gums, enamels, cellulose, lacquers etc.

Comments: This is another of the series of chlorinated solvents the concentration of which in drinking water is subject to strict controls.

Epichlorohydrin : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l	n/a	0.10	[1]

Notes

[1] The Directive states that: The parametric value refers to the residual monomer concentration in the water as calculated according to specifications of the maximum release from the corresponding polymer in contact with the water.

ESCHERICHIA COLI

(See "Coliforms, Faecal and Total")

ETHYLENE DICHLORIDE

(See "1,2-Dichloroethane")

FAECAL COLIFORMS

(See "Coliforms, Faecal and Total")

34. FLUORIDE

Chemical Symbol or Formula: F^-.

Units Used for Analytical Results: mg/I F.

Normal Method(s) of Analysis: Colorimetric (after distillation) [B]; Specific Ion Electrode [B].

Occurrence/Origin: Occurs naturally in quite rare instances; arises almost exclusively from fluoridation of public water supplies and from industrial discharges.

Health/Sanitary Significance: Health studies have shown that the addition of fluoride to water supplies in levels above 0.6 mg/l F leads to a reduction in tooth decay in growing children and that the optimum beneficial effect occurs around 1.0 mg/l.

Background Information: At levels markedly over 1.5 mg/l an inverse effect occurs and mottling of teeth (or severe damage at gross levels) will arise. For this reason there is a constraint on fluoride levels, the effects of which vary with temperature.

Comments: It should be noted that fluoride levels in fluoridated public water supplies in Ireland are legally restricted to the range 0.8-1.0 mg/l F. The same legislation specifies the distillation procedure for fluoride analysis. In making the 1988 Drinking Water Regulations the then Minister for the Environment fixed 1.0 mg/l F [1,000 µg/1 F] as the MAC. Thus the limit value for fluoride in Ireland is one-third less than that which applies elsewhere in the EU.

Fluoride : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l F	n/a	1.0	
	A2 waters	mg/l F	n/a	1.7	
	A3 waters	mg/l F	n/a	1.7	
Dangerous Substances Directive [76/464/EEC]			List II substance		
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		mg/l F	n/a	1.5	

FREE CARBON DIOXIDE

(See "Carbon Dioxide, Free")

35. GIARDIA

Chemical Symbol or Formula: Not Applicable [Microbiological parameter]

Units Used for Analytical Results: Number of cysts/100 litres.

Normal Method(s) of Analysis: Advanced Microbiological Techniques [C/D]

Occurrence/Origin: Present in human and animal wastes.

Health/Sanitary Significance: *Giardia* is a small (microscopic) parasite present in human and animal wastes which has pathogenic effects m both children and adults. If ingested in water, *Giardia* can cause fever, stomach upsets (often very severe) and diarrhoea; however, it is rarely fatal. The organism is protected by an outer shell (termed a cyst) which affords it protection and permits it to survive for long periods outside the body.

Background Information: A problem associated with *Giardia* is that the cysts are not very amenable to destruction by chlorine. Unless an enhanced chlorine dosage and extended contact time are used *Giardia* may survive the disinfection process.

Comments: If the quality of a drinking water is suspect, the water should be brought to the boil before consumption. This will destroy the *Giardia* and other micro-organisms present.

Giardia : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	-	-	-	[1]

Notes

[1] While the Directive does not include *Giardia* in any of its lists of parameters Article 4 stipulates that: "For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be clean and wholesome if it...is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to public health."

HALOFORMS

(See "Trihalomethanes")

36. HARDNESS

Chemical Symbol or Formula: Not Applicable [Bulk parameter].

Units Used for Analytical Results: mg/l $CaCO_3$.

Normal Method(s) of Analysis: Titration with EDTA [A].

Occurrence/Origin: Rock formations - limestone etc.

Health/Sanitary Significance: Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. Health studies in several countries in recent years indicate that mortality rates from heart diseases are lower in areas with hard water.

Background Information: Originally taken to be the capacity of a water to destroy the lather of soap, hardness was determined formerly by titration with soap solution. Nowadays, the analysis comprises the determination of calcium and magnesium which are the main constituents of hardness. Although barium, strontium and iron can also contribute to hardness, their concentrations are normally so low in this context that they can be ignored. Thus, *total hardness* is taken to comprise the calcium and magnesium concentrations expressed as mg/l $CaCO_3$. The widespread abundance of these metals in rock formations leads often to very considerable hardness levels in surface and ground waters.

The following is one of several such arbitrary classifications of waters by hardness[7]:

Soft	up to 50 mg/l $CaCO_3$	Moderately Hard	151-250 mg/l $CaCO_3$
Moderately Soft	51-100 mg/l $CaCO_3$	Hard	251-350 mg/l $CaCO_3$
Slightly Hard	101 - 150 mg/l $CaCO_3$	Excessively Hard	over 350 mg/l $CaCO_3$.

A variety of additional terms is used to describe different aspects of hardness. These are frequently encountered and are summarised briefly below:

Calcium Hardness is the expression of the results of the measurement of calcium only, as mg/l $CaCO_3$.

Carbonate Hardness is the hardness derived from the solubilisation of calcium or magnesium carbonate (by conversion of the carbonate to bicarbonate). This hardness is removed by heating (see below).

Magnesium Hardness The difference between total hardness and calcium hardness is taken as the magnesium hardness (all figures as mg/l $CaCO_3$.).

Non-carbonate Hardness is the hardness due to the solution of calcium chloride or magnesium sulphate, for example.

Permanent Hardness This is equivalent to non-carbonate hardness in that it cannot be reduced or removed by heating.

Temporary Hardness The same as carbonate hardness, this form may be removed by heating the waters, when chemical reactions occur as follows:

$$2HCO_3^- \rightarrow H_2O + CO_2 + CO_3^{--}$$
$$CO_3^{--} + Ca^{++} \rightarrow CaCO_3$$

Calcium Carbonate (insoluble)

This is in fact what happens in most cases when the temporary hardness is deposited as scale in boilers, etc.

Total Hardness is the expression of the results of direct measurement (principally of calcium and magnesium) expressed as mg/l $CaCO_3$.

Comments: As has been pointed out earlier (cf. "Copper") hardness levels have a bearing on the toxicity of some metals. In general, these toxic effects are markedly less in waters with a significant degree of hardness. The chief disadvantages of hard waters are that they neutralise the lathering power of soap (though not modern detergent formulations) and, more important, that they can cause blockage of pipes and severely reduced boiler efficiency because of scale formation. These effects will increase as the hardness rises to and beyond 200 mg/l $CaCO_3$.

Hardness: Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Freshwater Fish Directive [78/659/EEC]	(S)	-	-	-	[1]
	(C)	-	-	-	[1]

[7] The boundaries between the top of one hardness band and the bottom of the following one are nowhere near as exact as the presentation convention used apparently implies. Indeed, there is no rigidity about the classification, which should be used sensibly as a handy measure.

Hardness: Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Salmonid Waters Regulations [1988]	-	-	-	[2]
Drinking Water Directive [98/83/EC]	-	-	-	[3]

Notes

[1] There are no limits for hardness as such in this Directive, but Annex II contains data on the relationship between hardness and the acceptable levels of dissolved copper and total zinc in salmonid and cyprinid waters.
[2] There are no limits for hardness as such in the Regulations, but the Second Schedule contains data on the relationship between hardness and the permissible levels of dissolved copper and total zinc in salmonid waters.
[3] There is no reference to hardness in this Directive.

37. HEAVY METALS

Chemical Symbol or Formula: Varies with each metal.

Units Used for Analytical Results: µg/l or mg/l metal.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry[8] [B/C/D]

Occurrence/Origin: Principally from effluent discharges, or from distribution piping, or from geological formations.

Health/Sanitary Significance: Toxic to humans (to a degree varying greatly from metal to metal) and to fish (the hazard levels for which are generally very much lower). Easily accumulable in fish and other tissue and hence liable to enter food chain.

Background Information: The parameters in this very important category comprise principally those listed below. Arsenic, though non-metallic, is included for convenience as it is toxic and is generally referred to as a constituent of this group. All the elements listed below are discussed under separate paragraphs in this volume but the general class "Heavy Metals" has been included for completeness as references to the group are very common indeed. The term "heavy metals" is rather inaccurate and, indeed, could be misleading. It arises from the high atomic weights of several metals in the broad group, although other metals regarded as in the same group have low atomic weights. Nonetheless, the term both is widely current and a useful descriptor. The following is a listing of the more commonly referred to metals in this class:

Antimony	Cobalt	Nickel	Tin
Arsenic	Copper	Selenium	Titanium
Beryllium	Lead	Silver	Uranium
Cadmium	Mercury	Tellurium	Vanadium
Chromium	Molybdenum	Thallium	Zinc.

The individual substances are all more or less toxic to either man or fish or both, and their presence is highly undesirable in raw or finished public waters or in fishery waters, salmonid or cyprinid.

[8] And related techniques, including ICP [inductively-coupled plasma] spectroscopy.

Comments: It should be noted that in the case of some of these metals complexes can be formed with organic materials (so-called "organometallics"), the resultant compounds being very toxic indeed, perhaps far more so than the un-complexed elements. Examples of such noxious materials are methylmercury and tributyltin.

38. HYDROCARBONS, DISSOLVED & EMULSIFIED

Chemical Symbol or Formula: Not Applicable [Bulk parameter].

Units Used for Analytical Results: mg/l material.

Normal Method(s) of Analysis: Gravimetric [B/C] or Gas Chromatographic [C].

Occurrence/Origin: Effluent discharges, oil spillages etc.

Health/Sanitary Significance: The main implications are organoleptic in the context of this parameter as covered by the Directives and Regulations (see below), but many complex hydrocarbon materials are carcinogenic (e.g. polycyclic aromatic hydrocarbons, q.v.).

Background Information: This heading includes petroleum, oil, grease and related materials. Problems caused by these substances include interference with such vital processes as the mass transfer of oxygen from air to water (essential in river reaeration, for example), blockage of pipes, fouling of plant and animal life, odour and taste problems, and the like.

Comments: It is worth reiterating that this parameter as herein defined is an overall aggregate (or bulk) parameter which is nonetheless limited in its scope by the generalised nature of the relevvan analytical methods. A large number of specific (and potentially undesirable) hydrocarbon compounds are thus excluded from its coverage.

Hydrocarbons : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l	n/a	0.01	[1]
	A2 waters	mg/l	n/a	0.2	[1]
	A3 waters	mg/l	n/a	1	[1]
Bathing Water Regulations [1989-1998]		mg/l	-	-	[2,3]
Dangerous Substances Directive [76/464/EEC]			Lists I & II substances		[4,5]
Freshwater Fish Directive [78/659/EEC]	(S)	-	-	-	[6,7]
	(C)	-	-	-	[6,7]
Salmonid Waters Regulations [1988]		-	-	-	[6,7]
Shellfish Directive [79/923/EEC]		-	-	-	[6,8]
Ground Water Directive [80/68/EEC]			List I substances		[9]
Drinking Water Directive [98/83/EC]		-	-	-	[10]

Notes

[1] Parameter is designated as "Dissolved or emulsified hydrocarbons [after extraction by petroleum ether]."
[2] Parameter is described as "Mineral oils."
[3] Standard is "No film visible on the surface of bathing water and no odour. To be conformed with in 95% of inspections of bathing water. No two consecutive inspections to fail standard."
[4] Parameter is described as "Persistent mineral oils and hydrocarbons of petroleum origin" in List I.
[5] Parameter is described as "Non-persistent mineral oils/hydrocarbons of petroleum origin" in List II.
[6] Parameter is described as "Petroleum hydrocarbons."
[7] No units are quoted nor is any limit value, but the Directive and Regulations state [in Annex I, footnote 3, and in the Second Schedule, respectively]: "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 - produce harmful effects in fish."
[8] No units are quoted nor is any limit value, but the Directive states as the I value: "Hydrocarbons must not be present in the shellfish water in such quantities as to: - produce a visible film on the surface of the water and/or a deposit on the shellfish - have harmful effects on the shellfish."
[9] Parameter is described as "Mineral oils and hydrocarbons."
[10] The 1998 Drinking Water Directive contains no references to "hydrocarbons" *per se* as a generic parameter. The parametric values quoted in the Directive apply to specific compounds or to particular compound groups.

INDENO(l,2,3-c,d)PYRENE

(See "Polycyclic Aromatic Hydrocarbons)

39. IRON

Chemical Symbol or Formula: Fe.

Units Used for Analytical Results: mg/l Fe.

Normal Method(s) of Analysis: Colorimetric (o-Phenanthroline) [B]; Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Geological formations (especially under reducing conditions); acid drainage; effluent discharges.

Health/Sanitary Significance: The objections to iron are primarily organoleptic, but there has been recent medical concern about high levels in drinking water.

Background Information: Iron is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. Appreciable amounts of iron may therefore be present in ground waters. Severe problems can be caused in drinking water supplies by the presence of iron although there is normally no harmful effect on persons consuming waters with significant amounts of iron. Rather, the problems are primarily aesthetic, as the soluble (reduced) ferrous (Fe^{++}) iron is oxidised in air to the insoluble ferric (Fei^{+++}) form, resulting in colour or turbidity (or, in severe cases, precipitate formation). Laundry becomes stained if washed in water with excessive iron, and vegetables likewise become discoloured on cooking. Taste problems may also occur. When waters rich in iron are used to make tea (in which tannins are present) there may be a reaction giving rise to off-colours which may in severe cases resemble that of ink. Problems have been reported also with the addition of such waters to whiskey.

Comments: The metal is quite harmful to aquatic life, as evidenced by laboratory studies, but in nature the degree of toxicity may be lessened by the interaction of the iron with other constituents of a water. Should the metal be converted to an insoluble form then the iron deposits will interfere with fish food and with spawning.

Iron : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Fe	n/a	0.2	[1,2]
	A2 waters	mg/l Fe	n/a	2.0	[1,2]
	A3 waters	mg/l Fe	n/a	2.0	[1,2]
Drinking Water Directive [98/83/EC]		µg/l Fe	n/a	200	[3]

Notes

[1] Parameter is described as "Dissolved iron."
[2] Departure may be granted by the Minister "in. the case of surface water in shallow lakes or virtually stagnant surface water."
[3] Parameter is described as "Iron."

40. LEAD

Chemical Symbol or Formula: Pb.

Units Used for Analytical Results: mg/l Pb.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry s [B/C/D]

Occurrence/Origin: Leaching from ores; effluent discharges; attack on water pipes.

Health/Sanitary Significance: Toxic cumulative poison.

Background Information: Lead is one of the most commonly determined heavy metals. Because it accumulates in body tissue it follows that strict limits on its presence in raw and finished drinking waters must be imposed. Particular attention is paid to this element as in many older houses extensive use is made of lead piping and there is a danger of lead being brought into solution ("plumbosolvency"). Levels may be quite marked in samples taken first thing in the morning when the initial yield will be of water which has been standing in such pipes for perhaps twelve hours. Hence the recommendation that drinking water pipes be flushed briefly in the morning before the water is consumed.

Comments: The comments accompanying the standard in the Drinking Water Regulations reflect the fact that some waters which are in prolonged contact with old lead pipes are liable to dissolve possibly significant amounts of the metal. However, in Ireland there are no perceived risks from the normal daytime use of such water/plumbing combinations when throughput is likely to be high. In the EU as a whole, however, there is heightened concern about lead in drinking water, as is shown clearly in the notes below pertaining to Drinking Water Directive [98/83/EC].

Lead : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Fe	n/a	0.05	
	A2 waters	mg/l Fe	n/a	0.05	
	A3 waters	mg/l Fe	n/a	0.05	

Lead : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	mg/l Pb	-	-	[1]
Dangerous Substances Directive [76/464/EEC]		List II substance		
Shellfish Directive [79/923/EEC]	mg/l Pb	[2]	[3]	
Ground Water Directive [80/68/EEC]		List II substance		
Drinking Water Directive [98/83/EC]	µg/l Pb	n/a	10	[4,5]

Notes

[1] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in. the quality of waters..."
[2] "The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."
[3] "The concentration of [this] substance in the shellfish, water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of [this and other specified] metals must be taken into consideration."
[4] The value applies to a sample of water intended for human consumption obtained by an adequate sampling method ..... at the tap and taken so as to he representative of a weekly average value ingested by consumers. Where appropriate the sampling and monitoring methods must be applied in a harmonised fashion to be drawn up in accordance with Article 7(4). Member States must take account of the occurrence of peak levels that may cause adverse effects on human health.
[5] For water referred to in Article 6(l)(a), (b) and (d), the value must be met, at the latest, 15 calendar years after the entry into force of this Directive. The parametric value for lead from five years after the entry into force of this Directive until 15 years after its entry into force is 25 µg/l.
Member States must ensure that all appropriate measures are taken to reduce the concentration of lead in water intended for human consumption as much as possible during the period needed to achieve compliance with the parametric value.
When implementing the measures to achieve compliance with that value Member States must progressively give priority where lead concentrations in water intended for human consumption are highest.

41. MAGNESIUM

Chemical Symbol or Formula: Mg.

Units Used for Analytical Results: mg/l Mg.

Normal Method(s) of Analysis: Titration with EDTA [A]; Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Major constituent of geological formations.

Health/Sanitary Significance: Indirect (in conjunction with Sulphate, q.v.).

Background Information: Like calcium (q.v.), magnesium is abundant and a major dietary requirement for humans (0.3-0.5 g/day). It is the second major constituent of hardness (see above) and it generally comprises 15-20 per cent of the total hardness expressed as $CaCO_3$. Its concentration is very significant when considered in conjunction with that of sulphate (q.v.).

Comments: Magnesium sulphate is used medicinally as "Epsom Salts," a laxative.

Magnesium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				[1]

Notes

[1] The MAC specified in the 1980 Drinking Water Directive is not carried forward to the corresponding 1998 Directive, which makes no reference to magnesium or other elements of water hardness.

42. MANGANESE

Chemical Symbol or Formula: Mn.

Units Used for Analytical Results: mg/l Mn.

Normal Method(s) of Analvsis: Colorimetric (Persulphate) [B]; Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Widely distributed constituent of ores and rocks.

Health/Sanitary Significance: No particular toxicological connotations; the objections to manganese - like iron - are aesthetic.

Background Information: As with iron, manganese is found widely in soils and is a constituent of many ground waters. It, too, may be brought into solution in reducing conditions and the excess metal will be later deposited as the water is reaerated. The general remarks for iron (q.v.) apply to manganese but the staining problems with this metal may be even more severe, hence the quite stringent limits. A second effect of the presence of manganese much above the limits is an unacceptable taste problem.

Comments: Toxicity is not a factor, as waters with high levels of manganese will be rejected by the consumer long before any danger threshold is reached.

Manganese : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Mn	n/a	0.05	[1]
	A2 waters	mg/l Mn	n/a	0.3	[1]
	A3 waters	mg/l Mn	n/a	1.0	[1]
Drinking Water Directive [98/83/EC]		µg/l Mn	n/a	50	

Notes

[1] Departure may be granted by the Minister "in the case of surface water in shallow lakes or virtually stagnant surface water."

MBAS

(See "Methylene Blue-Active Substances")

43. MERCURY

Chemical Symbol or Formula: Hg.

Units Used for Analytical Results: µg/l Hg.

Normal Method(s) of Analysis: Flameless Atomic Absorption Spectrometry [C]; or ICP [inductively-coupled plasma] Spectroscopy [D].

Occurrence/Origin: Normally from industrial waste discharges.

Health/Sanitary Significance: Very toxic, especially in organo-mercury compounds (e.g. methyl-mercury).

Background Information: This is a very toxic element, the hazards of which are magnified by the accumulation of organo-mercury compounds in fish. It is generally industrial in origin (dental amalgams, anti-fouling paints, plastics manufacture, Hgttery-making, paper-making and so on) though some comes from the natural environment.

Comments: There have been some major pollution incidents (notably in Japan) where both death and severe damage to health has been caused to many people consuming fish and shellfish contaminated by heavy industrial discharges of mercury.

Mercury : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Hg	n/a	0.001	
	A2 waters	mg/l Hg	n/a	0.001	
	A3 waters	mg/l Hg	n/a	0.001	
Bathing Water Regulations [1989-1998]		mg/l Hg	-	-	[1]
Dangerous Substances Directive [76/464/EEC]			List I substance		
Shellfish Directive [79/923/EEC]		mg/l Hg	[2]	[3]	
Ground Water Directive [80/68/EEC]			List I substance		
Drinking Water Directive [98/83/EC]		µg/l Hg	n/a	1.0	

Notes

[1] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..."

[2] “The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."

(3] "The concentration of [this] substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of [this and other specified] metals must be taken into consideration."

44. METHYLENE BLUE-ACTIVE SUBSTANCES

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l reference material (Lauryl sulphate; Manoxol OT etc.).

Normal Method(s) of Analysis: Methylene Blue/Solvent Extraction [B]

Occurrence/Origin: Synthetic materials in domestic and industrial wastes.

Health/Sanitary Significance: No immediate implications as other problems (see below) will prevent consumption of waters with these materials present.

Background Information: Often abbreviated to MBAS, the designation of this parameter is the chemically correct term for the group of compounds commonly known as anionic detergents. To cloud the issue further, the non-specific terms surf octants (surface active agents) and sy ndets (synthetic detergents) are also used on occasion, the former more frequently. Synthetic detergents fall into three groups - anionic, cationic and non-ionic. The last-mentioned are all substituted polymers of ethylene oxide which do not ionise in water. They are more expensive than the anionic type but are coming into greater use. The cationic types are salts of quaternary ammonium hydroxide and are known for their properties of disinfection. The major group comprises the anionic detergents which are all sodium salts of organic sulphates or sulphonates. Such entities form ion pairs with the reagent methylene blue, a property which forms the basis of their estimation. The results are quoted as mg/l standard reference material. Some authorities specify lauryl sulphate which is used increasingly as a standard. However, UK practice has been to use a chemically similar but distinct material, Manoxol OT (sodium di-octyl sulphosuccinate), and it is therefore important to note which terms are used to express the results.

It is worth noting that other terms have been used in connection with synthetic detergents. "Hard" and "soft" detergents are those which are biodegraded with difficulty and with ease, respectively. The designations have nothing to do with the hardness of the waters in which they are used. Some of the original anionic detergents were very hard; structurally they were of the "ABS" (alkylbenzenesulphonate) type. Later, there was a move towards the much more biodegradable ("soft") linear alkylate sulphate/sulphonate ("LAS") detergents. This was to help eliminate the major problem of foaming. In the US very severe foaming problems were encountered in the days of first use of synthetic detergents. Other disadvantages associated with them include interference with the reaeration of water which is low in dissolved oxygen, and the synergistic foaming effects which can arise when waters containing sub-foaming concentrations of different types of detergents are mixed. Most detergent preparations contain around 20 per cent surface active agent (which is all that is determined in this test): the rest of the formulation consists of so-called "builders" which enhance the properties of the active constituent. Chief among these are phosphates which are of major environmental significance (see below).

Comments: It should be noted that, as there may be some extraneous matter which will also react with methylene blue, the analysis is more correctly designated as "methylene blue active substances" than as anionic detergents, even though the latter may in fact represent 100 per cent of levels found.

Methylene Blue - Active Substances : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l LAS	n/a	0.2	[1,2]
	A2 waters	mg/l LAS	n/a	0.2	[1,2]
	A3 waters	mg/l LAS	n/a	0.2	[1,2]

Methylene Blue - Active Substances : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	mg/l LAS	-	-	[2,3,4]
Drinking Water Directive [98/83/EC]	-	-	-	[5]

Notes

[1] Parameter is described as "Surfactants (reacting with methylene blue)."
[2] Unit of analysis is mg/l lauryl sulphate [LAS-type surfactant].
[3] Parameter is described as "Surface active substances reacting with methylene blue."
[4] Standard is "No lasting foam." Standard to be conformed with in 95% of inspections of bathing water. No two consecutive inspections to fail standard.
[5] The MAC specified in the 1980 Drinking Water Directive is not carried forward to the corresponding 1998 Directive, which makes no reference to MBAS or surfactant materials.

45. MOLYBDENUM

Chemical Symbol or Formula: Mo.

Units Used for Analytical Results: mg/l Mo.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: Industrial effluents, but low occurrence rate.

Health/Sanitary Significance: None.

Background Information: Natural molybdenum levels in waters likely to be used as sources of public supply are very low and, in any event, human toxicity caused by this metal is very rare. However, the sensitivity of livestock to the element has been found to be significant although no specific limits for water have apparently been set for animal drinking water

Comments: There are no applicable standards for this element.

Molybdenum : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance	
Ground Water Directive [80/68/EEC]			List II substance	

46. NICKEL

Chemical Symbol or Formula: Ni.

Units Used for Analytical Results: mg/l Ni.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: Principal sources are minerals and industrial wastes.

Health/Sanitary Significance: Very limited.

Background Information: This is another metallic element which is of moderate concern because of possible carcinogenicity as far as humans are concerned; it also has variable harmful effects on aquatic life. It is toxic to plant life, too, and is a hazard to fish (generally in the mg/l concentration range).

Comments: None.

Nickel : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]		List II substance		
Shellfish Directive [79/923/EEC]	mg/l Ni	[1]	[2]	
Ground Water Directive [80/68/EEC]		List II substance		
Drinking Water Directive [98/83/EC]	µg/l Ni	n/a	20	[3]

Notes

[1] "The concentration. of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shell fish products."

[2] "The concentration of [this] substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of [this and other specified] metals must be taken into consideration."

[3] The Directive states that "The value applies to a sample of water intended for human consumption obtained by an adequate sampling method ..... at the tap and taken so as to he representative of a weekly average value ingested by consumers. Where appropriate the sampling and monitoring methods must be applied in a harmonised fashion to be drawn up in accordance with Article 7(4). Member States must take account of the occurrence of peak levels that may cause adverse effects on human health."

47. NITRATE

Chemical Symbol or Formula: NO_3^-

Units Used for Analytical Results: mg/l N or mg/l NO_3^-.

Normal Methods of Analysis: Manual/Automated Colorimetry [A/B]; Specific Ion Electrode [B].

Occurrence/Origin: Oxidation of ammonia: agricultural fertiliser run-off.

Health/Sanitary Significance: Hazard to infants above 11 mg/l N [50 mg/l NO_3].

Background Information: Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilisers. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrate. Interest is centred on nitrate concentrations for various reasons. Most importantly, high nitrate levels in waters to be used for drinking will render them hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite [see also below] which reacts with blood haemoglobin to cause methaemoglobinaemia.

Of increasing importance is the degree to which fertiliser run-off can contribute to eutrophication problems in lakes. Sewage is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. Hence, the presence of nitrate in ground waters, for example, is cause for suspicion of past sewage pollution or of excess levels of fertilisers or manure slurries spread on land. (High nitrite levels would indicate more recent pollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation). In rivers high levels of nitrate are more likely to indicate significant run-off from agricultural land than anything else and the parameter is not of primary importance per se. However, it should be noted that there is a general tendency for nitrate concentrations in rivers to increase as a result of enhanced nutrient run-off; this may ultimately lessen their utility as potential sources of public water supply. Nitrite concentrations in rivers are rarely more than 1 - 2 per cent of the nitrate level so that it may therefore be acceptable to carry out the analytically convenient determination of nitrate + nitrite at the same time. This determination is correctly referred to as *total oxidised nitrogen*.

Comments: Although the topic of the units in which analytical results are expressed is dealt with in detail in Appendix 2, it should be noted here that very often nitrate results as expressed as NO_3 rather than as N and that there is over a four-fold difference between the applicable limit values, the former being the higher.

Nitrate : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l NO_3	n/a	50	[1]
	A2 waters	mg/l NO_3	n/a	50	[1]
	A3 waters	mg/l NO_3	n/a	50	[1]
Bathing Water Regulations [1989-1998]		mg/l NO_3	-	-	[2]
Drinking Water Directive [98/83/EC]		mg/l NO_3	n/a	50	[3]

Note

[1] Departure from standard may be granted by Minister "in the case of surface water in shallow lakes or virtually stagnant surface water" or "where exceptional meteorological or geographical conditions have arisen."

[2] Sampling to be carried out "where an investigation .... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..."

[3] The Directive specifies that "Member States must ensure that the condition that [nitrate]/50 + [nitrite]/3 $\leq$ 1, the square brackets signifying the concentrations in mg/l for nitrate (NO_3) and nitrite (NO_2), is complied with and that the value of 0.10 mg/l for nitrites is complied ex water treatment works."

48. NITRITE

Chemical Symbol or Formula: NO_2^-

Units Used for Analytical Results: mg/l NO_2^-.

Normal Methods of Analysis: Manual or Automated Colorimetry [A/B]

Occurrence/Origin: Generally from untreated or partially treated wastes.

Health/Sanitary Significance: Methaemoglobinaemia-causing agent [cf. Nitrate].

Background Information: Nitrite exists normally in very low concentrations and even in waste treatment plant effluents levels are relatively low, principally because the nitrogen will tend to exist in the more reduced (ammonia; NH_3) or more oxidised (nitrate; NO_3) forms.

Because nitrite is an intermediate in the oxidisation of ammonia to nitrate, because such oxidation can proceed in soil, and because sewage is a rich source of ammonia nitrogen, waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality. Levels in unpolluted waters are normally low, below 0.03 mg/l NC)2. Values greater than this may indicate sewage pollution.

Comments: The significance of nitrite (at the low levels often found in surface waters) is mainly as an indicator of possible sewage pollution rather than as a hazard itself although, as mentioned above under "Nitrate" (q.v.), it is nitrite rather than nitrate which is the direct toxicant. There is, accordingly, a stricter limit for nitrite in drinking waters. In addition, nitrites can give rise to the presence of nitrosamines by reaction with organic compounds and there may be carcinogenic effects.

Nitrite : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance		[1]
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l NO_2	$\leq$ 0.01	-	
	(C)	mg/l NO_2	$\leq$ 0.03	-	
Salmonid Waters Regulations [1988]		mg/l NO_2	n/a	$\leq$ 0.05	[2]
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		mg/l NO_2	n/a	0.50	[3,4]

Notes

[1] "Substances which have an adverse effect on the oxygen balance, particularly: ammonia, nitrites."

[2] Standard to be conformed with by 95°/o of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples.

[3] The Directive requires that "Member States must ensure that the condition that [nitrate]/50 + [nitrite]/3 $\leq$ 1, the square brackets signifying the concentrations in mg/l for nitrate (NO_3) and nitrite (NO_2), is complied with and that the value of 0.10 mg/l for nitrites is complied ex water treatment works."

[4] The latter requirement in note [3] appears inconsistent with the parametric value of 0.50 mg/l NO_2.

49. NITROGEN, KJELDAHL

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l N.

Normal Method(s) of Analysis: Digestion, Distillation, Colorimetry [B/C].

Occurrence/Origin: Principally from organic matter naturally present (e.g. from peat, falling leaves etc.) or added in discharges.

Health/Sanitary Significance: No direct significance but parameter is an indication of the overall purity of a water.

Background Information: This determination is for organically-bound nitrogen and, under the normal test conditions (without ammonia removal), it includes ammonia. However, the results do not include oxidised nitrogen. The sum of the organically-bound nitrogen and ammonia figures is the "Kjeldahl nitrogen" value; if the ammonia has been excluded the result is "organic nitrogen." The term "total nitrogen" refers to the sum of the Kjeldahl and total oxidised nitrogen figures.

In past years much reliance was placed on the so-called *albuminoid nitrogen* determination which was frequently carried out in conjunction with the manual distillation technique for measuring ammonia. In this test the ammonia-free residue from the initial distillation is treated with alkaline potassium permanganate and then distilled again to give a further quantity of ammonia which is derived from proteinaceous matter and is a reflection of the organic content. Although alternative procedures have superseded the albuminoid nitrogen determination, it may still be found useful especially in assessing water with possible sewage contamination. While high values are themselves indicative of pollution, the albuminoid nitrogen results are most often considered in conjunction with the figures for ammonia. This is because in natural waters the ratio of free/saline ammonia nitrogen to albuminoid nitrogen is normally significantly less than unity (frequently of the order of 0.2-0.4), being a reflection of the fact that albuminoid nitrogen sources (principally vegetable) occur with a natural frequency. When the ratio approaches or exceeds unity an extraneous source of free ammonia is indicated and in many cases this is a sewage discharge. Thus, by scrutinising this nitrogen ratio the analyst can get an early indication of possible sewage contamination of a water, an indication which may be reinforced by elevated chloride values (q.v.).

Comments: In the Kjeldahl nitrogen determination the sample is subjected to quite severe digestion conditions which break down proteins and other organic matter and convert the nitrogen to ammonia, in which form it is actually measured.

Nitrogen, Kjeldahl : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l N	n/a	1	[1]
	A2 waters	mg/l N	n/a	2	[1]
	A3 waters	mg/l N	n/a	3	[1]
Bathing Water Regulations [1989-1998]		-	-	-	[2]
Drinking Water Directive [98/83/EC]		-	-	-	[3]

Notes

[1] Parameter listed as "Nitrogen by Kjeldahl method (except in NO_2 and NO_3)."

[2] Parameter designated as: "Nitrogen Kjeldahl." Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters ... or, in the case of Nitrogen Kjeldahl..., that there is a tendency towards eutrophication."

[3] The MAC specified in the 1980 Drinking Water Directive is not carried forward to the corresponding 1998 Directive, which makes no reference to Kjeldahl nitrogen or to organic nitrogen.

NITROGEN, TOTAL

(See "Nitrogen, Kjeldahl")

50. ODOUR

Chemical Symbol or Formula: Not applicable [Organoleptic parameter].

Units Used for Analytical Results: Dilution Factor [@ stated temperature] /Qualitative Description.

Normal Method(s) of Analysis: Subjective personal assessment [A]; Odour Panel [D].

Occurrence/Origin: Due to presence of inorganic or organic contaminants in water, possibly greatly exacerbated by chlorination.

Health/Sanitary Significance: Organoleptic considerations only.

Background Information: Related to taste, a strong odour from a water for consumption will obviously cause revulsion or rejection on the part of the consumer. Its cause is normally dissolved volatile organic compounds small concentrations of which may have great organoleptic effects. However, in polluted rivers a very common cause is the presence of hydrogen sulphide gas produced from the reduction of sulphates in the anaerobic conditions which can prevail after a heavy organic discharge to the water. Likewise, the formation of a putrescible sludge on the bed of a river by deposition of settleable organic solids can give rise to sulphide odours.

Comments: In the case of such sludge formation the odour may emanate from the bottom deposits or from sludge particles brought to the surface with gas bubbles even though the water column above may not be anaerobic.

Odour : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	DF/25 ºC	n/a	5	[1]
	A2 waters	DF/25 ºC	n/a	10	[1]
	A3 waters	DF/25 ºC	n/a	20	[1]
Bathing Water Regulations [1989-1998]		-	-	-	[2]
Drinking Water Directive [98/83/EC]		-	-	Acceptable to consumers and no abnormal change	

Notes

[1] Unit of analysis is dilution factor [DF] at 25 °C.

[2] The standard for Mineral oils [cf. "Hydrocarbons" above] is "No film visible on the surface of bathing water and no odour." Assessment is visual and olfactory.

51. ORGANIC CARBON, TOTAL

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units used for Analytical Results: mg/l C.

Normal Method(s) of Analysis: Instrumental (Various techniques) [C]

Occurrence/Origin: Natural or added organic matter in water.

Health/Sanitary Significance: No direct significance, but an indicator of overall purity of water.

Background Information: The determination of total organic carbon [or TOC] is complementary to the oxygen demand analyses (biochemical and chemical) discussed below and, in strict terms, it is a better indicator of organic content in that it is a direct measurement of the key element. Also, it is theoretically independent of the form in which the carbon exists (i.e. the structure of the organic compounds) in the water and the analyses should therefore be comparable for a wide range of organically polluted waters.

The parameter is one which is relevant in the treatment of water for drinking, especially in the case of large supplies where it may be necessary to use water of A3 (or, possibly, A2) quality [cf. Surface Water Regulations] as a source. The capital costs of the instrumentation needed may well be justified in terms of the quality control benefits which would accrue during treatment.

Comments: Because of the relative infrequency of instrumental organic carbon measurements (the classic combustion methods do not lend themselves to routine use) there is little or no background information on naturally occurring levels in surface waters and there is accordingly no datum against which mild organic pollution may be assessed by this parameter. Many rivers are highly coloured, especially in flood, indicating a high content of humic matter and hence the background concentrations may be quite considerable in waters which receive no pollutional discharges.

Organic Carbon, Total : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	-	-	No abnormal change	

Notes

[1] The Directive states that "This parameter need not be measured for supplies of less than 10,000 m^3 a day."

52. ORGANO-HALOGENATED SUBSTANCES

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l Cl or mg/l compound(g).

Normal Method(s) of Analysis: Chromatographic techniques (GLC/HPLC) [C]

Occurrence/Origin: Synthetic materials arising from discharges, run-off etc.

Health/Sanitary Significance: Many are carcinogenic; all are undesirable.

Background Information: This bulk parameter includes all organic compounds containing halogens [bromine, chlorine, fluorine and iodine]. These range from structurally simple compounds like chloroform ($CHCl_3$) or methylene chloride (CH_2Cl_2) to extremely complex molecules such as are present in pesticide or PCB mixtures. The latter classes of compounds are discussed separately below. Haloforms (or *Trihalomethanes; THM*) have the general formula CHX_3, where X represents a halogen atom, and they are considered to be possible carcinogens and hence are undesirable in drinking water. One of the group, chloroform, has been detected increasingly in treated water supplies, being among the by-products of the chlorination step in water treatment. See "Trihalomethanes" below.

Comments: Because of the complexity of this whole subject and its interrelationship with pesticides (q.v.) the reader is referred to the original sources for the fullest available discussion. The 1998 Drinking Water Directive adopts a specific compound approach which is both welcome and helpful to the analyst and to the water quality regulator. Thus, it covers a series of specific organo-chlorine compounds and eschews the use of generalised parameter titles such as that under discussion.

Organo-Halogenated Substances : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Cl	-	-	[1]
	A2 waters	mg/l Cl	-	-	[1]
	A3 waters	mg/l Cl	-	-	[1]
Bathing Water Regulations [1989-1998]		-	-	-	[2,3]
Dangerous Substances Directive [76/464/EEC]			List I substance		[4]
Shellfish Directive [79/923/EEC]		-	[5]	[6]	
Ground Water Directive [80/68/EEC]			List I substance		[4]
Drinking Water Directive [98/83/EC]		-	-	-	[7]

Notes

[1] The Regulations refer to the parameter: "Total pesticides [parathion, BHC, dieldrin]," which falls under the heading of "Organo-Halogenated Substances." Pesticides are treated separately below (q.v.).

[2] The parameter is designated "Pesticides [parathion, HCH, dieldrin]."

[3] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..."

[4] List I refers to "Organohalogen compounds and substances which may form such compounds in the aquatic environment."

[5] "The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."

[6] "The concentration of [this] substance in the shellfish water or in shellfish flesh must not reach or exceed a level which has harmful effects on the shellfish and larvae.

[7] Drinking Water Directive [98/83/EC] includes the two parameters designated respectively "Pesticides" and "Pesticides - Total". See parameter "Pesticides" below.

53. OXIDISABILITY

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l O_2.

Normal Method(s) of Analysis: Various Wet Oxidation techniques [B]

Occurrence/Origin: Measure of organic (and other oxidisable) matter present in a water, naturally or from added wastes.

Health/Sanitary Significance: No direct significance but a reflection of overall purity of a water.

Background Information: All parameters covered by this heading are a measure of the organic content of a water (and of those inorganic constituents which are amenable to oxidation). They are determined by estimating the oxygen consumption from heated acid potassium permanganate solution. The European test procedures use boiling temperature and a short time but this has not been the common past practice in Ireland and the United Kingdom where analysis has been of the oxygen absorbed from acid permanganate solution in 4 hours at 27°C. The former method is specified by Directive [98/83/EC].

The result of the 4-hour/27°C test is the so-called permanganate value (PV) and it gives a useful, even if partial, picture of the organic content of a water. As with any test using a specific oxidant the results will reflect preferentially the presence of those compounds which are susceptible to the action of that oxidant, in this case acid potassium permanganate, and not those compounds which are largely unaffected by the reagent. For example, a highly coloured water which contains significant organic (humic) matter will have a very high permanganate value. Accordingly, there is generally a good correlation between permanganate value and colour. But as this humic matter is biologically inert it will not be assessed in a bioassay procedure such as the biochemical oxygen demand test (q.v.). Because of the variations in response of different types of water and waste water to the action of permanganate and, not least, because of the tedious nature of this rather arbitrary test procedure modern preferences are for the organic carbon determination in surface waters, and for the chemical oxygen demand (see below) for wastewaters, in addition, of course, to the biochemical oxygen demand test.

Comment: The topic of oxidisability is discussed further below - see "Oxygen Demand, Chemical."

Oxidisability : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	mg/l O_2	n/a	5.0	[1]

Notes

[1] Parameter is designated "Oxidisability" and is the subject of two notes. The first states that "This parameter need not be measured if the parameter TOC is measured" and the second requires that "Oxidation should be carried out for 10 minutes at 100 °C under acid conditions using permanganate." The results of analysis are therefore not comparable with those of the so-called "Permanganate Value" which also uses potassium permanganate [$KMnO_4$] as oxidant, but with incubation at 27°C for 4 hours.

54. OXYGEN DEMAND, BIOCHEMICAL

Chemical Symbol or Formula: Not applicable [Bulk parameter]

Units Used for Analytical Results: mg/l O_2.

Normal Method(s) of Analysis: Incubation technique with oxygen determinations by Winkler Method or by Oxygen Meter [A).

Occurrence/Origin: Natural or introduced organic matter in water.

Health/Sanitary Significance: No direct health implications, but an important indicator of overall water quality.

Background Information: When organic matter is discharged into a watercourse it serves as a food source for the bacteria present there. These will sooner or later commence the breakdown of this matter to less complex organic substances and ultimately to simple compounds such as carbon dioxide and water. If previously unpolluted, the receiving water will be saturated with dissolved oxygen (DO), or nearly so, and the bacteria present in the water will be aerobic types. Thus the bacterial breakdown of the organic matter added will be an aerobic process - the bacteria will multiply, degrading the waste and utilising the DO as they do so. If the quantity of waste present is sufficiently large, the rate of bacterial uptake of oxygen will outstrip that at which the DO is replenished from the atmosphere and from photosynthesis, and ultimately the receiving water will become anaerobic.

Bacterial degradation of the waste will continue but now the products will be offensive in nature -for example, hydrogen sulphide. Even if the uptake of oxygen is not sufficient to result in anaerobic conditions there will be other undesirable effects as the DO level falls, notably damage to fisheries and, ultimately, fish deaths. Where levels are around 50 per cent saturation for significant periods there may be adverse, though non-lethal, effects on game fish. Coarse fish will be likewise affected if levels are regularly around 30 per cent saturation.

Because of the potential danger to the oxygen levels in receiving waters from waste discharges considerable emphasis is placed in the laboratory on the estimation of the oxygen demand of wastes: i.e. the amount of oxygen which will be required in their breakdown. This is done chemically and biologically, by a variety of tests which are also employed to assess the actual effects of waste discharges on receiving water, as discussed below. As in most cases the oxygen demand of a waste on the DO level of a receiving water results from biological action, it follows that the most important analytical method should also depend on a biological process, to measure the biochemical oxygen demand or BOD. The principle of this test, which was devised some 85 years ago, is straightforward. The (five-day) BOD of a water is the amount of dissolved oxygen taken up by bacteria in degrading oxidisable matter in the sample, measured after 5 days incubation in the dark at 20°C. The BOD is simply the amount by which the DO level has dropped during the incubation period. This technique is the basis of BOD analyses for all types of sample even though considerable extensions of procedure are necessary in dealing with wastewaters and polluted surface waters.

The *Eighth Report of the Royal Commission on Sewage Disposal* (1912) contained a classification of river waters based on BOD levels which has been very widely quoted in the ensuing years. In some respects the classification was too precise in that it tried to distinguish between clean waters, very clean waters and so on. Current scientific opinion is that such a rigid approach is unjustified and that waters with a BOD failing within the range of 0 - 4 mg/l O_2 are of satisfactory quality for salmonid fish and thus for other beneficial uses. If an upper limit for BOD of 4 mg/l O_2 is adopted as a criterion of satisfactory quality then it is possible to assess the degree to which waters are polluted by reference to this datum. It is most important to remember, however.. that a BOD figure for a receiving water indicates the maximum extent to which the oxygen level may be depleted by the organic matter present. In reality, no appreciable deoxygenation may occur because of factors such as low temperatures, reaeration at weirs or shallows, dilution by tributaries and so on. Conversely, in some waters which do not have high BOD levels, but which are eutrophic, there may be severe night-time DO depletions caused by algal respiration (see below). Notwithstanding the many often contradictory considerations which govern the interpretation of BOD data the analysis is one of the most important elements in river quality surveillance and it seems unlikely to be superseded for a long time yet.

Somewhat different considerations apply to the BOD analysis of effluents. BOD data are normally required for one of two purposes. Firstly, it is necessary to know the strength of a waste which is to be treated by biological means, as in an oxidation ditch or percolating filter. This is essential so that adequate treatment capacity may be provided for in the design of the plant. Secondly.. where wastes are being discharged to receiving waters a knowledge of their strength and the magnitude of the river discharge will permit the dilution to be calculated and hence the maximum potential change in the river BOD at the boundary of the mixing zone. A factor which must be borne in mind in obtaining and in assessing BOD results is nitrification. This is the oxidation of ammonia to nitrate by suitable micro-organisms and if the process is occurring under test conditions high oxygen uptake values will be recorded. For normal river waters the onset of nitrification under BOD test conditions does not occur within the 5-day period of the analysis but in the case of waters or wastewaters containing nitrifying organisms this phenomenon will take place much more promptly. Unless suitable precautions are taken the result is an apparently very high BOD level which, if the analysis is being used to check the performance of a waste treatment works (with respect to the removal of organic matter), for example, may lead to serious errors in the interpretation and use of the data.

The recommendations of the Royal Commission referred to above also dealt with the quality of sewage effluents and they included the so-called "20/30" effluent standard (i.e. an effluent of BOD value 20 mg/l O_2 and suspended solids 30 mg/l) which has been widely used and misused since. It is often forgotten that the standards were based on the premise that in no case would the BOD value of the river receiving the discharge be increased to more than 4 mg/l O_2. The "20/30" standard was suggested as one which would, even in cases of limited available dilution, ensure that the resultant river BOD would be less than 4 mg/l O_2. It was in no way advocated as the ultimate goal of all treatment processes, the thinking being that it was more important to specify a limit for the river after receiving a discharge than to fix general effluent standards.

Comments: The DO level of a receiving water may also be depleted by some inorganic waste discharges. A waste containing sulphite, for example, can have serious effects. These will include the direct chemical uptake of oxygen during the BOD incubation period, the extent of which uptake will contribute to the apparent BOD value of the sample. It is arguable, however, that in such cases while a percentage of the oxygen depletion may be caused by chemical rather than biochemical reaction, the results will still reflect the maximum possible oxygen depletion effects in the receiving water. See also the comments on "Oxygen Demand, Chemical."

Oxygen Demand, Biochemical : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l O_2	n/a	5	[1,2]
	A2 waters	mg/l O_2	n/a	5	[1,2]
	A3 waters	mg/l O_2	n/a	7	[1,2]
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l O_2	≤ 3	-	[3]
	(C)	mg/l O_2	≤ 6	-	[3]
Salmonid Waters Regulations [1988]		mg/l O_2	n/a	≤ 5	[4]

Notes

[1] Parameter is described as "Biochemical oxygen demand [BOD_5] [at 20°C without nitrification]." A nitrification inhibitor should therefore he used in the analytical procedure.

[2] Departure may he granted by the Minister "in the case of surface water in shallow lakes or virtually stagnant surface water."

[3] Nitrification [cf. Note 1 immediately above] should not be inhibited.

[4] "Where weed or sewage fungus growths are excessive appropriate measures for control should be taken. Standard to he conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples."

55. OXYGEN DEMAND, CHEMICAL

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l O_2.

Normal Method(s) of Analysis: Microdigestion and Colorimetry [A]; Titrimetric following Reflux Distillation with Acid Potassium Dichromate [B].

Occurrence/Origin: Natural or, more probably, added organic matter.

Health/Sanitary Significance: No direct hazard implications; COD is an indicator of overall water quality.

Background Information: Except in special cases, the five-day BOD analysis gives a measure of the oxygen demand of biodegradable carbonaceous matter in a sample. The oxidation is not complete and the five-day BOD value in a properly conducted test usually amounts to some 65 percent of the total carbonaceous oxygen demand. To measure the latter in the BOD test would take some four times as long and would involve special measures to counter the side-effects of oxidation of nitrogenous matter, the nitrification referred to above (cf. "Oxygen Demand, Biochemical").

The ideal approach is to obtain a rapid, accurate measurement of the total carbonaceous oxygen demand and, in an attempt to reach this goal, chemical methods have been devised. The first point to consider is that in any such method the only organic compounds affected will be those amenable to oxidation by the particular chemical agent used. (This point has been touched on above under the parameter "Oxidisability"; q.v.). There is a wide variety of chemical oxidants and hence there will be a correspondingly wide range of effects.

Potassium permanganate has been widely used to measure the oxygen demand of river waters but there may be little or no correlation with BOD figures. As mentioned above, peaty waters of low BOD often have very high permanganate values, reflecting the intense colour caused by the presence of biologically inert but chemically oxidisable vegetable matter. However, for any one type of sample the permanganate values may be useful (in indicating changes in the performance of a treatment plant, for example), and it may be possible to correlate the figures with those for BOD after a sufficiently large number of analyses have been carried out.

The reagent favoured in U.S. methods is potassium dichromate and although the term chemical oxygen demand (COD) is a general one, which should be qualified by the mention of the actual oxidant used, in practice the abbreviation COD refers specifically to the test in which potassium dichromate is used to carry out the oxidation. A drawback is that the standard test procedure is in practice applicable only to very heavily polluted waters or to effluents, though its use for the latter makes it a most valuable method. Comparisons have been made between the permanganate value test and the COD and have indicated the variability of the former as a general oxidant.

The COD test procedure involves the use of additional reagents to catalyse the oxidation of organic matter and to suppress the effects of interfering substances such as chloride, and, as a result, in many cases the oxidation achieved is at or very near the maximum level. As pointed out earlier, for biodegradable compounds the five-day BOD level corresponds to some 65 per cent oxidation of the total organic matter present so that, if for such compounds the chemical oxidation is fully efficient, the COD/BOD ratio should be 100:65 or 1.54: 1. This is the case for domestic sewage for which COD values around 480-500 mg/l and BOD figures in the region of 310 mg/l give a good correspondence with the ratio. It is possible to work out the applicable ratio for wastes which do not change their composition but which are only partially affected in either oxygen demand test. Application of the COD/BOD ratio to the results of a quickly performed COD test is very useful for the analyst and for the plant manager.

Comments: It has been mentioned that the COD test is applicable to heavily polluted waters and to wastewaters. This is because the sensitivity of the normal test procedure is not adequate for waters with an oxygen demand of only a few mg/l O_2. There is a "low level" test but this is best applied to waters with an oxygen demand in the vicinity of 25 mg/l O_2 which is rather larger than one would hope to find in clean waters. It may be noted that the original (U.S.) standard method for COD used quite large volumes of sample and reagents. As the latter contain toxic and/or expensive additives (mercury and silver salts are used in relatively large amounts to suppress interference and catalyse the oxidation, respectively), and as the reaction mixture comprises 50 per cent sulphuric acid, it is highly desirable on grounds of both safety and economy that quantities should be scaled down. The use of "miniature" digestion apparatus is therefore recommended strongly.

Oxygen Demand, Chemical : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l O_2	n/a	-	[1]
	A2 waters	mg/l O_2	n/a	-	[1]
	A3 waters	mg/l O_2	n/a	40	[1]

Notes

[1] Value specified in Regulations for A3 water only,

56. OXYGEN, DISSOLVED

Chemical Symbol or Formula: O_2.

Units Used for Analytical Results: mg/l O_2.

Normal Method(s) of Analysis: Electrometric [DO Meter] [A/B]; Winkler Titration [A/B].

Occurrence/Origin: Natural characteristic of clean waters.

Health/Sanitary Significance: Slight organoleptic significance only, but critical for survival of fish.

Background Information: The importance of dissolved oxygen [DO] has already been touched upon in the discussion of BOD above. The prime requirements for DO arise in connection with fish life and it is generally true that if water quality is suitable for fish it will also meet the criteria for most if not all other beneficial uses and be of good ecological status, as required by the Water Framework Directive. The cardinal point about the solubility of oxygen in water is that it has an inverse relationship with temperature, as shown in the table below. The consequence is that the actual concentrations of DO in a river will be lowest in summertime when it is usually the case that the risk of damage to a water supply source or of environmental pollution is greatest, especially in areas developed as tourist centres or where such farming operations as silage-making are carried on.

SOLUBILITY OF OXYGEN IN WATER IN CONTACT WITH WATER-SATURATED AIR AT 760 MM Hg

OXYGEN CONCENTRATIONS IN ***mg/litre*** CORRESPONDING TO 100% SATURATION

Temp °C	DO mg/l	Temp °C	DO mg/l	Temp °C	DO mg/l	Temp °C	DO mg/l	Temp °C	DO mg/l
0	14.6	5	12.8	10	11.3	15	10.2	20	9.2
1	14.2	6	12.5	11	11.1	16	10.0	21	9.0
2	13.8	7	12.2	12	10.8	17	9.7	22	8.8
3	13.5	8	11.9	13	10.6	18	9.5	23	8.7
4	13.1	9	11.6	14	10.4	19	9.4	24	8.5

The saturation concentration of 9.2 mg/l O_2 at 20°C (around the normal Irish summer temperature) is not a large quantity and, although it is fully adequate to support the fauna and flora of an unpolluted river, it will be depleted very rapidly (even after allowing for natural reaeration over weirs, rocks and so on) by the bacterial degradation of even a small amount of organic matter. See also the discussion under "Oxygen Demand, Biochemical."

Because such biological activity takes place in receiving waters it is essential that DO levels are measured *in situ* by instrumental means, or at least that chemical reagents are added at once to the samples to "fix" the DO for a reliable subsequent laboratory analysis. Delayed DO values obtained from analysis of unfixed samples are meaningless and are potentially grossly misleading. As indicated above (under "Oxygen Demand, Biochemical"), salmonid fish will begin to be affected as DO levels drop to around 50 per cent saturation; cyprinid fish are likewise affected at levels in the vicinity of 30 per cent. In many instances of fish kills the mortality is directly due to asphyxiation as the DO levels fall massively because of organic pollution. Should levels around zero persist then anaerobic (or septic) conditions will set in and any remaining organic matter will undergo anaerobic decomposition to yield products such as methane and ammonia. Coupled with this will be the reduction of sulphates present to sulphide and the consequent emission of offensive odours. Restoration of aerobic conditions will cure the last mentioned problem.

The effects of eutrophication are closely related to the DO regime in both rivers and lakes. Where there are dense growths of phytoplankton, photosynthesis will take place during the extended daylight periods of summertime, resulting in the production of oxygen which may lead to water DO levels far in excess of 100 per cent saturation. An excess of DO is not a problem in itself but it indicates that the daytime conditions may be mirrored by an equally large undersaturation of oxygen at night-time when photosynthesis ceases and plant respiration supervenes with the consumption of oxygen. The DO concentrations may, therefore, follow something like a "sine wave" pattern with the troughs occurring in the early hours of the morning, just before dawn. Where the amplitude of this "sine wave" is great the DO minimum may be such as to cause fish kills. It should be remembered that the magnitude of this so-called *diurnal variation* will be greatest where there are both eutrophication and organic pollution effects. But while a high day-time DO may not (in the absence of organic pollution) be matched by a critically low night-time level it is indicative nonetheless of less than satisfactory conditions.

Comments: The importance of DO is underlined by the comprehensive requirements of the Freshwater Fish Directive and Salmonid Waters Regulations. The values specified below, along with the accompanying notes, are worthy of study,

Oxygen, Dissolved : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	% sat'n O_2	n/a	> 60%	[1]
	A2 waters	% sat'n O_2	n/a	> 50%	[1]
	A3 waters	% sat'n O_2	n/a	> 30%	[1]
Bathing Water Regulations [1989-1998]		% sat'n O_2	n/a	$\geq$ 70 and $\leq$ 120	[2]
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l O_2	50% $\geq$ 9	50% $\geq$ 9	[3]
		mg/l O_2	100% $\geq$ 7		
	(C)	mg/l O_2	50% $\geq$ 8	50% $\geq$ 7	[4]
		mg/l O_2	100% $\geq$ 5		
Salmonid Waters Regulations [1988]		pH units	n/a	$\geq$ 6 and $\leq$ 9	[5]
Shellfish Directive [79/923/EEC]		% sat'n O_2	$\geq$ 80	$\geq$ 70	[6,7]

Oxygen, Dissolved : Notes

[1] Parameter is "Dissolved oxygen saturation rate." Departure from the standard may be granted by the Minister "in the case of surface water in shallow lakes or virtually stagnant surface water."
[2] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing.. that there has been a deterioration in the quality of waters..." Standard to be conformed with by 95% of samples. No two consecutive samples to fall outside range,
[3] The I value for salmonid water contains the provision: "When the oxygen concentration falls below 6 mg/l, Member States shall implement the provisions of Article 7 [3] [of the Directive]. The competent authority must prove that this situation will have no harmful consequences for the balanced development of the fish population."
[4] The I value for cyprinid water contains the provision: "When the oxygen concentration falls below 4 mg/l, Member States shall implement the provisions of Article 7 [3] [of the Directive]. The competent authority must prove that this situation will have no harmful consequences for the balanced development of the fish population."
[5] The Regulations specify: 50% $\geq$ 9 mg/l O_2. "When the oxygen content falls below 6 mg/litre the local authority must prove that there will he no harmful consequences for the balanced development of the fish population."
[6] The I value quoted is an average value; there are also the following provisions: "Should an individual measurement indicate a value lower than 70%, measurements shall he repeated. An individual measurement may not indicate a value of less than 60% unless there are no harmful consequences for the development of shellfish colonies."
[7] The sampling frequency is given as "monthly, with a minimum of one sample representative of low oxygen conditions on the day of sampling... Where major daily variations are suspected, a minimum of two samples in one day shall be taken."

57. PATHOGENIC STAPHYLOCOCCI

Chemical Symbol or Formula: Not applicable [Microbiological Parameter].

Units Used for Analytical Results: Number of organisms/100 ml water.

Normal Method(s) of Analysis: Membrane Filtration Technique [B].

Occurrence/Origin: Sewage discharges.

Health/Sanitary Significance: Pathogenic micro-organisms (causing food poisoning and related illnesses).

Background Information: Staphylococci are likely to be present in sewage-contaminated waters and in bathing waters. However, their determination is not carried out routinely, the main emphasis being put on the detection of total and faecal coliforms. By relying on the use of indicator organisms rather than the estimation of the staphylococci directly, the approach is very conservative, making for a high degree of protection.

Comments: See also "Coliforms, Faecal and Total" above.

Pathogenic Staphylococci : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	*No reference / parametric value*			[1]

Notes

[1] Directive [98/83/EC] makes no reference to staphylococci, but incorporates the following relevant provisions: *Article 4(1)* Without prejudice to their obligations under other Community provisions, Member States shall take the measures necessary to ensure that water intended for human consumption is wholesome and clean. For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be wholesome and clean if it; (a) is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health.

Article 7(6) Member States shall ensure that additional monitoring is carried out on a case-by-case basis of substances and micro-organisms for which no parametric value has been set in accordance with Article 5, if there is reason to suspect that they may be present in amounts or numbers which constitute a potential danger to human health.

PCBs & PCTs

(See "Polychlorinated Biphenyls")

PERCHLOROETHYLENE

(See "Tetrachloroethylene")

58. PESTICIDES (INDIVIDUAL & TOTAL)

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: µg/l specific compound(s).

Normal Method(s) of Analysis: Chromatographic techniques (GLC & HPLC) [B/C]

Occurrence/Origin: Synthetic compounds - agricultural discharges, spillages or runoff, industrial waste discharges.

Health/Sanitary Significance: Compounds of great acute or chronic toxicity.

Background Information: This broad designation is used in EU Directives to encompass a large group of compounds with either related uses or similar chemical composition. The substances covered comprise insecticides (organo-chlorine and organo-phosphorus), herbicides, fungicides, PCBs (polychlorinated biphenyls) and PCTs (polychlorinated terphenyls). Compounds such as pesticides are among those which cause mortality or severe reproductive or genetic problems in fauna and which also qualify for inclusion under the broad heading of substances which possess carcinogenic, mutagenic or teratogenic properties (see below). As such, they are highly undesirable in waters of virtually any type. Even if levels in, say, a river water are very low there is the probability of bioaccumulation in fish or other living tissue and, to compound the matter, of retention on the *in-situ* sediments.

Comments: PCBs and PCTs are dealt with jointly in this volume under the heading "Polychlorinated Biphenyls."

Pesticides : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l	n/a	0.0005	[1]
	A2 waters	mg/l	n/a	0.0025	[1]
	A3 waters	mg/l	n/a	0.005	[1]

Pesticides : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	mg/l	-	-	[2,3]
Dangerous Substances Directive [76/464/EEC]		List I substance		[4]
Shellfish Directive [79/923/EEC]	-	[5]	[6]	[7]
Ground Water Directive [80/68/EEC]		List I substance		[4]
Drinking Water Directive [98/83/EC]	µg/l	n/a	0.10	[8,9]
	µg/l	n/a	0.10	[8,10]

Notes

[1] Parameter is described as '"Total pesticides [parathion, BHC, dieldrin]." Note that this is a misleading definition [which, however, is taken from the Directive, although virtually meaningless] and that the number of compounds covered is a tiny fraction of the real total [which will, in any event, grow as new compounds are developed].

[2] The definition is "Pesticides (parathion, HCH [BHC], dieldrin)."

[3] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..."

[4] List I includes "organohalogen compounds and substances which may form such compounds in the aquatic environment" and "organophosphorus compounds." Both compound groups include many pesticides.

[5] "The concentration of each substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."

[6] "The concentration of each substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae."

[7] Parameter quoted as "Organohalogenated substances." Although this parameter is dealt with separately and its definition would imply a potentially wide range of compounds, in practice it is usually taken to mean organohalogen pesticides.

[8] "Pesticides" means:

- organic insecticides,
- organic fungicides,
- organic acaricides,
- organic rodenticides
- organic herbicides,
- organic nematocides,
- organic algicides,
- organic slimicides,
- related products (inter alia, growth regulators)

and their relevant metabolites, degradation and reaction products.

Only those pesticides which are likely to be present in a given supply need be monitored.

[9] The parametric value applies to each individual pesticide. In the case of aldrin, dieldrin, heptachlor and heptachlor epoxide the parametric value is **0.030** µg/l.

[10] "Pesticides - Total" means the sum of all individual pesticides detected and quantified in the monitoring procedure.

59. pH

Chemical Symbol: Not applicable [Physical parameter].

Units Used for Analytical Results: pH units.

Normal Method(s) of Analysis: Electrometry [pH electrode] [A/B]

Occurrence/Origin: Physical characteristic of all waters/solutions.

Health/Sanitary Significance: None - except that extreme values will show excessive acidity/alkalinity, with organoleptic consequences.

Background Information: By definition pH is the negative logarithm of the hydrogen ion concentration of a solution and it is thus a measure of whether the liquid is acid or alkaline. The pH scale (derived from the ionisation constant of water) ranges from 0 (very acid) to 14 (very alkaline). The range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in waters where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0.

In waters with low dissolved solids, which consequently have a low buffering capacity (i.e. low internal resistance to pH change), changes in pH induced by external causes may be quite dramatic. Extremes of pH can affect the palatability of a water but the corrosive effect on distribution systems is a more urgent problem (see Appendix 4). The effect of pH on fish is also an important consideration and values which depart increasingly from the normally found levels will have a more and more marked effect on fish, leading ultimately to mortality. The range of pH suitable for fisheries is considered to be 5.0-9.0, though 6.5-8.5 is preferable.

Comments: Apart from the aspects just mentioned, pH values govern the behaviour of several other important parameters of water quality. Ammonia toxicity, chlorine disinfection efficiency, and metal solubility are all influenced by pH, for example.

pH : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	pH units	n/a	5.5-8.5	
	A2 waters	pH units	n/a	5.5-9.0	
	A3 waters	pH units	n/a	5.5-9.0	
Bathing Water Regulations [1989-1998]		pH units	n/a	$\geq$ 6 and $\leq$ 9	[1]
Freshwater Fish Directive [78/659/EEC]	(S)	pH units	n/a	$\geq$ 6.0 and $\leq$ 9.0	[2,3]
	(C)	pH units	n/a	$\geq$ 6.0 and $\leq$ 9.0	[2,3]
Salmonid Waters Regulations [1988]		pH units	n/a	$\geq$ 6 and $\leq$ 9	[2,4]
Shellfish Directive [79/923/EEC]		pH units	n/a	7.0-9.0	
Drinking Water Directive [98/83/EC]		pH units	n/a	$\geq$ 6.5 and $\leq$ 9.5	[5]

Notes

[1] Sampling to be carried out "where an investigation, ..shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..." No two consecutive samples to fall outside the range.

[2] "Artificial pH variations with respect to the unaffected values shall not exceed ± 0.5 of a pH unit within the limits 6 and 9 provided that these variations do not increase the harmfulness of other substances present in the water,"

[3] Derogations possible "because of exceptional weather or special geographical conditions."

[4] Standard to he conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples.

[5] Parameter is designated: "Hydrogen ion concentration," with the comments: "The water should not be aggressive," and "For still water put into bottles or containers, the minimum value may be reduced to 4.5 pH units. For water put into bottles or containers which is naturally rich in or artificially enriched with carbon dioxide, the minimum value may be lower."

60. PHENOLS

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l C_6H_5OH [Phenol].

Normal Method(s) of Analysis: Chloroform/4-Aminoantipyrene Extraction Method [B/C]; Instrumental Chromatographic Techniques [C].

Occurrence/Origin: Polluted surface waters (roads/roadworks run-off); industrial effluents.

Health/Sanitary Significance: Many phenolic compounds are corrosive and toxic to a marked extent, but their primary significance in waters is organoleptic.

Background Information: Phenol itself (carbolic acid; C_6H_5OH) is used as a reference material for this determination, which includes many related compounds, including some natural phenolic types, although the last-mentioned are not normally problem-causing. The main difficulties which arise (even in waters with minute traces of phenols) are of taste and odour which are magnified greatly when the water is chlorinated. Severe problems are caused and rejection of supplies by consumers is likely.

Comments: The compounds originate in industrial processes and can reach water sources from discharges or they can be leached from road covering materials. Instances of severe contamination of wells have been reported consequent on the tarmacadaming of nearby yards or areas.

Phenols : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l C_6H_5OH	n/a	0.0005	[1]
	A2 waters	mg/l C_6H_5OH	n/a	0.005	[1]
	A3 waters	mg/l C_6H_5OH	n/a	0.1	[1]
Bathing Water Regulations [1989-1998]		mg/l C_6H_5OH	-	-	[2]
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l C_6H_5OH	-	-	[3]
	(C)	mg/l C_6H_5OH	-	-	[3]
Salmonid Waters Regulations [1988]		-	-	-	[4]
Drinking Water Directive [98/83/EC]		-	-	-	[5]

Notes

[1] Parameter appears in the Regulations as "Phenols [phenol index] paranitraniline 4-aminoantipyrene." This is potentially confusing to the non-chemist as the latter two words are the names of re agents used in different analytical procedures for phenols.

[2] Parameter is "Phenols [phenol indices]." Standard is $\leq$ 0.05 mg/l and no specific odour. Standard to be conformed with by 95% samples and not to be exceeded by any two consecutive samples. No sample to exceed 0.075 mg/l [C_6H_5OH]. [Note that the Regulations erroneously give the units as mg/l C_4H_3OH].

[3] Parameter is "Phenolic compounds" which "must not be present in such concentrations that they adversely affect fish flavour."

[4] Regulations specify that "Phenolic compounds must not be present in such quantities that they adversely affect fish flavour."

[5] There is no reference to phenols in this Directive.

61. PHOSPHATES

Chemical Symbol or Formula: PO_4^{---}

Units Used for Analytical Results: mg/l P.

Normal Method (s) of Analysis: Manual or Automated Colorimetry [B/C].

Occurrence/Origin: Phosphorus occurs widely in nature in plants, in micro-organisms, in animal wastes and so on. It is widely used as an agricultural fertiliser and as a major constituent of detergents, particularly those for domestic use. Run-off and sewage discharges are thus important contributors of phosphorus to surface waters.

Health/Sanitary Significance: None.

Background Information: The significance of phosphorus is principally in regard to the phenomenon of eutrophication (over-enrichment) of lakes and, to a lesser extent, rivers. Phosphorus gaining access to such water bodies, along with nitrogen as nitrate, promotes the growth of algae and other plants leading to blooms, littoral slimes, diurnal dissolved oxygen variations of great magnitude and related problems, as discussed elsewhere in this volume.

There is considerable debate as to the availability of the various forms of phosphorus (orthophosphate, polyphosphate, organic phosphate and so on) for the growth of algae although it is considered that orthophosphate is the most readily used form. Phosphorus may be in true solution, in colloidal suspension or adsorbed onto particulate matter, and it is very difficult to differentiate between the various fractions by separation (e.g. filtration) or analysis. A useful parameter is orthosphosphate (strictly, total filtrable and non-filtrable orthophosphate) which is the phosphate responding to the analytical procedure without any pre-treatment such as hydrolysis or oxidative digestion. Caution must be exercised in considering the results of phosphorus analysis as the element exists in bound and unbound forms which are very difficult to separate totally in analysis. There is always the likelihood, for example, of some of the bound polyphosphate forms being changed by hydrolysis to orthophosphate under the actual analytical conditions. However, the determination of orthophosphate as specified is of great use in highlighting the presence of one of the most important nutrients and the results are of special interest in waters receiving sewage discharges.

The importance of controlling phosphorus levels in the Irish aquatic environment is highlighted by the publication (in May 1997) by the Minister for the Environment and Local Government of a 10-year strategy paper entitled *Managing Ireland's Rivers and Lakes - A Catchment-Ba-sed Strategy Against Eutrophication*. This document deals with the topic of phosphorus levels (expressed as mg/l median Molybdate-Reactive Phosphate [MRP] [9]) and it sets out interim statutory standards, in terms of MRP, for the year 2007 for water in several quality classes, rivers and lakes being treated separately.

Comments: These statutory standards are presented below, following the details of phosphorus standards in other legislation.

Phosphates : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l P_2O_5	n/a	0.5	[1]
	A2 waters	mg/l P_2O_5	n/a	0.7	[1]
	A3 waters	mg/l P_2O_5	n/a	0.7	[1]

[9] This precisely-defined unit is broadly equivalent to "orthophosphate" as determined using the ascorbic acid/molybdate colorimetric procedure.

Phosphates : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	-	-	-	[2]
Dangerous Substances Directive [761464/EEC]		List II substance		[3]
Ground Water Directive [80168/EEC]		List II substance		[3]
Drinking Water Directive [98/83/EC]	-	-	-	[4]

Phosphorus : INTERIM STATUTORY STANDARDS FOR RIVERS

Phosphorus Parameter	*Environmental Waters*	*Existing Biological Quality [Q] Rating*		*EQS [as annual median value as MRP [mg/l P] for year 2007*	*Corresponding Minimum Target Q Rating*
Molybdate- Reactive Phosphate [MRP] *[mg/I* P]	Rivers	5] 4 - 5] 4]	Unpolluted	0.015 0.020 0.030	5 4 - 5 4
		3 - 4	Slightly polluted	0.080	4
		3] 2 - 3]	Moderately polluted	0.050 0.070	3 - 4* 3*
		<2	Seriously polluted	0.070	3*

Phosphorus : INTERIM STATUTORY STANDARDS FOR LAKES

Phosphorus Parameter	*Environmental Waters [Q] Rating*	*Existing Trophic Status*	*Target Trophic Status for year 2007*	*EQS [as annual average Total P (µg/l P)] in 2007*
Total Phosphorus [µg/l P]	Clear Water Lakes	Ultra-Oligotrophic	Ultra-Oligotrophic	< 5
		Oligotrophic	Oligotrophic	5 - 10
		Mesotrophic *[satisfactory]*	Mesotrophic [or Oligotrophic**]	10 - 20 [5 - 10]
		Eutrophic	Mesotrophic	10 - 20
		Hypertrophic *[unsatisfactory]*	Eutrophic	20 - 50

Phosphorus : INTERIM STATUTORY STANDARDS FOR LAKES

Phosphorus Parameter	Environmental Waters [Q] Rating	Existing Trophic Status	Target Trophic Status for year 2007	EQS [as annual average Total P (µg/l P)] in 2007
Total Phosphorus [µg/l P]	Other Lakes	Oligotrophic	Oligotrcphic	< 10
		Mesotrophic *[satisfactory]*	Mesotrophic [or Oligotrophic**]	10 - 35 [< 10]
		Eutrophic	Mesotrophic	10 - 35*
		Hypertrophic *[unsatisfactory]*	Eutrophic	35 - 100*

* Proposed *interim* EQSs. ** In the case of lakes which were originally of this quality

Notes

[1] Departure may be granted by the Minister "in the case of surface water in shallow lakes or virtually stagnant surface water."

[2] Parameter is designated: "Phosphates" Sampling to be carried out 'where an investigation shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters

[3] List II refers to "Inorganic compounds of phosphorus and elemental phosphorus."

[4] There is no reference to phosphate or phosphorus in this Directive.

62. PHOSPHORUS, TOTAL

Chemical Symbol or Formula; Not applicable [Bulk parameter).

Units Used for Analytical Results: mg/l P.

Normal Method(s) of Analysis: Digestion, followed by determination of the resultant orthophosphate (see above) [B/C]

Occurrence/Origin: Natural or added organic matter (wastes, vegetation etc.).

Health/Sanitary Significance: Indirect - indicates overall water quality.

Background Information: This is the most complete determination of the element phosphorus, irrespective of the compounds in which it is actually present in the water. All forms of phosphorus are converted to soluble orthophosphate which is the species detected by the chemical reaction used in the analysis.

It has been the practice in lake investigations to determine total phosphorus as one of the most meaningful parameters in the assessment of eutrophication but there is a difficulty in that not all the phosphorus measured under test conditions may be effectively available in the environment to promote algal growth. Orthophosphate is thus determined frequently as well.

Comments: An advantage of this parameter is that it is a total one: it is thus subject to less ambiguity of interpretation than other phosphorus parameters.

Phosphorus, Total : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l P	-	-	[1]
	(C)	mg/l P	-	-	[1]

Notes

[1] No figures whatever are quoted but there is the following comment: "In the case of lakes of average depth between 18 and 300 m, the following formula could be applied:

$$L \leq 10^{Z/Tw}\,(1 + Tw^{-2})$$

where L = loading expressed as mg P/square metre lake surface/year
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 PO_4 [corresponding to 0.062 and 0.124 mg/l as P, respectively], may be regarded as indicative in order to reduce eutrophication." The parameter is not included in the Regulations for salmonid waters.

POLYAROMATIC HYDROCARBONS

(See "Polycyclic Aromatic Hydrocarbons")

63. POLYCHLORINATED BIPHENYLS & TERPHENYLS

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: µg/l reference PCB/PCT (mixture) used.

Normal Method(s) of Analysis: Gas-Liquid Chromatography (GLC) [G].

Occurrence/Origin: Synthetic components of transformer coolant oils which gain access to water by spillages or industrial discharges.

Health/Sanitary Significance: Compounds of marked chronic toxicity; they are actual or potential carcinogens.

Background Information: Commonly termed PCBs/PCTs, this parameter covers those chlorinated compounds which have been used as mixtures in transformer coolant oils. The mixtures are normally designated by a proprietary name, for example "Aroclor," to which is suffixed a number, e.g. 1254 or 1260. The first two digits represent the number of carbon atoms in the molecule and the second two the percentage by weight of chlorine. The basic molecules present are biphenyl, which is $C_{12}H_{10}$ and comprises two benzene rings joined together, or terphenyl ($C_{18}H_{14}$, consisting of three fused benzene rings).

When these are chlorinated a whole range of polychlorinated compounds is produced and the mixtures are of such complexity that no effort is made to identify the individual components. The mixtures are dense and extremely stable, resisting biodegradation and conventional incineration procedures.

[The best process currently available for their destruction is very high temperature "flash" incineration. It is not without significance that, according to current estimates, about 90% of the total world production of these materials since the 1940s, when they were introduced, is still extant].

PCBs/PCTs are toxic, causing genetic effects and mortality to fauna. They are accumulated to a very great extent by fauna and there are many literature references to concentration factors of over 100,000 - in other words, an infinitesimal concentration in a water may be matched by 100,000 times that amount in the tissue of fish or animals normally resident in that water. When these toxicants enter the food chain, through consumption of fish for example, there is a health risk to man.

Comments: Minor spillages of PCBs are not uncommon and in order to minimise their effects on the environment it is essential that specialist expertise be used in both disposal of these materials and cleaning up after any spillage has occurred.

Polychlorinated Biphenyls & Terphenyls : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	-	-	-	[1]

Notes

[1] In contrast to Directive 80/778/EEC, the 1998 Drinking Water Directive makes no express reference to PCBs or PCTs.

64. POLYCYCLIC AROMATIC HYDROCARBONS

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l PAH [or specific PAH compound(s)].

Normal Method(s) of Analysis: High Pressure Liquid Chromatography (HPLC) [C].

Occurrence/Origin: Synthetic compounds occurring in soot, tar, vehicle exhausts, combustion products of hydrocarbon fuels.

Health/Sanitary Significance: Carcinogens of greater or lesser potency.

Background Information: This term, while strictly applicable to very many substances, has been defined as applying to six specific compounds:

Fluoranthene	*3,4-benzofluoranthene [benzo(b)fluoranthene]*
11,12-benzofluoranthene [benzo(k)fluoranthene]	3,4-benzopyrene [benzo(a)pyrene]
1,12-benzoperylene [benzo(ghi)perylene}	*indeno(l,2,3-cd)pyrene*

but in the 1998 Drinking Water Directive fluoranthene has been omitted, while benzo(a)pyrene [3,4-benzopyrene] has been listed as a separate parameter, leaving the four remaining compounds (shown in italics) to constitute the group designated: "Polycyclic Aromatic Hydrocarbons."

It may be useful to comment on the nomenclature of these compounds and related materials. They are so-called aromatic compounds, the term being used for those substances containing the "aromatic ring" (i.e. the cyclic molecular structure of benzene) a basic element of their composition. As the substances contain more than one such ring, they are termed polycyclic (or sometimes, poly-aromatic compounds). The compounds are hydrocarbons - i.e. they consist of the elements carbon and hydrogen only.

The alternative often-used designation - "polynuclear aromatic hydrocarbons" • arises from the (inaccurate) use by organic chemists of the word "nucleus" to refer to the benzene ring structure. As there is more than one such ring in these compounds they are termed "polynuclear."

All of these materials are complex organic molecules which originate typically in the combustion of organic compounds. Their analysis, like that of many other so-called micropollutants, is difficult, but the procedures are justified because of the potential health hazards posed by the PAH. The listed compounds can be determined relatively easily, albeit with advanced instrumental techniques, and their presence is also taken as indicative of the possible occurrence of other undesirable aromatic compounds. While all have been regarded previously as carcinogens, the six listed compounds comprising the most widely found such group in the environment, by far the most hazardous compound among them is benzo(a)pyrene [3,4-benzopyrene], which, as mentioned, has been highlighted in Drinking Water Directive [98/83/EC].

Comments: The compounds covered by the Surface Water Regulations are the six originally identified by the WHO, although this is implicit rather than stated. The 1998 Drinking Water Directive treats benzo(a)pyrene separately and the remaining substances (other than the omitted fluoranthene) as a group parameter.

Polycyclic Aromatic Hydrocarbons : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l	n/a	0.0002	[1]
	A2 waters	mg/l	n/a	0.0002	[1]
	A3 waters	mg/l	n/a	0.001	[1]
Drinking Water Directive [98/83/EC]		µg/l	n/a	0.10	[2,3]

Notes

[1] The parameter is termed "Polycyclic aromatic hydrocarbons" without any qualification.

[2] The parameter is termed "Polycyclic aromatic hydrocarbons," with a statement that "The specified compounds are: benzo(b)fluoranthene; benzo(k)fluoranthene; benzo(ghi)perylene; indeno(l,2,3-cd)pyrene." It should be noted that the variations in nomenclature arise from the use of different naming conventions by the EU and the WHO.

[3] The Directive notes that the parametric value applies to the "Sum of concentrations of specified compounds."

POLYNUCLEAR AROMATIC HYDROCARBONS

(See "Polycyclic Aromatic Hydrocarbons")

65. POTASSIUM

Chemical Symbol or Formula: K.

Units Used for Analytical Results: mg/l K.

Normal Method(s) of Analysis: Flame Photometry [B/C], Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Geological formations.

Health/Sanitary Significance: None, except at gross levels.

Background Information: Potassium is an essential constituent of many artificial fertiliser formulations, and hence its determination is often carried out on lake waters when an assessment is being made of nutrient input. However, potassium tends to be "fixed" in soils and is not that easily leached out. There are no implications of toxicity.

Comments: Very often potassium is measured on samples solely to permmit the calculation of an "ion balance" for the verification of the analysis.

Potassium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	-	-	-	[1]

Notes

[1] The limit value for potassium in the earlier Directive has not been carried forward to Directive [98/83/EC] in which there is no reference to this element.

66. PSEUDOMONAS AERUGINOSA

Chemical Symbol or Formula: Not applicable [Microbiological parameter].

Units Used for Analytical Results: No of organisms/250 ml sample.

Normal Method(s) of Analysis: Most Probable Number (MPN; Multiple Tube Method) [B]; Membrane Filtration Method [B].

Occurrence/Origin: Pseudomonas bacteria are ubiquitous in the environment and can metabolise most types of organic matter in a variety of conditions. The specific organism *Pseudomonas aeruginosa* is the only one of the group which is pathogenic to man; it is abundant in sewage.

Health/Sanitary Significance: *Pseudomonas aeruginosa* is associated with eye and ear infections.

Background Information: The presence of *Pseudomonas aeruginosa* is undesirable in recreational waters - in swimming pools and at bathing beaches.

Comments: The only current limit value applies to bottled drinking water.

***Pseudomonas aeruginosa* : Recommended or Mandatory Limit Values**

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	no/250 ml	n/a	0	[1]

Notes

[1] The limit value "applies to water offered for sale in bottles or containers."

RESIDUAL CHLORINE

(See "Chlorine, Residual")

67. SALINITY

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: ‰ [parts per thousand].

Normal Method(s) of Analysis: Electrometric (Salinity/Conductivity Meter) [A/B].

Occurrence/Origin: Natural property of seawater.

Health/Sanitary Significance: Organoleptic considerations only.

Background Information: This specific parameter is of interest only in tidal waters or in other surface waters where there may be infiltration of seawater. The presence of a high salt content (the greater constituent of which is chloride, q.v.) may render a water unsuitable for domestic, agricultural or industrial use, or may affect its suitability for shellfish.

Comments: Full seawater is 35 parts per thousand salinity, about 35,000 mg/l Cl.

Salinity: Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Shellfish Directive [79/923/EEC]	‰	12-38	≤ 40	[1,2]

Notes

[1] Unit of analysis is parts per thousand (‰).

[2] The following qualification applies to the I value: "[A] discharge affecting shellfish waters must not cause their salinity to exceed by more than 10% the salinity of waters not so affected."

68. SALMONELLA

Chemical Symbol or Formula: Not applicable [Microbiological parameter].

Units Used for Analytical Results: Number of organisms/specified volume of water.

Normal Method(s) of Analysis: Membrane Filtration technique [B].

Occurrence/Origin: Sewage and similar wastes.

Health/Sanitary Significance: Pathogenic micro-organisms causing diseases such as typhoid fever, paratyphoid fever etc.

Background Information: The most commonly occurring pathogenic micro-organisms in polluted water include salmonella types, for example *Salmonella typhi* and *Salmonella paratyphi*, which are causes of enteric diseases of greater or lesser severity. There are also milder forms of

gastric illnesses caused by other bacteria of the salmonella type. The analysis for these organisms is not always carried out, in contrast to the tests for total and faecal conforms [see under that heading for a fuller discussion of pathogens], but salmonella are determined more frequently than are staphylococci.

Comments: As with pathogenic staphylococci (q.v.) the non-determination of the specific pathogens in a routine analysis does not at all imply a reduced level of concern over their presence or absence. Instead, the policy of reliance on the test for the far more abundant coliform organisms (q.v.), used as indicators of the *possible* presence of pathogens, makes for a rather greater safety margin.

Salmonella : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	no/500 ml	n/a	0	
	A2 waters	no/100 ml	n/a	0	
	A3 waters	-	-	-	[1]
Bathing Water Regulations [1989-1998]		no/1000 ml	n/a	0	[2]
Drinking Water Directive [98/83/EC]		-	-	-	[3]

Notes

[1] No standard specified for A3 waters.

[2] Sampling to be carried out "where an investigation ... shows, or there are other grounds for believing, that there has been a deterioration in the quality of waters..." Standard to be conformed with by 95% of samples. Not to be exceeded by any two consecutive samples.

[3] Article 4(1) of the Directive states, inter alia, that; "For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be wholesome and clean if it ...is free from any microorganisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health....."; Article 7(6) requires that "Member States shall ensure that additional monitoring is carried out on a case-by-case basis of substances and micro-organisms for which no parametric value has been set in accordance with Article 5, if there is reason to suspect that they may be present in amounts or numbers which constitute a potential danger to human health." There is no express reference to salmonella.

SEC

(See "Substances Extractable in Chloroform")

69. SELENIUM

Chemical Symbol or Formula: Se.

Units Used for Analytical Results: µg/l Se.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [C]

Occurrence/Origin: Weathering of rocks/soils, but major environmental sources are man-made.

Health/Sanitary Significance: Toxic element except in trace concentrations.

Background Information: Although it is an essential biological requirement for both man and animals, selenium in more than very small amounts is toxic, causing a variety of illnesses. There have been conflicting reports as to whether or not the element is carcinogenic.

Comments: Where selenium is found it is probably of industrial origin. It is used as a chemical catalyst, in photographic equipment and processes, in electrical components and so on.

Selenium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Se	n/a	0.01	
	A2 waters	mg/l Se	n/a	0.01	
	A3 waters	mg/l Se	n/a	0.01	
Dangerous Substances Directive [76/464/EEC]			List II substance		
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		µg/l Se	-	10	

70. SILICA

Chemical Symbol or Formula: SiO_2.

Units Used for Analytical Results: mg/l SiO_2.

Normal Method(s) of Analysis: Manual/Automated Colorimetric technique (Molybdate/ Amino-naphtholsulphonic Acid) [B/C].

Occurrence/Origin: Rocks and geological formations.

Health/Sanitary Significance: No definite health implications in water.

Background Information: Silicon (as silica) is the most abundant element found in rocks and it will always be present in natural waters. The element is a major component of the structure of diatoms *(Bacillariophyta)*, one of the main divisions of the algae, and when algal growth takes place in a water there will be a dramatic drop in the silica levels as the diatom population rises. The subsequent replenishment of silica is principally from run-off.

Comments: It is in connection with the diatom population that silica is determined as there are no apparent connotations for the purity of the water or its suitability for consumption.

Silica : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

71. SILICON, TOXIC OR PERSISTENT ORGANIC COMPOUNDS

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l Si [or compound(s) detected].

Normal Method(s) of Analysis: [Specialised analytical techniques] [C/D]

Occurrence/Origin: Industrial wastes, tip-head leachates.

Health/Sanitary Significance: Toxic materials.

Background Information: There are no specified limits or identified compounds and the parameter is a general "catch-all" for hazardous, silicon-containing organic materials.

Comments: It is worthy of note that the parameter is mentioned only in the two Directives [Dangerous Substances and Groundwater] which seek to prevent rather than detect discharges.

Silicon, Toxic/Persistent Organic Compounds : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]		List II substance		[1]
Ground Water Directive [80/68/EEC]		List II substance		[1]

Notes

[1] List II refers to "Toxic or persistent organic compounds of silicon, and substances which may give rise to such compounds in water, excluding those which are biologically harmless or are rapidly converted in water to harmless substances."

72. SILVER

Chemical Symbol or Formula: Ag.

Units Used for Analytical Results: mg/l Ag.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: Ores, industrial wastes (e.g. photographic effluents).

Health/Sanitary Significance: Metal of varying toxicity.

Background Information: This metal is toxic, especially to micro-organisms, and its soluble salts are excellent disinfectants. It is not considered particularly toxic to humans and, as it is likely to be found only in very low levels (such that it would be practically impossible to reach hazardous levels through consumption of water and food), few limits have been set. However, it has been reported that restrictions on its use were introduced to discourage the use of silver as a disinfectant because of possible health effects if used unduly liberally.

Comments: Nowadays, economic considerations are likely to restrict the discharge of silver.

Silver : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]		List II substance		
Shellfish Directive [79/923/EEC]	mg/l Ag	[1]	[2]	
Ground Water Directive [80/68/EEC]		List II substance		
Drinking Water Directive [98/83/EC]	-	-	-	[3]

Notes

[1] "The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."
[2] "The concentration of [this] substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of [this and other specified] metals must be taken into consideration."
[3] The limit value for silver in the earlier Directive has not been carried forward to Directive [98/83/EC] in which there is no reference to this element.

73. SODIUM

Chemical Symbol or Formula: Na.

Units Used for Analytical Results: mg/l Na.

Normal Method(s) of Analysis: Flame Photometry [B/C]; Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Abundant constituent of rocks and soils.

Health/Sanitary Significance: Causes hypertension if taken in excess.

Background Information: Sodium is always present in natural waters. It is also an essential dietary requirement and the normal intake is as common salt (sodium chloride) in food; daily consumption may amount to 5 grams or more. The main reason for limiting it is the joint effect which it exercises with sulphate (see below) but too excessive an intake (the latter normally being 2-3 times the dietary threshold) can cause hypertension, as mentioned.

Comments: Sodium sulphate is used medicinally as a laxative ["Glauber Salts"].

Sodium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	mg/l Na	n/a	200	

74. SOLIDS, SETTLEABLE

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: millilitres/litre [ml/l] solids.

Normal Method(s) of Analysis: Settlement in lmhoffCone [A]

Occurrence/Origin: Not a normal determinand in analysis of water unless it is grossly polluted.

Health/Sanitary Significance: No direct implications, but in water is an indicator of gross pollution.

Background Information: This parameter is not normally determined in water analysis where reliance is placed on suspended solids (see below), but is one of those measured in the analysis of sewage effluents. Its main use is in the assessment of treatment plant performance.

Comments: There is an obvious relationship to the parameter "Solids, Suspended" (q.v.). Both are therefore of concern in fishery waters where high deposition of solids can interfere with fish and with spawning grounds.

Solids, Settleable : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

75. SOLIDS, SUSPENDED

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l solids (Dried at stated temperature).

Normal Method(s) of Analysis: Gravimetric (Filtration, with drying at stated temperature) [A].

Occurrence/Origin: Natural deposition in or discharges to water.

Health/Sanitary Significance: No direct significance.

Background Information: Matter which is suspended in quiescent water consists of finely divided light solids which may never settle or do so only very slowly. Indeed, the net effect may be one of apparent turbidity without any discernible solids. In flowing water, on the other hand, the solids which are kept in suspension by the turbulence may be settleable if the water is let stand. While the latter would be determinable as "Solids, Settleable," and the former could possibly be assessed as "Turbidity," there will be those solids of intermediate grading which also require estimation. To determine as much as possible of the solids present (not in solution), the determination of "suspended" solids is carried out.

The procedure consists of filtering the sample through a defined medium (a common specification is through a 0.45 µm membrane) and drying at a specified temperature (commonly 105°C) with gravimetric estimation of the concentration. Failing the use of a membrane fitter, glass-fibre paper (grade GF/C) may be used although its porosity is much greater than the former. It is important that the temperature of the drying be adhered to and also quoted with the results. It is clear that the term "suspended solids" is in fact defined by the filtration conditions.

The significance of suspended solids in water is great, on a number of grounds. The solids may in fact consist of algal growths and hence be indicative of severely eutrophic conditions; they may indicate the discharge of washings from sandpits, quarries or mines; they will reduce light penetration in surface waters and interfere with aquatic plant life; they will seriously damage fishery waters and may affect fish life; they may form deposits on the bed of rivers and lakes which will in turn give rise to septic and offensive conditions; and they may indicate the presence of unsatisfactory sewage effluent discharges.

Comments: The Royal Commission on Sewage Disposal (Eighth Report, 1912), referred to under "BOD" above, recommended that suspended solids be limited in effluents, and the second element in the "20/30" effluent previously discussed is a level of 30 mg/l suspended solids.

It is in the context of effluent analysis that suspended solids measurements are most relevant as they are good indicators of both the pollution potential of an effluent and the performance efficiency of treatment plant.

Solids, Suspended : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l	n/a	50	[1]
	A2 waters	mg/l	n/a	-	[1]
	A3 waters	mg/l	n/a	-	[1]
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l	$\leq$ 25	-	[2]
	(C)	mg/l	$\leq$ 25	-	[2]
Salmonid Waters Regulations [1988]		mg/l	n/a	$\leq$ 25	[3]
Shellfish Directive [79/923/EEC]		mg/l	-	-	[4]

Notes

[1] Parameter is "Total suspended solids." Standard specified for A1 waters only.

[2] "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." Departures are possible "because of exceptional weather or special geographical conditions."

[3] "The standard is expressed as an average concentration over a period of 12 months and does Not apply to suspended solids with harmful chemical properties."

[4] The I value quoted is: "A discharge affecting shellfish waters must not cause the suspended solid content of the waters to exceed by more than 50% the content of waters not so affected."

76. SOLIDS, TOTAL

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l solids (Dried at stated temperature).

Normal Method(s) of Analysis: Gravimetric (Dried at stated temperature) [A]

Occurrence/Origin: Natural and added solids present in water.

Health/Sanitary Significance: Primarily of organoleptic concern.

Background Information: This parameter comprises the total solids present in the whole sample which is analysed directly without filtration. It is referred to also as *Dry Residue(s)* or *Total Residue(s).* The drying temperature must he quoted with the results. There are two commonly used drying temperatures - 105°C and 180°C, the latter being favoured in some continental European standards.

At 105°C the residue may retain some water even after an hour's drying. There will be some conversion of bicarbonates to carbonates by loss of carbon dioxide but loss of organic matter will be minimal. At 180°C virtually all the water will be lost, as will some organic matter. In addition to loss of carbon dioxide in bicarbonates, some further loss may occur in carbonates. Because of these differences in behaviour the temperature must be quoted to obtain the most meaningful picture from the results.

At times the residue from the total solids determination is analysed further by igniting it for an hour in a furnace at 550-600°C. Under this drastic heat, organic matter will be volatilised and there will be some further loss in weight by destruction of some inorganic compounds. The weight lost represents the *Volatile Solids* and the ultimate residue is the so-called *Fixed Residue* or Non-*Volatile Solids,* present in the sample.

Comments: While there is no direct correlation between loss in weight on ignition of a sample and its organic content, in certain circumstances (as, for example, an investigation of the extent to which organic sludge is deposited over an area of river bed), the determination of volatile solids will give a useful trace of the levels of organic matter.

Solids, Total : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

77. SOLIDS, TOTAL DISSOLVED

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l solids (Dried at stated temperature).

Normal Method (s) o f Analysis: Gravimetric (Dried at stated temperature after filtration) [A].

Occurrence/Origin: Natural or added solutes present in a water.

Health/Sanitary Significance: Principally organoleptic implications.

Background Information: The parameter is determined as for total solids except that the sample is filtered through a defined medium (membrane or glass fibre paper; cf. "Solids, Suspended") beforehand. The term *Total Filtrable Solids* is also used. It is often convenient and acceptable to use the very rapid determination of conductivity (q.v.) to give an estimation of the total dissolved solids.

Comments: As discussed earlier, the *total dissolved solids*, or *TDS*, includes ionised and non-ionised matter but only the former is reflected in the conductivity. Where TDS are high the water may be "saline" and the applicable parameter "Salinity."

Solids, Total Dissolved : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

SS

(See "Solids, Suspended")

SUSPENDED SOLIDS

(See "Solids, Suspended")

TDS

(See "Solids, Total Dissolved")

TOTAL DISSOLVED SOLIDS

(See "Solids, Total Dissolved")

STANDARD PLATE COUNT(S)

(See "Colony Counts")

STREPTOCOCCI, FAECAL

(See "Enterococci")

78. SUBSTANCES AFFECTING TASTE

Chemical Symbol or Formula: Not applicable [Organoleptic parameter].

Units Used for Analytical Results: mg/l compound(s) identified/detected.

Normal Method(s) of Analysis: [Specific techniques as appropriate] [C]

Occurrence/Origin: Naturally occurring or added solutes.

Health/Sanitary Significance: Primarily organoleptic effects.

Background Information: This is a somewhat ill-defined parameter in that there are potentially so many of these substances that their control, while most desirable (particularly for fishery and shellfish waters, and for drinking water sources), is virtually impossible to achieve. The only practicable approach is to monitor and regulate the presence of selected pollutants (phenols, metals and so on) which are known to have deleterious effects.

Comments: The parameter is closely related to Tainting Substances, and for all practical purposes the two may be taken as one.

Substances Affecting Taste : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]		List II substance		[1]
Shellfish Directive [79/923/EEC]	-	-	-	[2]
Ground Water Directive [80/68/EEC]		List II substance		[3]

Notes

[1] List II includes "Substances which, have a deleterious effect on the taste and/or smell of the products for human consumption derived from the aquatic environment."

[2] Parameter is "Substances affecting the taste of the shellfish." The I value is a "Concentration lower than that liable to impair the taste of the shellfish."

[3] List II includes "Substances which have a deleterious effect on the taste and/or odour of groundwater, and compounds liable to cause the formation of such substances in such water and to render it unfit for human consumption."

79. SUBSTANCES EXTRACTABLE IN CHLOROFORM

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l SEC.

Normal Method(s) of Analysis: Extraction, Drying & Gravimetry [B/C]

Occurrence/Origin: Principally from waste discharges of all types.

Health/Sanitary Significance: General indicator of organic content of water.

Background Information: Commonly abbreviated to *SEC*, this is a bulk parameter which encompasses many organic contaminants in water. In one respect it is selective as it relates to a single solvent, admittedly a powerful one, which is used for the direct extraction of organic matter from a water sample. A related parameter is the *Carbon-Chloroform Extract (CCE),* in which the sample is passed through a column of activated carbon to permit removal of the organics by adsorption: subsequent recovery is .effected by extraction of the carbon with chloroform. There is a third, related test the *Carbon-Alcohol Extract (CAE)* - in which alcohol replaces chloroform as the recovery solvent.

Comments: Chloroform and alcohol are both powerful solvents and their use in these determinations is intended to ensure as near quantitative extraction (or recovery from carbon) of organics as possible. As such, the tests are complementary to total organic carbon determinations (see above) in that each will give a general overall indication of organic content which may not be reflected completely or at all in oxygen demand or oxidisability analyses.

It should be noted that the SEC analysis has fallen out of favour for two main reasons. First, the relative crudity of the analytical procedure does not match the comparative stringency of the limits for surface waters, in particular A1 waters. A high degree of analytical skill is required if errors are to be avoided. Second, and of much greater importance, is the health hazard to analysts carrying out extractions with chloroform, which is considered to be carcinogenic. The use of chloroform is increasingly being ruled out for laboratory use on health and safety grounds.

Substances Extractable in Chloroform : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l SEC	n/a	0.2	
	A2 waters	mg/l SEC	n/a	0.4	
	A3 waters	mg/l SEC	n/a	1.0	

80. SUBSTANCES WHICH POSSESS CARCINOGENIC, MUTAGENIC OR TERATOGENIC PROPERTIES

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l compound(s) identified/detected.

Normal Method (s) of Analysis: [Appropriate specific analytical techniques] [C/D]

Occurrence/Origin: Wastes, effluents, leachates etc.

Health/Sanitary Significance: Apparent from designation of parameter.

Background Information: While the significance of this parameter is immediately obvious, it is also clear that because of its great scope there is no way in which specific analysis can be carried out under this heading. Instead, limits have been and will continue to be placed on individual substances which are known to be cancer causing or which cause mutagenic or genetic disorders of any kind, and control will be exercised by limiting the individual chemicals or groups of substances as they become known.

Comments: This another of the essentially preventative rather than detection parameters which arise mainly under the Dangerous Substances and Ground Water Directives. While its desirability is clear, its practicality from the control point of view is questionable.

Substances which Possess...Properties : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]		List I substance		[1]
Ground Water Directive [80/68/EEC]		List I substance		[2]

Notes

[1] List I refers to "Substances in respect of which it has been. proved that they possess carcinogenic properties in or via the aquatic environment."
[2] List I refers to "Substances which possess carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment."

81. SULPHATE

Chemical Symbol or Formula: SO_4^{--}

Units Used for Analytical Results: mg/l SO_4

Normal Method(s) of Analysis: Turbidimetric (Barium Sulphate) [B/G]; Ion Chromatography [C].

Occurrence/Origin: Rocks, geological formations, discharges and so on .

Health/Sanitary Significance: Excess sulphate has a laxative effect, especially in combination with magnesium and/or sodium.

Background Information: Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. They are often derived from the sulphides of heavy metals (iron, nickel, copper and lead). Iron sulphides are present in sedimentary rocks from which they can be oxidised to sulphate in humid climates; the latter may then leach into watercourses so that ground waters are often excessively high in sulphates. As magnesium and sodium are present in many waters their combination with sulphate will have an enhanced laxative effect of greater or lesser magnitude depending on concentration. The utility of a water for domestic purposes will therefore be severely limited by high sulphate concentrations, hence the limit of 250 mg/l SO_4.

Comments: Other problems are associated with sulphate. In polluted waters in which the dissolved oxygen i.e. zero, sulphate is very readily reduced to sulphide causing noxious odours. Waters containing sulphates in excess will also attack the fabric of concrete sewer pipes.

Sulphate : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l SO_4	n/a	200	
	A2 waters	mg/l SO_4	n/a	200	[1]
	A3 waters	mg/l SO_4	n/a	200	[1]
Drinking Water Directive [98/83/EC]		mg/l SO_4	n/a	250	[2]

Notes

[1] Departure may be granted by the Minister "where exceptional meteorological or geographical conditions have arisen." [A2 and A3 water only.]
[2] "The water must not he aggressive."

82. SULPHIDE

Chemical Symbol or Formula: S^{--}.

Units Used for Analytical Results: mg/l S.

Normal Method(s) of Analysis: Lead Acetate Paper (Qualitative) [A]; Specific Ion Electrode [B].

Occurrence/Origin: From anaerobic decomposition of organic matter in water or in waste, and from bacterial reduction of sulphate.

Health/Sanitary Significance: Toxic effects on man and aquatic life (see discussion below).

Background Information: The principal interest in sulphide arises because of its toxicity, and also the odour problems associated with the presence of undissociated hydrogen sulphide (H_2S) which is produced by anaerobic reduction of sulphate. There is an equilibrium relationship between the dissociated and undissociated H_2S forms which is dependent on pH. If the latter is above 8 there will be no odour problems but as the pH drops to under 7 any H_2S present will give rise to offensive odours. This is because the chemical equilibria:

$$H_2S \quad \Leftrightarrow \quad H^+ + HS^- \quad \Leftrightarrow \quad H^+ + S^{--}$$

will shift to the left, favouring the presence of undissociated hydrogen sulphide, which is a highly toxic substance. It is the H_2S species which particularly affects aquatic life and which has caused fatalities to persons working in sewers.

Comments: A problem associated with sulphide is the so-called "crown corrosion" of concrete sewers. If these are not well ventilated the H_2S present can be converted by aerobic bacteria resident on the sewer walls above the level of the wastewater to sulphuric acid which will then attack the sewer.

Sulphide : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
No reference/recommendation				

SUSPENDED SOLIDS

(See "Solids, Suspended")

TAINTING SUBSTANCES

(See "Substances Affecting Taste")

83. TARRY RESIDUES AND FLOATING MATTER

Chemical Symbol or Formula: Not applicable [General bulk parameter].

Units Used for Analytical Results: General description of environment.

Normal Method(s) of Analysis: Visual [A].

Occurrence/Origin: Jetsam, littering, discharges.

Health/Sanitary Significance: None with litter; hazard with sewage solids and the like.

Background Information: The environmental relevance of the parameter - which is fully defined in Note [3] on page 106 - is obvious.

Comments: River surveys in Ireland have shown on occasion that alleged pollution of a river has in fact been despoliation of the river banks and surface by littering.

Tarry Residues and Floating Matter; Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	-	n/a	-	[1,2]
Dangerous Substances Directive [76/464/EEC]		List I substance		[3]

Notes

[1] Parameter is described as "Tarry residues. Floating matter such as wood, plastic articles...bottles, containers of glass, plastic, rubber and other substances. Waste or splinters."
[2] Standard is "No offensive presence." Standard to be conformed with in 95% of inspections of bathing water. No two consecutive inspections to fail standard.
[3] List I refers to "Persistent synthetic substances which may float, remain in suspension or sink, and which may interfere with any use of the waters."

84. TASTE

Chemical Symbol or Formula: Not applicable [Organoleptic parameter].

Units Used for Analytical Results: Dilution Factor at Stated Temperature [D].

Normal Method(s) of Analysis: Taste Panel in Controlled Conditions (see "Comments" below).

Occurrence/Origin: Presence of offensive solutes, natural or added.

Health/Sanitary Significance: Principally organoleptic.

Background Information: As with odour (q.v.), taste is a parameter which can lead to severe consumer reaction which may necessitate the condemnation of a water supply. While astringent tastes can be caused by the presence of excessive amounts of metals or dissolved salts, there are often other more serious problems which arise in such cases (e.g. physiological effects). Purely organoleptic taste problems arise most commonly from algae and from phenols after chlorination. Decaying algal masses can release to the water trace organic compounds (including phenolic types) which produce offensive tastes after chlorination during treatment.

Comments: It should be noted that, in practice, in the great majority of cases, taste is assessed by an individual analyst and is described subjectively. The use of a taste pane! is a very complex and expensive matter if the specified procedures are adhered to correctly.

Taste : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Freshwater Fish Directive [78/659/EEC]	(S)	-	-	-	[1]
	(C)	-	-	-	[1]
Salmonid Waters Regulations [1988]		-	-	-	[1]
Shellfish Directive [79/923/EEC]		-	-	-	[2]

Taste : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	-	-	Acceptable to consumers and no abnormal change	

Notes

[1] No specific mention in parameter list but references under "Hydrocarbons" and "Phenols" [q.v.].
[2] See "Substances affecting taste" above.

TDS

(See "Solids, Total Dissolved")

85. TELLURIUM

Chemical Symbol or Formula: Te.

Units Used for Analytical Results: mg/l Te.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C]

Occurrence/Origin: Minerals and wastes (porcelain, enamel, glass, electronic).

Health/Sanitary Significance: Toxic metal.

Background Information: Among the effects of ingestion of tellurium are nausea, vomiting and depression, but these are rarely found because of the comparatively low exposure risk.

Comments: The lack of reference in the Directives (apart from Dangerous Substances and Ground Water) indicates an absence of immediate concern over tellurium.

Tellurium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance	
Ground Water Directive [80/68/EEC]			List II substance	

86. TEMPERATURE

Chemical Symbol or Formula: Not applicable [Physical parameter]

Units Used for Analytical Results: Degrees Celsius [°C].

Normal Method(s) of Analysis: Thermometry [A] or Thermistor [as in DO probe] [A/B], with measurement in the field (usually in association with the DO measurement: q.v.).

Occurrence/Origin: Generally climatologically influenced (in the absence of thermal discharges).

Health/Sanitary Significance: None.

Background Information: The natural variation in temperature found in Irish surface waters is of the order of 25°C - from freezing point to a summer maximum of around 25°C in occasional years. Thermal pollution would, of course, alter the position, possibly very significantly. The effect of temperature, and especially changes in temperature, on living organisms can be critical and the subject is a very wide and complex one. Where biochemical reactions are concerned, as in the uptake of oxygen by bacteria, a rise of 10°C in temperature leads to an approximate doubling of the rate of reaction. Conversely, such reactions are retarded by cooling, hence the recommendation often made that waters be cooled to 4°C in the interval between sampling and analysis.

Another most important factor is that some key constituents of a water either change their form (as in the ionisation of ammonia) or alter their concentration (as with dissolved oxygen) when temperature changes. In fact, the primary interest in the temperature of surface waters is due to the inverse relationship between it and oxygen solubility (See "Oxygen, Dissolved"). However, elevated temperatures and, more importantly, steep temperature gradients can have directly harmful effects on fish. It is for the latter reason that changes in temperature are subject to limits. The table comprising Appendix 3 shows the complex relationship between temperature, pH value and the concentration in water of the toxic equilibrium species of ammonia. A table showing the oxygen solubility/temperature relationship appears under the parameter "Oxygen, Dissolved."

Comments: The most comprehensive provisions concerning temperature arise under the Freshwater Fish Directive and Salmonid Waters Regulations.

Temperature : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	ºC	n/a	25	[1]
	A2 waters	ºC	n/a	25	[1]
	A3 waters	ºC	n/a	25	[1]
Freshwater Fish Directive [78/659/EEC]	(S)	ºC	-	-	[2,3]
	(C)	ºC	-	-	[2,3]
Salmonid Waters Regulations [1988]		mg/l Zn	n/a	-	[4]
Shellfish Directive [79/923/EEC]		mg/l Zn	-	-	[5]

Notes

[1] Departure may be granted by the Minister "where exceptional meteorological or geographical conditions have arisen.."

[2] I value is: "... 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" in salmonid waters and "3.0"C" in cyprinid waters. "Derogations limited in geographical scope may be decided by Member States in particular conditions if the competent authority can prove that there are no harmful consequences for the balanced development of the fish population."

[3] "Thermal discharges must not cause the temperature downstream of the point of thermal discharge [at the edge of the mixing zone] to exceed the following: 21.5°C¶/10°C" in salmonid waters and 28°C¶/10°C in cyprinid waters.

"The 10°C temperature limit applies only to breeding periods of species which need cold water for reproduction and only to waters which may contain such species." Temperature limits may, however, be exceeded for 2% of the time.

[4] Standard laid down in Regulations is: "Temperature measured downstream of a point of thermal discharge [at the edge of the mixing zone as determined by the local authority] must not -

[a] exceed the unaffected temperature by more than. 1.5°C

[b] exceed [i] 21.5°C, or [ii] 10°C during the period from I November to 30 April where species which need cold water for reproduction are present.

A thermal discharge must not cause sudden variations m temperature." "[Temperature limits to be conformed with for 98% of the time.]"

[5] G value is; "A discharge affecting shellfish waters must not cause the temperature of the waters to exceed by more than 2°C the temperature of water not so affected."

TETRACHLOROETHENE

(See "Tetrachloroethylene")

87. TETRACHLOROETHYLENE

Chemical Symbol or Formula: C_2Cl_4.

Units Used for Analytical Results: µg/l C_2Cl_4.

Normal Method(s) of Analysis: Gas Chromatography [B/C].

Occurrence/Origin: Synthetic solvent used extensively in dry-cleaning industry; also used to a significant extent for degreasing metals.

Health/Sanitary Significance: Toxic solvent which can cause narcosis, dermatitis and ultimately fatal intoxication. However, when handled according to proper procedures and with adequate ventilation, tetrachloroethylene may be used without problems.

Background Information: Synonyms for tetrachloroethylene are tetrachloroethene and perchloroethylene. It is the most commonly used dry-cleaning solvent.

Comments: As with all chlorinated solvents, this substance should be handled with care, and in well-ventilated areas.

Tetrachloroethylene: Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l	n/a	10	[1]

Notes

[1] The parameter is designated "Tetrachloroethene and trichloroethene" and the parametric value is the "Sum of concentrations of specified parameters."

¶ : Departures possible "because of exceptional weather or special geographical conditioas."

88. THALLIUM

Chemical Symbol or Formula: Tl.

Units Used for Analytical Results: mg/l Tl.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Minerals, but more often from discharges.

Health/Sanitary Significance: Causes a wide variety of effects including nausea, vomiting, pain and, ultimately, death.

Background Information: The metal is used at 2-3% concentration in rodent poisons, and is also used in the electrical components industry.

Comments: As with tellurium there is a low risk of exposure.

Thallium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance	
Ground Water Directive [80/68/EEC]			List II substance	

THM

(See "Trihalomethanes")

89. TIN

Chemical Symbol or Formula: Sn.

Units Used for Analytical Results: mg/l Sn.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Ores, effluents from tin-plating and alloy manufacture.

Health/Sanitary Significance: Little concern regarding tin itself and its inorganic compounds, but see next parameter below.

Background Information: Tin has only rarely been found in water - and then only in trace concentrations. The level of exposure from foods, natural as well as canned, is rather higher than would be expected to result from consumption of a water supply.

Comments: No specific standards have been laid down for (inorganic) tin.

Tin : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance	
Ground Water Directive [80/68/EEC]			List II substance	

90. TIN, ORGANO-COMPOUNDS

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results: mg/l Sn [or specific compound(s)].

Normal Method(s) of Analysis: Atomic Absorption Spectrometry/Gas Liquid Chromatography [C].

Occurrence/Origin: Principally synthetic substances used for pest control.

Health/Sanitary Significance: High to very high toxicity, depending on the compound structure.

Background Information: This parameter comprises another group of specific organometallic substances, all of which, as mentioned, are toxic and highly undesirable in the environment. Compounds such as tributyltin and triphenyltin are present in antifouling marine paints and have become a problem particularly in enclosed marina areas and in some shellfishery waters. Consequently, their use has been prohibited in Ireland.

Comments: There is a problem for analysts in that for some of the organotin compounds of concern there are as yet no satisfactory methods of determination.

Tin, Organo-Compounds : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List I substance	
Ground Water Directive [80/68/EEC]			List I substance	

91. TITANIUM

Chemical Symbol or Formula: Ti.

Units Used for Analytical Results: mg/l Ti.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [C]

Occurrence/Origin: Minerals and industrial wastes; found rarely.

Health/Sanitary Significance: No practical significance.

Background Information: The metal is used in some bronze alloys and in steel to increase greatly its tensile strength.

Comments: No quality criteria or standards specified.

Titanium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance	
Ground Water Directive [80/68/EEC]			List II substance	

TOC

(See "Organic Carbon, Total")

TOTAL BACTERIA COUNT(S)

(See "Colony Counts")

TOTAL COLIFORMS

(See "Coliforms, Faecal & Total")

TOTAL COLONY COUNT(S)

(See "Colony Counts")

TOTAL DISSOLVED SOLIDS

(See "Solids, Total Dissolved")

TOTAL HARDNESS

(See "Hardness")

92. TOTAL INDICATIVE DOSE [RADIOACTIVITY] [10]

[10] This parameter is included as it is among those covered by Drinking Water Directive [98/83/EC]. However, there are as yet no definitive requirements in the Directive, which states the following:

[Note 9] Excluding tritium, potassium-40, radon and radon decay products; monitoring frequencies, monitoring methods and the most relevant locations for monitoring points to be set later in Annex II.

[Note 10] 1. The proposals required by Note 8 on monitoring frequencies, and Note 9 on monitoring frequencies, monitoring methods and the most relevant locations for monitoring points in Annex II shall be adopted in accordance with the procedure laid down in Article 12. When elaborating these proposals the Commission shall take into account *inter alia* the relevant provisions under existing legislation or appropriate monitoring programmes including monitoring results as derived from them. The Commission shall submit these proposals at the latest within 18 months following the date referred to in Article 18 of the Directive.

2. A Member State is not required to monitor drinking water for tritium or radioactivity to establish total indicative dose where it is satisfied that, on the basis of other monitoring carried out, the levels of tritium of the calculated total indicative dose are well below the parametric value. In that case, it shall communicate the grounds for its decision to the Commission, including the results of this other monitoring carried out.

TOTAL NITROGEN

(See "Nitrogen, Kjeldahl")

TOTAL ORGANIC CARBON

(See "Organic Carbon, Total")

TOTAL PLATE COUNT(S)

(See "Colony Counts")

TOTAL SOLIDS

(See "Solids, Total")

93. TRANSPARENCY

Chemical Symbol or Formula: Not applicable [Physical parameter].

Units Used for Analytical Results: metres Secchi.

Normal Method(s) of Analysis: Visual observation with Secchi Disc [A].

Occurrence/Origin: Physical property of water.

Health/Sanitary Significance: None, except as indicator of possible loss of quality.

Background Information: This parameter gives an indication of the presence or absence of suspended matter, living or inert, and hence it is a reflection of the overall quality of a water. However, it must be remembered that the presence of any undesirable substances in solution will not be indicated by transparency. It is expressed as the maximum depth in metres at which it is possible to distinguish the markings of a Secchi disc, and it is widely used in studies on lakes to assess the abundance of algae.

The parameter is also determined in bathing waters as a check on aesthetic suitability.

Comments: Transparency is related to "Turbidity" (q.v.).

Transparency : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Bathing Water Regulations [1989-1998]	metres/depth	-	≥ 1	[1]

Notes

[1] Standard "to be conformed with in 95% of inspections of bathing water. No two consecutive inspections to fail standard. Transparency never to be less than 0.5." [Units are equivalent to metres Secchi].

TRIBUTYLTIN

(See "Tin, Organo-Compounds")

TRICHLOROETHENE

(See "Trichloroethylene")

94. TRICHLOROETHYLENE

Chemical Symbol or Formula: C_2HCl_3.

Units Used for Analytical Results: µg/l C_2HCl_3.

Normal Method(s) of Analysis: Gas Chromatography [B/C].

Occurrence/Origin: Synthetic solvent used in various industrial and manufacturing processes (e.g. solvent for paints, varnishes, resins etc); used in dry-cleaning and in metals degreasing.

Health/Sanitary Significance: Potential carcinogen. Causes narcosis and effects similar to alcohol inebriation. See also "Tetrachloroethylene," which is a very similar compound.

Background Information: Trichloroethylene is used in the manufacture of organic chemicals and pharmaceuticals, and it also has some medical uses.

Comments: See observations under "Tetrachloroethylene."

Trichloroethylene : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l	n/a	10	[1]

Notes

[1] The parameter is designated “Tetrachloroethene and trichloroethene” and the parametric value is the "Sum of concentrations of specified parameters."

95. TRIHALOMETHANES

Chemical Symbol or Formula: CHX_3 [where X indicates chlorine (Cl) and/or bromine (Br) atoms.

Units Used for Analytical Results: [µg/l compound(s).

Normal Method(s) of Analysis: Gas Chromatography [C].

Occurrence/Origin: Synthetic constituents of some chlorinated drinking waters.

Health/Sanitary Significance: Some of the compounds are actual or potential carcinogens and have also been held responsible for other physiological ill-effects.

Background Information: Trihalomethanes, as the name indicates, are derivatives of the simplest organic compound - methane, CH_4 - in which three of the hydrogen atoms are substituted by halogen atoms. The principal halogens are fluorine (F_2), chlorine (Cl_2), bromine (Br_2) and iodine (I_2), but, while many combinations are theoretically possible, the term trihalomethanes is applied to four specific compounds containing only chlorine and/or bromine as the halogen elements. The four compounds are: chloroform [$CHCl_3$] - bromodichloromethane [$CHBrCl_2$] - dibromochloromethane ($CHBr_2Cl$) - bromoform ($CHBr_3$). As two of the four substances are chloroform and bromoform, the alternative designation *haloforms* is quite frequently applied to the group, which, however, is most often referred to simply as THMs.

THMs are unwelcome by-products of the disinfection by chlorination of water containing organic matter. The most common source of such matter is the natural colour of many raw waters which are abstracted from surface water sources, principally rivers and streams. While very many of the larger public water supplies derived from such sources will involve multi-stage treatment, including flocculation (coagulation) which is aimed specifically at colour removal, the opposite is the case with very many smaller supplies where the sole stage of treatment is disinfection, invariably chlorination.

As a powerful oxidising agent, chlorine breaks down the complex - and inert - organic molecules which are the colouring agents, forming smaller, reactive entities which react with chlorine (and with bromine derived from the oxidation by chlorine of bromide naturally present) to form the THM compounds, the most abundant of which is chloroform. There is thus a fairly straightforward relationship between the degree of colour in the water prior to chlorination and the quantities of THMs present following chlorination. If colour is present at the point of chlorination, THMs will be formed. They will also be formed if the multi- stage treatment of a coloured raw water includes a pre-chlorination process, where chlorine is added at the outset to reduce the complexity of organic materials present in order to make them more amenable to subsequent treatment stages. The latter will not remove any THMs formed at the initial stage and they will pass through to the final water. It may be noted that, in sharp contrast, the chlorination of ground waters - which are essentially uncoloured - will give rise to negligible, if any, THM concentrations.

Comments: While the presence of THMs in drinking water is a relatively widespread phenomenon, and one which is a matter for concern, as reflected in the provisions of Drinking Water Directive [98/83/EC] - see below - it must be remembered that the compounds are not "new" or recent pollutants. In fact, their presence - though unknown and undetected - will have declined steadily over the century since chlorination was first introduced. This is because water treatment processes have been developed, improved and extended over the years, with the result that colour levels nowadays are much lower than they were in earlier decades. Nonetheless, as the Directive indicates, the need for conformity with acceptable limits is a matter of priority. Another by-product of chlorination (which is a matter for equal if not greater concern) is bromate (q.v.).

Trihalomethanes : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l	n/a	100	[1,2]

Notes

[1] The parameter is designated "Trihalomethanes - Total" and the parametric value applies to the "Sum of concentrations of specified compounds."

[2] The Directive contains the following important Note:

Where possible, without compromising disinfection, Member States should strive for a lower value,
The specified compounds are: chloroform, bromoform, dibromochloromethane, bromodichloromethane.

For the water referred to in Article 6(l)(a), (h) and (d), the value must be met, at the latest, 10 cal endar years after the entry into force of this Directive. The parametric value for total THMs from five years after the entry into force of this Directive until 10 years after its entry into force is 150 µg/l.

Member States must ensure that all appropriate measures are taken to reduce the concentration of THMs in water intended for human consumption as much as possible during the period needed to achieve compliance with the parametric value.

When implementing the measures to achieve this value, Member States must progressively give priority to those areas where THM concentrations in water intended for human consumption are highest.

TRIPHENYLTIN

(See "Tin, Organo-Compounds)

96. TRITIUM [11]

Chemical Symbol or Formula: $^{3}_{1}$H or T

Units Used for Analytical Results: Bq/l. [Becquerels/litre]

Comments: See footnote below.

Tritium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	Bq/l	n/a	100	

97. TURBIDITY

Chemical Symbol or Formula: Not applicable [Bulk physical parameter].

Units Used for Analytical Results: Formazin Turbidity Units [FTU]; Jackson Turbidity Unit [JTU]; Nephelometric Turbidity Units [NTU]; Silica Units [SiO_2].

Normal Method(s) of Analysis: Turbidimeter orNephelometer [B/C]

Occurrence/Origin: Clay particles, sewage solids, silt and sand washings, organic and biological sludges etc.

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[11] This parameter is included as it is among those covered by Drinking Water Directive [98/83/EC]. However, there are as yet no definitive requirements in the Directive, which states the following:

[Note 8] Monitoring frequencies to be set later in Annex II.

[Note 10] 1. The proposals required by Note 8 on monitoring frequencies, and Note 9 on monitoring frequencies, monitoring methods and the most relevant locations for monitoring points in Annex II shall be adopted in accordance with the procedure laid down in Article 12. When elaborating these proposals the Commission shall take into account *inter alia* the relevant provisions under existing legislation or appropriate monitoring programmes including monitoring results as derived from them. The Commission shall submit these proposals at the latest within 18 months following the date referred to in Article 18 of the Directive.

2. A Member State is not required to monitor drinking water for tritium or radioactivity to establish total indicative dose where it is satisfied that, on the basis of other monitoring carried out, the levels of tritium of the calculated total indicative dose are well below the parametric value. In that case, it shall communicate the grounds for its decision to the Commission, including the results of this other monitoring carried out.

Health/Sanitary Significance: Direct health effects depend on the precise composition of the turbidity-causing materials, but there are other implications, as discussed below.

Background Information: Turbidity in water arises from the presence of very finely divided solids (which are not filtrable by routine methods). The existence of turbidity in water will affect its acceptability to consumers and it will also affect markedly its utility in certain industries. The particles forming the turbidity may also interfere with the treatability of waters and in the case of the disinfection process the consequences could be grave. As turbidity can be caused by sewage matter in a water there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant.

Comments: As indicated above, there is a relative multiplicity of units for turbidity in water, a fact which has caused a marked degree of confusion at times. However, the position is rather simpler than at first appears, as FTU (formazin), JTU (Jackson) and NTU (nephelometric) are virtually equivalent and are used interchangeably. Silica units differ. The 1980 Drinking Water Directive showed the following "parallel" MAC values for turbidity (from which the relationship may be inferred): Jackson units [JTU/FTU/NTU] - MAC 4; Silica units - MAC 10 mg/l SiO_2. It will be noted below that Drinking Water Directive [98/83/EC] adverts to nephelometric units [NTU].

Turbidity : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	-	-	Acceptable to consumers and no abnormal change	[1]

Notes

[1] The Directive states that. "In the case of surface water treatment, Member States should strive for a parametric value not exceeding 1.0 NTU (nephelometric turbidity units) in. the water ex treatment works."

98. URANIUM

Chemical Symbol or Formula: U.

Units Used for Analytical Results: mg/l U.

Normal Method(s) of Analysis: Radiometric or Fluorometric techniques [D]

Occurrence/Origin: Rare natural occurrence; equally rare in effluents.

Health/Sanitary Significance: Highly toxic, with a variety of effects leading ultimately to death.

Background Information: This radioactive element is used in the nuclear industry and is thus far from being universally encountered. There is no general concern in the context of drinking water quality. The EU controls arise in the Dangerous Substances and Ground Water Directives which seek to limit discharges.

Comments: There are atomic absorption spectrometric procedures for uranium analysis but (ICP analysis excepted) their sensitivity is generally inadequate for very low levels.

Uranium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance	
Ground Water Directive [80/68/EEC]			List II substance	

99. VANADIUM

Chemical Symbol or Formula: V.

Units Used for Analytical Results: mg/l V.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Widespread in rocks and minerals.

Health/Sanitary Significance: Some undesirable physiological effects (e.g. ear, nose, throat irritation) but not a hazard of significance in water.

Background Information: This element is naturally quite abundant and in addition relatively large amounts enter the environment from industrial and related activities.

Comments: Levels for other than human life are quite low.

Vanadium : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance	
Ground Water Directive [80/68/EEC]			List II substance	

100. VINYL CHLORIDE

Chemical Symbol or Formula: C_2H_3Cl.

Units Used for Analytical Results: µg/l C_2H_3Cl.

Normal Method(s) of Analysis: Gas Chromatography [C].

Occurrence/Origin: Synthetic gaseous compound which polymerises very readily and is an important raw material in the manufacture of plastics. It is also used as a refrigerant.

Health/Sanitary Significance: Being very volatile it can caused local frostbite, if spilled on skin, as it evaporates. More importantly, it is a suspected causative agent of liver cancer.

Background Information: Although a very reactive monomer which forms plastic polymers very easily, it is almost inevitable that in some cases the resultant polymer - the most common of which is polyvinyl chloride or PVC - will contain vestigial amounts of vinyl chloride itself. Thus, in the first use, in particular, of vessels made of PVC there is the possibility of residual monomer gaining access to water. The note in Drinking Water Directive [98/83/EC] is appended with this in mind (q.v.).

Comments: Vinyl chloride was not a parameter in Directive [80/778/EEC].

Vinyl Chloride : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations	*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Drinking Water Directive [98/83/EC]	µg/l	n/a	0.50	[1]

Notes

[1] Note 1 states that "The parametric value refers to the residual monomer concentration in the water as calculated according to specifications of the maximum release from the corresponding polymer in contact with the water."

101. ZINC

Chemical Symbol or Formula: Zn.

Units Used for Analytical Results: mg/l Zn.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Natural geological occurrence and from wastes.

Health/Sanitary Significance: Inhalation of zinc-containing fumes can cause a variety of physiological effects, but principal significance of excessive amounts in water is that emetic effects occur.

Background Information: Zinc is essential to man but if ingested in gross amounts it has an emetic effect. However, the concern in water supply arises in regard to taste not toxicity, and quite high levels are permissible. In fishery water, in contrast, the toxic action is much more important and very much lower limits have been imposed.

Comments: The toxicity of zinc to aquatic life is (as with copper) dependent on the hardness of the water: it decreases with rising hardness.

Zinc : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Surface Water Regulations [1989]	A1 waters	mg/l Zn	n/a	3.0	
	A2 waters	mg/l Zn	n/a	5.0	
	A3 waters	mg/l Zn	n/a	5.0	

Zinc : Recommended or Mandatory Limit Values

EU Directive or National [Ministerial] Regulations		*Units of Analysis*	*G Value*	*I/PV Value*	*Note(s)*
Dangerous Substances Directive [76/464/EEC]			List II substance		
Freshwater Fish Directive [78/659/EEC]	(S)	mg/l Zn	n/a	$\leq$ 0.3	[1]
	(C)	mg/l Zn	n/a	$\leq$ 1.0	[1]
Salmonid Waters Regulations [1988]		mg/l Zn	n/a	$\leq$ 0.03	[2,6]
		mg/l Zn	n/a	$\leq$ 0.2	[3,6]
		mg/l Zn	n/a	$\leq$ 0.3	[4,6]
		mg/l Zn	n/a	$\leq$ 0.5	[5,6]
Shellfish Directive [79/923/EEC]		mg/l Zn	[7]	[8]	
Ground Water Directive [80/68/EEC]			List II substance		
Drinking Water Directive [98/83/EC]		-	-	-	[9]

Notes

[1] Parameter is "Total zinc." The I values given are with reference to a hardness value of 100 mg/l $CaCO_3$. Relevant values for other hardness levels are as follows;

Hardness		10	50	100	500	mg/l $CaCO_3$
Zinc	(S) [salmonid]	0.03	0.2	0.3	0.5	mg/l Zn
	(C) [cyprinid]	0.3	0.7	1.0	2.0	mg/l Zn

[2] Standard applies to water of hardness 10 mg/l $CaCO_3$
[3] Standard applies to water of hardness 50 mg/l $CaCO_3$
[4] Standard applies to water of hardness 100 mg/l $CaCO_3$
[5] Standard applies to water of hardness 500 mg/l $CaCO_3$
[6] Standard to be conformed with by 95% of samples over a period of 12 months where sampling is carried out at least once per month; where sampling is less frequent the standard shall be conformed with by all samples.
[7] "The concentration of [this] substance in shellfish flesh must be so limited that it contributes, in accordance with Article 1 [of the Directive], to the high quality of shellfish products."
[8] "The concentration of [this] substance in the shellfish water or in the shellfish flesh must not exceed a level which gives rise to harmful effects on the shellfish and their larvae. The synergic effects of [this and other specified] metals must be taken into consideration."
[9] The MAC values specified in Directive [80/778/EEC] have not been carried forward to Directive [98/83/EC], and the latter makes no reference to zinc.

APPENDICES

Appendix 1

VARIATIONS IN WATER QUALITY IN SPACE AND TIME

Effects of Note	TYPE OF WATER								
	River	Lake	Raw	Drinking	Bathing	Fishing	Shellfish	Ground	
	x	x	x	x	x	x	x	x	
Variations in Space									
Geological formations	x	x	x	-	-	x	-	x	1
Bogs (worked or not)	x	x	x	-	x	x	-	-	2
Discharges from towns	x	x	x	-	x	x	x	x	3
Other point-source dischrgs	x	x	x	-	x	x	x	x	3
Diffuse discharges	x	x	x	-	x	x	x	x	4
Tributary streams	x	x	x	-	-	x	-	-	5
Tides	x	-	-	-	-	-	x	-	6
Distribution systems	-	-	-	x	-	-	-	-	7
Variations in Time									
Variations in discharges	x	x	x	-	x	x	-	x	8
Eutrophic'n/Photosynthesis	x	x	x	x	x	x	-	-	9
Flooding/Rainstorms	x	-	x	x	x	x	-	-	10
Changes in land use	x	x	x	-	x	x	-	x	11
Agriculture/Climate	x	x	x	-	x	x	-	x	12

NOTES

1. The principal effect is on the hardness of the water although in ore-bearing areas the metals content will be affected. This may lead to direct or indirect consequences for drinking water sources and fishery waters, the former being the toxicity of some metals and the latter the effects of hardness. If hardness is very high the water may need softening before use in large supplies. However, the toxic effect of metals is less pronounced in hard than in soft waters.

2. Peaty waters are characteristically of high colour which may render them unacceptable for drinking or bathing on aesthetic grounds. They may also be acid and therefore unsuitable for fish or for acceptance into a distribution system on the grounds of corrosion. In worked bog areas there is a likelihood of high suspended solids which will damage fishery waters both by direct interference with fish and by settling on the bed with consequent damage to spawning.

3. The effects of discharges from point sources (sewage works, industries, intensive agriculture etc) are physical, chemical and microbiological, depending on the precise nature of the pollutants being released. Accordingly, waters of all types may be affected. Details of the effects are discussed fully under the headings of the individual parameters in the main text.

4. Diffuse discharges can also affect all waters, though the consequences are chronic rather than acute and consist principally of eutrophication aspects (weed growths etc.).

5. Depending on the quality of a tributary stream the receiving water body may be improved or become more polluted below the confluence. The general characteristics of the receiving water may also be affected if there are significant differences between it and the tributary in such parameters as hardness, colour etc.

Appendix 1 : Variations in Water Quality in Space And Time : Continued

6. The overriding tidal effect is of salinity, an increase in which will rule out a water as a source of public or domestic supply. However, large variations in salinity in an estuary, for example, will affect shellfish development. A consequential tidal effect in some estuaries is that a segment or "plug" of water containing a pollution discharge may be subject to tidal movements and, instead of being dispersed promptly to sea, may move up and down the estuary for a considerable time.

7. These effects include the dissolution of metals from the distribution system, a well known case being the attack of some waters on lead piping in houses: the loss of disinfection protection by absorption of residual chlorine by organic matter in fouled mains; and the risk of bacterial recontamination in cracked or leaking mains.

8. Water quality may vary greatly because of changes in the composition of discharges over both short and extended periods. Sewage discharges, for example, vary significantly from night to day and also within the day. Some industrial discharges may be seasonal in nature and for many months of the year there may be no effect on water quality.

9. Eutrophication effects are seasonal and occur principally in the period of maximum sunlight, in summertime. There are also in-day changes as a consequence of eutrophication. In daytime, when it is light, algae will carry out photosynthesis, producing oxygen and possibly leading to supersaturation of dissolved oxygen. At night, respiration predominates, with oxygen being consumed and dissolved oxygen levels falling. The magnitude of this fall may have serious (even fatal) consequences for fish. In addition, the physical presence of heavy algal growths affects the value of various types of water.

10. Changes caused as a result of floods include a lowering of the dissolved salts (by straightforward dilution), an increase - often dramatic - in the colour of the water because of the stirring up of decaying vegetable matter, and often, arising from the same cause, a large rise in suspended solids and biochemical oxygen demand levels, which may consequently put the dissolved oxygen values at risk.

11. These long-term effects arise mainly from the intensification of animal-rearing, with the consequent concentration of previously weaker or well dispersed wastes, and the making of silage on a large scale. The resultant pollution will in many cases be point-source although in others (for example, the use of artificial fertilisers and, in many instances, where animal slurries are spread on land) the effects are diffuse.

12. There is a close interrelationship between agricultural land use and climate, especially with regard to such operations as the spreading of artificial fertilisers, the land-disposal of animal slurries, and the siting of silage pits and soakaways. The adoption of incorrect procedures will lead to excessive runoff of nutrients and organic matter in times of heavy rainfall.

Appendix 2

UNITS OF ANALYSIS

For very many parameters the results of analysis are expressed in terms of the weight of the determinand per unit volume of water. For example, the expression 0.07 mg/l Mn represents a concentration of 0.07 milligrams of manganese, expressed as Mn (i.e. as metal only, not in any of its compounds), per litre of water. There is a significant number of other parameters, however, which are or may be described in various terms, and it is essential that the usage of these be understood fully if serious errors of interpretation are to be avoided. For convenience, the parameters covered in the present volume are grouped below:

Individual Parameters expressed as themselves - Weight per unit Volume (w/v)

Acrylamide	µg/l compound	Benzo(a)pyrene	µg/l compound
Aluminium	mg/l Al [1]	Benzo(b)fluoranthene	µg/l compound
Antimony	mg/l Sb	Benzo(ghi)perylene	µg/l compound
Arsenic	mg/l As	Benzo(k)fluoranthene	µg/l compound
Barium	mg/l Ba	Beryllium	mg/l Be
Benzene	µg/l compound	Boron	mg/l B

1 Or as µg/l Al, ng/l Al etc, as appropriate

Appendix 2 : Units of Analysis : Continued

Individual Parameters expressed as themselves - Weight per unit Volume (w/v) : Continued

Bromate	mg/l BrO_3	Nickel	mg/l Ni
Cadmium	mg/lCd	Nitrogen, Kjeldahl	mg/l N
Calcium	mg/l Ca	Oxygen, Dissolved	mg/l O_2
Carbon Dioxide	mg/l CO_2	Pesticides (Individual)	µg/l individ compds
Chloride	mg/l Cl	Potassium	mg/l K
Chlorine	mg/l Cl_2	Selenium	mg/l Se
Chlorophyll	µg/l compound	Silver	mg/l Ag
Chromium	mg/l Cr	Sodium	mg/l Na
Cobalt	mg/l Co	Sulphate	mg/l SO_4
Copper	mg/l Cu	Sulphide	mg/l S
Cyanide	mg/l CN	Tellurium	mg/l Te
1,2-Dichloroethane	µg/l compound	Tetrachloroethylene	µg/l compound
Epichlorohydrin	µg/l compound	Thallium	mg/l Tl
Fluoride	mg/l F	Tin	mg/l Sn
lndeno(l,2,3-c,d)pyrene	µg/l compound	Titanium	mg/l Ti
Iron	mg/l Fe	Trichloroethylene	µg/l compound
Lead	mg/l Pb	Uranium	mg/l U
Magnesium	mg/l Mg	Vanadium	mg/l V
Manganese	mg/l Mn	Vinyl chloride	µg/l compound
Mercury	mg/l Hg	Zinc	mg/l Zn
Molybdenum	mg/l Mo		

Bulk Parameters expressed as a single unit - Weight per unit Volume (w/v)

Acidity	mg/l $CaCO_3$
Alkalinity	mg/l $CaCO_3$
Hardness	mg/l $CaCO_3$
Hydrocarbons, Dissolved and Emulsified	mg/l dry weight
Methylene Blue Active Substances (MBAS)	mg/l lauryl sulphate (see text)
Organic Carbon, Total	mg/l C
Organo-Halogenated Substances	mg/l halogen
Oxidisability	mg/l O_2
Oxygen Demand, Biochemical	mg/l O_2
Oxygen Demand, Chemical	mg/l O_2
Pesticides	mg/l reference compounds [2]
Phenols	mg/l C_6H_5OH [3]
Polychlorinated Biphenyls & Terphenyls (PCBs & PCTs)	mg/l reference material [4]
Polynuclear Aromatic Hydrocarbons (PAH)	mg/l reference compounds [2]
Silicon, Toxic or Persistent Organic Compounds	mg/l Si
Solids, Settleable	mg/l residue at given temperature
Solids, Suspended	mg/l residue at given temperature
Solids, Total	mg/l residue at given temperature
Solids, Total Dissolved	mg/l residue at given temperature
Substances affecting Taste	mg/l specific substances (see text)
Substances Extractable in Chloroform	mg/l dry residue
Substances which possess Carcinogenic, Mutagenic or Teratogenic Properties	mg/l specific substances .(see text)
Tarry Residues and Floating Matter	[descriptive assessment only]
Tin, Organo-Compounds	mg/l Sn
Trihalomethanes	µg/l total trihalomethanes [5]

[2] These, while apparently bulk parameters, are not strictly so, as each constituent in the mixture must be expressed in w/v terms on its own.

[3] It should also be noted that, in some cases, e.g. Phenols, the result for a group parameter is given in terms of a single compound, in this case Phenol itself, C_6H_5OH

[4] Because of the complexity of PCB/PCT mixtures it is impractical to report individual compound concentrations.

[5] The individual concentrations of the four THM compounds are reported as µg/l of the respective compounds.

Appendix 2 : Units of Analysis : Continued

Parameters expressed as units other than Weight per unit Volume

Clostridium perfringens (including spores)	number/20 ml
Coliforms, Faecal [*E. coli* (Type 1)]	number/100 ml
Coliforms, Total	number/100 ml
Colony counts [22 °C & 37 °C]	number/ml at respective temperatures
Colour	mg/l Pt/Co [Hazen units]
Conductivity	µS/cm at stated temperature
Cryptosporidium	number of cysts/100 litres
Enterococci	number/100 ml
Enteropathogenic Viruses	PFU (Plaque-forming units) /10 litres
Giardia	number of cysts/100 litres
Odour	dilution rate at stated temperature
Pathogenic Staphyllococci	number/100 ml
pH	pH units
Salinity	‰ (parts per thousand)
Salmonella	number/litre
Taste	dilution rate at stated temperature
Temperature	degrees C/ ºC [Celsius]
Transparency	metres (Secchi)
Turbidity	FTU (Formazin Turbidity Units) or NTU (Nephelometric Turbidity Units) or JTU (Jackson Turbidity Units) or mg/l Silica (SiO_2).[6, 7]

Individual Parameters commonly expressed in more than one unit (w/v)

Ammonia	mg/l N	mg/l NH_3	mg/l NH_4
Chlorine, Residual	mg/l Cl	mg/l HOCl	-
Nitrate	mg/l N	mg/l NO_3	-
Nitrite	mg/l N	mg/l NO_2	-
Nitrogen, Kjeldahl	mg/l N	mg/l NH_3	-
Phosphates	mg/l P	mg/l P_2O_5	mg/l PO_4
Phosphorus, Total	mg/l P	mg/l PO_4	-
Silica	mg/l Si	mg/l SiO_2.	-

The multiplicity of units generally arises from the chemical relationships between the different forms of a parameter and/or from the nature of the analytical methodology used in its determination. In the case of total phosphorus, for example, the most meaningful (and obvious) unit for the parameter is mg/l P. However, the actual determination process involves the conversion of all the phosphorus forms in the sample to orthophosphate (PO_4) in which form it is measured and in terms of which it may not unreasonably be expressed. A similar reasoning can be applied to ammonia, by which the unit mg/l N is most frequently adopted in order to give a commonality of reporting with other forms of nitrogen. The term mg/l NH_3 reflects the form in which the species is determined, while mg/l NH_4 arises from the chemical equilibrium between different ammonia species.

Example:

Nitrate (NO_3) may be reported as µg or mg/l NO_3 or as µg or mg/l N. As the units of expression are in direct relation to the atomic/molecular weights of the species in terms of which the results are quoted there is in this example a four-fold difference in numerical terms between, the two expressions:

Nitrate as NO_3	1	x	14	+	3	x	16	=	62		
			ATOMIC WT. OF NITROGEN				ATOMIC WT. OF OXYGEN		MOLECULAR WT. OF NITRATE		
Nitrate as N	1	x	14					=	14		
			ATOMIC WT. OF NITROGEN						ATOMIC WT. OF NITROGEN		
	NO_3		**:**	**N**	**=**	**62**	**:**	**14**	**=**	**4.43**	**:** **1**

[6] See suitable analytical text for further details of procedures, units etc.

[7] Note that not all the commonly used units for turbidity are equivalent.

Appendix 2 : Units of Analysis : Continued

General Observations

The following additional points should also be noted concerning the expression of analytical results. Firstly, the most common expression is as "milligrams/litre" (mg/l), i.e. an expression of weight per unit volume [w/v]. The term "parts per million" (ppm) implies a relationship of either volume with volume [v/v] or weight with weight [w/w]. However, as the density of water is almost exactly unity, 1 ml weighing 1 gram, the terms "parts per million" (v/v) and "milligrams/litre" (w/v) are in effect synonymous and are widely regarded as such. Preferred usage, however, is mg/l rather than ppm. One reason for the avoidance of the expression "parts per million" is that it can easily lead to the term "parts per billion" when dealing with micropollutants, for example. An ambiguity could possibly arise because of the 1000-fold difference between the American "billion" and the established (though currently changing) English meaning of the word.

Secondly, in the case of micropollutants which are present normally in water in infinitesimal amounts, common practice is to use such terms as microgram per litre (ng/l) or even nanograms per litre (ng/l). The relationship between them is:

1 milligram/litre	=	1,000	micrograms/litre
1 microgram/litre	=	1,000	nanograms/litre
1 milligram/litre	=	1,000,000	nanograms/litre.

Occasionally, hardness and alkalinity values, in particular, are quoted in terms of milliequivalents per litre (meq/l). The normal expression of these determinands is as concentrations of $CaCO_3$, the molecular weight of which is 100 and the equivalent weight 50. The conversion to meq/l is therefore:

$$X \text{ mg/l } CaCO_3 = X / 50 \text{ meq/l } CaCO_3.$$

Appendix 3

CONCENTRATIONS IN MILLIGRAMS/LITRE OF TOTAL AMMONIA IN FRESH WATER WHICH CONTAIN AN UN-IONISED AMMONIA CONCENTRATION OF 0.02 mg/l NH_3

pH / **Temp (° C)**	**6.0**	**6.5**	**7.0**	**7.5**	**8.0**	**8.9**	**9.0***	**9.5***
5	160.	51.	16.	5.1	1.6	0.53	0.18	0.071
10	110.	34.	11.	3.4	1.1	0.36	0.13	0.054
15	73.	23.	7.3	2.3	0.75	0.25	0.09	0.043
20	50.	16.	5.1	1.6	0.52	0.18	0.07	0.036
25	35.	11.	3.5	1.1	0.37	0.13	0.055	0.031
30	25.	7.9	2.5	0.8	0.27	0.10	0.045	0.028

* *Criteria may be unduly low if there is low free carbon dioxide in the water.*

[NOTE that the value of 0.02 mg/l NH_3 is a long-term toxic effect level for fish, both salmonid and cyprinid. Lethal levels are about ten times greater].

References

European Inland Fisheries Advisory Commission, 1970. *Water Quality Criteria for European Freshwater Fish*, Report on Ammonia and Inland Fisheries. EIFAC Technical Paper No 11.

Thurston, R.V., et al., 1974. *Aqueous Ammonia Equilibrium Calculations*. Fisheries Bioassay Laboratory Technical Report No. 74 - 1, Montana State University.

Appendix 4

SATURATION INDEX - LANGELIER INDEX - CALCIUM CARBONATE SATURATION INDEX

Background

A water with a pH value under 7 may dissolve metals to an extent which, if not causing deterioration of storage tanks or distribution mains, may nonetheless give rise to undesirable metal concentrations. Such waters are also unlikely to deposit calcium carbonate as a protective scale in pipes. The interrelationship between pH, hardness and alkalinity was studied by Langelier who in 1936 proposed a means of calculating the corrosivity or scale-forming tendencies of a water.

Significance

Langelier took account of calcium concentration, alkalinity, pH, temperature and total dissolved solids [TDS] concentration in postulating the *saturation pH* or *pHs*. This is the pH value at which the water would be just saturated with respect to calcium carbonate.

The Langelier Index is: **pH** - **pHs**
actual pH saturation pH [calculated].

A value of zero indicates a stable water. If the value of the Index is negative the water will tend to dissolve calcium carbonate and, by inference, be corrosive. A positive Index indicates scale-forming propensities.

Calculation Method

There is no direct analysis involved. Instead, the Index is calculated from the values observed for the relevant parameters, in conjunction with constants from the tables given below. It should be noted that the following is a modified equation (by Larson):

$$\mathbf{pHs = A + B - \log [Ca^{++}] - \log [alkalinity]}$$

where A and B are constants as functions of temperature and TDS, respectively, and [ ] indicates concentrations as mg/litre $CaCO_3$.

Interpretation of Index

It must be remembered that the Index gives an indication of how a water *may* behave with respect to corrosion of or deposition of scale on distribution mains. A water with a positive Index may not, in fact, deposit scale, perhaps because of the presence of polyphosphates which act as sequestering agents, or it may do so erratically and not give a protective shell.

Table 1

Temp. of Sample deg C	Constant A
0	2.60
4	2.50
8	2.40
12	2.30
16	2.20
20	2.10

Table 2

TDS of Sample mg/l	Constant B
0	9.70
100	9.77
200	9.83
400	9.86
800	9.89
1000	9.90

Table 3

$[Ca^{++}]$ or [alkalinity] mg/l $CaCO_3$	Log.	$[Ca^{++}]$ or [alkalinity] mg/l $CaCO_3$	Log.
10	1.00	200	2.30
20	1.30	300	2.48
30	1.48	400	2.60
40	1.60	500	2.70
50	1.70	600	2.78
60	1.78	700	2.84
70	1.84	800	2.90
80	1.90	900	2.95
100	2.00	1000	3.00

Appendix 5

A : SUPPLEMENTARY LIST OF EU DIRECTIVES CONCERNING THE AQUATIC ENVIRONMENT [1]

Formal Title [with date adopted & O.J.[2] reference]	Informal Title
Council Directive 82/176/EEC of 22 March 1982 on limit values and quality objectives for mercury discharges by the chlor-alkali electrolysis industry. [*O.J.*, L 81, 27 March 1982]	Mercury from Chlor-Alkali industry
Council Directive 83/513/EEC of 26 September 1983 on limit values and quality objectives for cadmium discharges. [*O.J.*, L 291, 24 October 1983]	Cadmium
Council Directive 84/156/EEC of 8 March 1984 on limit values and quality Objectives for mercury discharges by sectors other than the chlor-alkali electrolysis industry. [*O.J.*, L 74, 17 March 1984]	Mercury from other than Chlor-Alkali industry
Council Directive 84/491/EEC of 9 October 1984 on limit values and quality objectives for discharges of hexachlorocyclohexane. [*O.J.*, L 274, 17 October 1984]	Hexachlorocyclohexane
Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment. [*O.J.*, L 175, 05 July 1985]	Environmental Impact
Council Directive 86/278/EEC of 12 June 1986 on the protection of the Environment and in particular of the soil when sewage sludge is used in agriculture. [*O.J.*, L 181, 8 July 1986]	Sewage Sludge
Council Directive 86/280/EEC of 12 June 1986 on limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC. [*O.J.*, L 181, 8 July 1986]	List I Substances ["Standard Articles"]
Council Directive 88/347/EEC of 16 June 1988 amending Annex II to Directive 86/280/EEC. [*O.J.*, L 158, 25 June 1988]	[Chlorinated Compounds]
Council Directive 90/415/EEC of 27 July 1990 amending Annex II to Directive 86/280/EEC. [*O.J.*, L 219, 14 August 1990]	EDC/TRI/PER/TCB [3]
Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment, [*O.J.*, L135, 30 May 1991]	Urban Waste Water
Council Directive 91/414/EEC of 15 July 1991 concerning the placing of plant protection products on the market. [*O.J.*, L 206, 22 July 1992]	Plant Protection
Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. [*O.J.*, L375,31 December 1991]	Nitrates
Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild flora and fauna. {O.J., L 206, 22 July 1992]	Habitats
Council Directive 96/6 I/EC of 24 September 1996 concerning integrated poll-ution prevention and control. {O.J., L 257, 10 October 1996]	IPPC
Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances. [O.J., L 10, 14 January 1997]	Seveso

[1] *In addition to these Directives there is an important related EU document which is relevant in the context of the present volume although it will be supplanted by an Annex of the Water Framework Directive (with a similar purpose) :* Communication from the Commission to the Council on dangerous substances which might be included in List I of Council Directive 76/464/EEC. [*O.J.*, C 176. 14 July 1982]. (The so-called "List of 129 Substances").

[2] O. J. denotes the Official Journal of the European Communities in which Directives etc are published

[3] EDC: 1,2-Dichloroethane: TRI: Trichloroethylene: PER: Perchloroethylene; TCB: Trichlorobenzene.

B : SUPPLEMENTARY LIST OF NATIONAL REGULATIONS CONCERNING THE AQUATIC ENVIRONMENT [3]

Title [with Statutory Instrument (S.I.) reference]

Local Government (Water Pollution) (Control of Cadmium Discharges) Regulations, 1985. [S.I. No 294 of 1985.]

Local Government (Water Pollution) Act, 1977 (Control of Hexachlorocyclohexane and Mercury Discharges) Regulations, 1986. [S.I. No 55 of 1986.]

European Communities (Quality of Water Intended for Human Consumption) Regulations, 1988. [S.I. No 81 of 1988. [4]]

European Communities (Quality of Salmonid Waters) Regulations, 1988. [S.I. No 293 of 1988.]

European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989. [S.I. No 294 of 1989. 5]

Quality of Bathing Water Regulations, 1992. [S.I. No 155 of 1992.]

Local Government (Water Pollution) Regulations, 1992. [S.I. No 271 of 1992.]

Local Government (Water Pollution) Acts, 1977 and 1990 (Control of Aldrin, Dieldrin, Endrin, Isodrin, HCB, HCBD and $CHCl_3$ Discharges), Regulations, 1993. [S.I. No 348 of 1993.S]

Quality of Shellfish Waters Regulations, 1994. [S.I. No 200 of 1994.]

Local Government (Water Pollution) Acts, 1977 and 1990 (Control of Carbon tetrachloride, DDT and Pentachlorophenol Discharges), Regulations, 1994. [S.I. No 43 of 1994.]

Local Government (Water Pollution) Acts, 1977 and 1990 (Control of EDO, TRI, PER and TCB Discharges), Regulations, 1994. [S.I. No 245 of 1994.[5]]

Environmental Protection Agency Act, 1992, [Urban Waste Water Treatment] Regulations, 1994. [S.I. No 419 of 1994.]

Quality of Bathing Water Regulations, 1996. [S.I. No 230 of 1996.]

Local Government (Water Pollution) (Nutrient Management Planning Consultation) Regulations, 1998. [S.I. No 257 of 1998.]

Local Government (Water Pollution) Act, 1977 (Water Quality Standards for Phosphorus) Regulations, 1998. [S.I. No 258 of 1998.]

Protection of Groundwater Regulations, 1999. [S.I. No 41 of 1999.]

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[3] For the sake of completeness details of the Regulations (where adopted) corresponding to the Directives listed in Part A are presented below.

[4] These Regulations are the topic of a publication "A Handbook on Implementation for Sanitary Authorities." There are separate handbooks for the Drinking Water and Surface Water Regulations. The latter is out of print but a new edition of the Drinking Water Handbook has been published by the EPA.

[5] $CHCl_3$ Chloroform; HCB; Hexachlorobenzene; HCBD; Hexachlorobutadiene.

[6] See footnote 3 on page 127.

Appendix 6

DANGEROUS SUBSTANCES DIRECTIVE 76/464/EEC
LIST I & LIST II SUBSTANCES

LIST I OF FAMILIES AND GROUPS OF SUBSTANCES

List I contains certain individual substances which belong to the following families and groups of substances, selected mainly on the basis of their toxicity, persistence and bioaccumulation with the exception of those which are biologically harmless or which are rapidly converted into substances which are biologically harmless.

1. Organohalogen compounds and substances which may form such compounds in the aquatic environment
2. Organophosphorus compounds
3. Organotin compounds
4. Substances in respect of which it has been proved that they possess carcinogenic properties in or via the aquatic environment [1]
5. Mercury and its compounds
6. Cadmium and its compounds
7. Persistent mineral oils and hydrocarbons of petroleum origin

And for the purpose of implementing Articles 2, 8, 9 and 14 of this Directive:

8. Persistent synthetic substances which may float, remain in suspension or sink and which may interfere with any use of the waters.

LIST II OF FAMILIES AND GROUPS OF SUBSTANCES

List II contains:

- Substances belonging to the families and groups of substances in List I for which the limit values referred to in Article 6 of the Directive have not been determined
- Certain individual substances and categories of substances belonging to the families and groups of substances listed below

and which have a deleterious effect on the aquatic environment, which can, however, be confined to a given area and which depend on the characteristics and location of the water into which they are discharged.

Families and groups of substances referred to in the second indent:

1. The following metalloids and their compounds:

1 Zinc	6 Selenium	11 Tin	16 Vanadium
2 Copper	7 Arsenic	12 Barium	17 Cobalt
3 Nickel	8 Antimony	13 Beryllium	18 Thallium
4 Chromium	9 Molybdenum	14 Boron	19 .Tellurium
5 Lead	10 Titanium	15 Uranium	20 Silver.

2. Biocides and their derivatives not appearing in List I
3. Substances which have a deleterious effect on the taste and/or smell of the products for human consumption derived from the aquatic environment, and compounds liable to give rise to such substances in water
4. Toxic or persistent organic compounds of silicon and substances which may give rise to such compounds in water, excluding those which are biologically harmless or are rapidly converted in water into harmless substances
5. Inorganic compounds of phosphorus and elemental phosphorus
6. Non-persistent mineral oils and hydrocarbons of petroleum origin
7. Cyanides, fluorides
8. Substances which have an adverse effect on the oxygen balance, particularly: ammonia, nitrites.

[1] Where certain substances in List II are carcinogenic they are included in category 4 of this list.

Appendix 7

GROUNDWATER DIRECTIVE 80/68/EEC
LIST I & LIST II SUBSTANCES

LIST I OF FAMILIES AND GROUPS OF SUBSTANCES

List I contains the individual substances which belong to the families and groups of substances enumerated below, with the exception of those which are considered inappropriate to List I on the basis of a low
risk of toxicity, persistence and bioaccumulation.

Such substances which with regard to toxicity, persistence and bioaccumulation are appropriate to List II are to be classed in List II.

1. Organohalogen compounds and substances which may form such compounds in the aquatic environment
2. Organophosphorus compounds
3. Organotin compounds
4. Substances which possess carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment [1]
5. Mercury and its compounds
6. Cadmium and its compounds
7. Mineral oils and hydrocarbons
8. Cyanides.

LIST II OF FAMILIES AND GROUPS OF SUBSTANCES

List II contains the individual substances and the categories of substances belonging to the families and groups of substances listed below which could have a harmful effect on groundwater.

1. The following metalloids and metals and their compounds:

1 Zinc	6 Selenium	11 Tin	16 Vanadium
2 Copper	7 Arsenic	12 Barium	17 Cobalt
3 Nickel	8 Antimony	13 Beryllium	18 Thallium
4 Chrome	9 Molybdenum	14 Boron	19 Tellurium
5 Lead	10 Titanium	15 Uranium	20 Silver.

2. Biocides and their derivatives not appearing in List I
3. Substances which have a deleterious effect on the taste and/or odour of groundwater and compounds liable to cause the formation of such substances in such water and to render it unfit for human consumption
4. Toxic or persistent organic compounds of silicon, and substances which may cause the formation of such compounds in water, excluding those which are biologically harmless or are rapidly converted in water into harmless substances
5. Inorganic compounds of phosphorus and elemental phosphorus
6. Fluorides
7. Ammonia and nitrites.

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[1] Where certain substances in List II are carcinogenic, mutagenic or teratogenic, they are included in category 4 of this list.

Appendix 8

WORLD HEALTH ORGANISATION GUIDELINES [1993] FOR THE Bacteriological Quality of Drinking-water [a]

Organisms	Guideline value
All water intended for drinking	
E. coli or thermotolerant coliform bacteria [b]	Must not be detectable in any 100-ml sample
Treated water entering the distribution system	
E. coli or thermotolerant coliform bacteria [b]	Must not be detectable in any 100-ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample
Treated water in the distribution system	
E. coli or thermotolerant coliform bacteria [b]	Must not be detectable in any 100-ml sample
Total coliform bacteria	Must not be detectable in any 100-ml sample. In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period

a - Immediate investigative action must be taken if either *E. coli* or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling; if these bacteria are detected in the repeat sample, the cause must be determined by immediate further investigation.

b - Although *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests must be carried out. Total coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies, particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies.

Source: *Guidelines for drinking-water quality*, Second Edition, World Health Organisation, Geneva. 1993.

Appendix 9

WORLD HEALTH ORGANISATION RECOMMENDED TREATMENTS FOR DIFFERENT WATER SOURCES TO PRODUCE WATER WITH NEGLIGIBLE VIRUS RISK [a]

Type of Source	Recommended Treatment
GROUND WATER	
Protected, deep wells: essentially free of faecal contamination	Disinfection [b]
Unprotected, shallow wells; faecally contaminated	Filtration and disinfection
SURFACE WATER	
Protected, impounded upland water; essentially free of faecal contamination	Disinfection
Unprotected impounded water or upland river; faecal contamination	Filtration and disinfection
Unprotected lowland rivers; faecal contamination	Pre-disinfection or storage, filtration, disinfection
Unprotected watershed; heavy faecal contamination	Pre-disinfection or storage, filtration, additional treatment and disinfection
Unprotected watershed; gross faecal contamination	Not recommended for drinking-water supply

a - For all sources, the median value of turbidity before terminal disinfection must not exceed 1 nephelometric turbidity unit (NTU) and must not exceed 5 NTU in single samples.
Terminal disinfection must produce a residual concentration of free chlorine of $\geq$ 0.5 mg/litre after at least 30 minutes of contact in water at pH < 8.0, or must be shown to be an equivalent disinfection process in terms of the degree of enterovirus inactivation (> 99.99%).
Filtration must be either slow sand filtration or rapid filtration (sand, dual, or mixed media) pre ceded by adequate coagulation-flocculation (with sedimentation or flotation). Diatomaceous earth filtration or a filtration process demonstrated to be equivalent for virus reduction can also be used. The degree of virus reduction must be > 90%.
Additional treatment may consist of slow sand filtration, ozonation with granular activated carbon adsorption, or any other process demonstrated to achieve > 99°/o enterovirus reduction.

b - Disinfection should be used if monitoring has shown the presence of *E. coli* or thermotolerant coliform bacteria.

Source: *Guidelines for drinking-water quality*, Second Edition, World Health Organisation, Geneva. 1993.