Guidelines for Drinking-Water Quality - Second Edition - Volume 1 - Recommendations

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Preface

In 1984 and 1985, the World Health Organization (WHO) published the first edition of *Guidelines for drinking-water quality* in three volumes. The development of these guidelines was organized and carried out jointly by WHO headquarters and the WHO Regional Office for Europe (EURO).

In 1988, the decision was made within WHO to initiate the revision of the guidelines. The work was again shared between WHO headquarters and EURO. Within headquarters, both the unit for the Prevention of Environmental Pollution (PEP) and the ILO/UNEP/WHO International Programme on Chemical Safety (IPCS) were involved, IPCS providing a major input to the health risk assessments of chemicals in drinking-water.

The revised guidelines are being published in three volumes. Guideline values for various constituents of drinking-water are given in Volume 1, *Recommendations* together with essential information required to understand the basis for the values. Volume 2, *Health criteria and other supporting information*, contains the criteria monographs prepared for each substance or contaminant; the guideline values are based on these. Volume 3, *Surveillance and control of community supplies*, is intended to serve a very different purpose; it contains recommendations and information concerning what needs to be done in small communities, particularly in developing countries, to safeguard their water supplies.

The preparation of the current edition of the *Guidelines for drinking-water quality* covered a period of four years and involved the participation of numerous institutions, over 200 experts from nearly 40 different developing and developed countries and 18 meetings of the various coordination and review groups. The work of these institutions and scientists, whose names appear in Annex 1, was central to the completion of the guidelines and is much appreciated.

For each contaminant or substance considered, a lead country prepared a draft document evaluating the risks for human health from exposure to the contaminant in drinking-water. The following countries prepared such evaluation documents: Canada, Denmark, Finland, Germany, Italy, Japan, Netherlands, Norway, Poland, Sweden, United Kingdom of Great Britain and Northern Ireland and United States of America.

Under the responsibility of a coordinator for each major aspect of the guidelines, these draft evaluation documents were reviewed by several scientific institutions and selected experts, and comments were incorporated by the coordinator and author prior to submission for final evaluation by a review group. The review group then took a decision as to the health risk assessment and proposed a guideline value.

During the preparation of draft evaluation documents and at the review group meetings, careful consideration was always given to previous risk assessments carried out by IPCS, in its Environmental Health Criteria monographs, the International Agency for Research on Cancer, the joint FAO/WHO Meetings on Pesticide Residues, and the joint FAO/WHO Expert Committee on Food Additives, which evaluates contaminants such as lead and cadmium in addition to food additives.

It is clear that not all the chemicals that may be found in drinking-water were evaluated in developing these guidelines. Chemicals of importance to Member States which have not been evaluated should be brought to the attention of WHO for inclusion in any future revision.

It is planned to establish a continuing process of revision of the *Guidelines for drinking-water quality* with a number of substances of agents subject to evaluation each year. Where appropriate, addenda will be issued, containing evaluations of new substances or substances already evaluated for which new scientific information has become available. Substances for

which provisional guideline values have been established will receive high priority for re-evaluation.

Acknowledgements

The work of the following coordinators was crucial in the development of Volumes 1 and 2 of the *Guidelines:*

J. K. Fawell, Water Research Centre, England (inorganic constituents)

J. R. Hickman, Department of National Health and Welfare, Canada (radioactive materials)

U. Lurid, Water Quality Institute, Denmark (organic constituents and pesticides)

B. Mintz, Environmental Protection Agency, United States of America (disinfectants and disinfectant by-products)

E. B. Pike, Water Research Centre, England (microbiology)

The coordinator for Volume 3 of the *Guidelines* was J. Bartram of the Robens Institute of Health and Safety, England.

The WHO coordinators were as follows:

Headquarters H. Galal-Gorchev, International Programme on Chemical Safety; R. Helmer, Division of Environmental Health.

Regional Office for Europe: X. Bonnefoy, Environment and Health; O. Espinoza, Environment and Health.

Ms Marla Sheffer of Ottawa, Canada, was responsible for the scientific editing of the guidelines.

The convening of the coordination and review group meetings was made possible by the financial support afforded to WHO by the Danish International Development Agency (DANIDA) and the following sponsoring countries: Belgium, Canada, France, Italy, Netherlands, United Kingdom of Great Britain and Northern Ireland and United States of America.

In addition, financial contributions for the convening of the final task group meeting were received from the Norwegian Agency for Development Cooperation (NORAD), the United Kingdom Overseas Development Administration (ODA) and the Water Services Association in the United Kingdom, the Swedish International Development Authority (SIDA), and the Government of Japan.

The efforts of all who helped in the preparation and finalization of the *Guidelines for drinking-water quality* are gratefully acknowledged.

Acronyms and abbreviations used in the text

ADI	acceptable daily intake
FAO	Food and Agriculture Organization of the United Nations
IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
ILO	International Labour Organisation
IPCS	International Programme on Chemical Safety
IQ	intelligence quotient
ISO	International Organization for Standardization
JECFA	Joint FAO/WHO Expert Committee on Food Additives
JMPR	Joint FAO/WHO Meeting on Pesticide Residues
LOAEL	lowest-observed-adverse-effect level
NOAEL	no-observed-adverse-effect level
NTU	nephelometric turbidity unit
PMTDI	provisional maximum tolerable daily intake
PTWI	provisional tolerable weekly intake
TCU	true colour unit
TDI	tolerable daily intake
UNEP	United Nations Environment Programme
WHO	World Health Organization.

1. Introduction

This volume of the *Guidelines for drinking-water quality* explains how guideline values for drinking-water contaminants are to be used, defines the criteria used to select the various chemical, physical, microbiological, and radiological contaminants included in the report, describes the approaches used in deriving guideline values, and presents brief summary statements either supporting the guideline values recommended or explaining why no health-based guideline value is required at the present time.

This edition of the guidelines considers many drinking-water contaminants not included in the first edition. It also contains revised guideline values for many of the contaminants included in the first edition, which have been changed as a result of new scientific information. The guideline values given here supersede those in the 1984 edition.

Although the number of chemical contaminants for which guideline values are recommended is greater than in the first edition, it is unlikely that all of these chemical contaminants will occur in all water supplies or even in all countries. Care should therefore be taken in selecting substances for which national standards will be developed. A number of factors should be considered, including the geology of the region and the types of human activities that take place there. For example, if a particular pesticide is not used in the region, it is unlikely to occur in the drinking-water.

In other cases, such as the disinfection by-products, it may not be necessary to set standards for all of the substances for which guideline values have been proposed. If chlorination is practised, the trihalomethanes, of which chloroform is the major component, are likely to be the main disinfection by-products, together with the chlorinated acetic acids in some instances. In many cases, control of chloroform levels and, where appropriate, trichloroacetic acid will also provide an adequate measure of control over other chlorination by-products.

In developing national standards, care should also be taken to ensure that scarce resources are not unnecessarily diverted to the development of standards and the monitoring of substances of relatively minor importance.

Several of the inorganic elements for which guideline values have been recommended are recognized to be essential elements in human nutrition. No attempt has been made here to define a minimum desirable concentration of such substances in drinking-water.

1.1 General considerations

The primary aim of the *Guidelines for drinking-water quality* is the protection of public health. The guidelines are intended to be used as a basis for the development of national standards that, if properly implemented, will ensure the safety of drinking-water supplies through the elimination, or reduction to a minimum concentration, of constituents of water that are known to be hazardous to health. It must be emphasized that the guideline values recommended are not mandatory limits. In order to define such limits, it is necessary to consider the guideline values in the context of local or national environmental, social, economic, and cultural conditions.

The main reason for not promoting the adoption of international standards for drinking-water quality is the advantage provided by the use of a risk-benefit approach (qualitative or quantitative) to the establishment of national standards and regulations. This approach should lead to standards and regulations that can be readily implemented and enforced. For example, the adoption of drinking-water standards that are too stringent could limit the availability of water supplies that meet those standards - a significant consideration in regions of water shortage. The standards that individual countries will develop can thus be influenced by national priorities and economic factors. However, considerations of policy and convenience must never be allowed to endanger public health, and the implementation of standards and regulations will require suitable

facilities and expertise as well as the appropriate legislative framework.

The judgement of safety - or what is an acceptable level of risk in particular circumstances - is a matter in which society as a whole has a role to play. The final judgement as to whether the benefit resulting from the adoption of any of the guideline values given here as standards justifies the cost is for each country to decide. What must be emphasized is that the guideline values have a degree of flexibility and enable a judgement to be made regarding the provision of drinking-water of acceptable quality.

Water is essential to sustain life, and a satisfactory supply must be made available to consumers. Every effort should be made to achieve a drinking-water quality as high as practicable. Protection of water supplies from contamination is the first line of defence. Source protection is almost invariably the best method of ensuring safe drinking-water and is to be preferred to treating a contaminated water supply to render it suitable for consumption. Once a potentially hazardous situation has been recognized, however, the risk to health, the availability of alternative sources, and the availability of suitable remedial measures must be considered so that a decision can be made about the acceptability of the supply.

As far as possible, water sources must be protected from contamination by human and animal waste, which can contain a variety of bacterial, viral, and protozoan pathogens and helminth parasites. Failure to provide adequate protection and effective treatment will expose the community to the risk of outbreaks of intestinal and other infectious diseases. Those at greatest risk of waterborne disease are infants and young children, people who are debilitated or living under unsanitary conditions, the sick, and the elderly. For these people, infective doses are significantly lower than for the general adult population.

The potential consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised.

The assessment of the risks associated with variations in microbial quality is difficult and controversial because of insufficient epidemiological evidence, the number of factors involved, and the changing interrelationships between these factors. In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with human and animal excreta. Microbial risk can never be entirely eliminated, because the diseases that are waterborne may also be transmitted by person-to-person contact, aerosols, and food intake; thus, a reservoir of cases and carriers is maintained. Provision of a safe water supply in these circumstances will reduce the chances of spread by these other routes. Waterborne outbreaks are particularly to be avoided because of their capacity to result in the simultaneous infection of a high proportion of the community.

The health risk due to toxic chemicals in drinking-water differs from that caused by microbiological contaminants. There are few chemical constituents of water that can lead to acute health problems except through massive accidental contamination of a supply. Moreover, experience shows that, in such incidents, the water usually becomes undrinkable owing to unacceptable taste, odour, and appearance.

The fact that chemical contaminants are not normally associated with acute effects places them in a lower priority category than microbial contaminants, the effects of which are usually acute and widespread. Indeed, it can be argued that chemical standards for drinking-water are of secondary consideration in a supply subject to severe bacterial contamination.

The problems associated with chemical constituents of drinking-water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure; of particular concern are contaminants that have cumulative toxic properties, such as heavy metals, and substances that are carcinogenic.

It should be noted that the use of chemical disinfectants in water treatment usually results in the formation of chemical by-products, some of which are potentially hazardous. However, the risks to health from these by-products are extremely small in comparison with the risks associated with inadequate disinfection, and it is important that disinfection should not be compromised in attempting to control such by-products.

The radiological health risk associated with the presence of naturally occurring radionuclides in drinking-water should also be taken into consideration, although the contribution of drinking-water to total ambient exposure to these radionuclides is very small under normal circumstances. The guideline values recommended in this volume do not apply to water supplies contaminated during emergencies arising from accidental releases of radioactive substances to the environment.

In assessing the quality of drinking-water, the consumer relies principally upon his or her senses. Water constituents may affect the appearance, odour, or taste of the water, and the consumer will evaluate the quality and acceptability of the water on the basis of these criteria. Water that is highly turbid, is highly coloured, or has an objectionable taste or odour may be regarded by consumers as unsafe and may be rejected for drinking purposes. It is therefore vital to maintain a quality of water that is acceptable to the consumer, although the absence of any adverse sensory effects does not guarantee the safety of the water.

Countries developing national drinking-water limits or standards should carefully evaluate the costs and benefits associated with the control of aesthetic and organoleptic quality. Enforceable standards are sometimes set for contaminants directly related to health, whereas recommendations only are made for aesthetic and organoleptic characteristics. For countries with severely limited resources, it is even more important to establish priorities, and this should be done by considering the impact on health in each case. This approach does not underestimate the importance of the aesthetic quality of drinking-water. Source water that is aesthetically unsatisfactory may discourage the consumer from using an otherwise safe supply. Furthermore, taste, odour, and colour may be the first indication of potential health hazards.

Many parameters must be taken into consideration in the assessment of water quality, such as source protection, treatment efficiency and reliability, and protection of the distribution network (e.g., corrosion control). The costs associated with water quality surveillance and control must also be carefully evaluated before developing national standards. For guidance on these issues, the reader should refer to other more comprehensive publications (see Bibliography).

1.2 The nature of the guideline values

Guideline values have been set for potentially hazardous water constituents and provide a basis for assessing drinking-water quality.

(a) A guideline value represents the concentration of a constituent that does not result in any significant risk to the health of the consumer over a lifetime of consumption.

(b) The quality of water defined by the *Guidelines for drinking-water quality* is such that it is suitable for human consumption and for all usual domestic purposes, including personal hygiene. However, water of a higher quality may be required for some special purposes, such as renal dialysis.

(c) When a guideline value is exceeded, this should be a signal: (i) to investigate the cause with a view to taking remedial action; (ii) to consult with, and seek advice from, the authority responsible for public health.

(d) Although the guideline values describe a quality of water that is acceptable for lifelong consumption, the establishment of these guideline values should not be regarded as implying that

the quality of drinking-water may be degraded to the recommended level. Indeed, a continuous effort should be made to maintain drinking-water quality at the highest possible level.

(e) Short-term deviations above the guideline values do not necessarily mean that the water is unsuitable for consumption. The amount by which, and the period for which, any guideline value can be exceeded without affecting public health depends upon the specific substance involved. It is recommended that when a guideline value is exceeded, the surveillance agency (usually the authority responsible for public health) should be consulted for advice on suitable action, taking into account the intake of the substance from sources other than drinking-water (for chemical constituents), the toxicity of the substance, the likelihood and nature of any adverse effects, the practicability of remedial measures, and similar factors.

(f) In developing national drinking-water standards based on these guideline values, it will be necessary to take account of a variety of geographical, socioeconomic, dietary, and other conditions affecting potential exposure. This may lead to national standards that differ appreciably from the guideline values.

(g) In the case of radioactive substances, screening values for gross alpha and gross beta activity are given, based on a reference level of dose.

It is important that recommended guideline values are both practical and feasible to implement as well as protective of public health. Guideline values are not set at concentrations lower than the detection limits achievable under routine laboratory operating conditions. Moreover, guideline values are recommended only when control techniques are available to remove or reduce the concentration of the contaminant to the desired level.

In some instances, *provisional* guideline values have been set for constituents for which there is some evidence of a potential hazard but where the available information on health effects is limited. Provisional guideline values have also been set for substances for which the calculated guideline value would be (i) below the practical quantification level, or (ii) below the level that can be achieved through practical treatment methods. Finally, provisional guideline values have been set for certain substances when it is likely that guideline values will be exceeded as a result of disinfection procedures.

Aesthetic and organoleptic characteristics are subject to individual preference as well as social, economic, and cultural considerations. For this reason, although guidance can be given on the levels of substances that may be aesthetically unacceptable, no guideline values have been set for such substances where they do not represent a potential hazard to health.

The recommended guideline values are set at a level to protect human health; they may not be suitable for the protection of aquatic life. The guidelines apply to bottled water and ice intended for human consumption but do not apply to natural mineral waters, which should be regarded as beverages rather than drinking-water in the usual sense of the word. The Codex Alimentarius Commission has developed Codex standards for such mineral waters.

1.3 Criteria for the selection of health-related drinking-water contaminants

The recognition that faecally polluted water can lead to the spread of microbial infections has led to the development of sensitive methods for routine examination to ensure that water intended for human consumption is free from faecal contamination. Although it is now possible to detect the presence of many pathogens in water, the methods of isolation and enumeration are often complex and time-consuming. It is therefore impracticable to monitor drinking-water for every possible microbial pathogen. A more logical approach is the detection of organisms normally present in the faeces of humans and other warm-blooded animals as indicators of faecal pollution, as well as of the efficacy of water treatment and disinfection. The various bacterial

indicators used for this purpose are described in section 2.2. The presence of such organisms indicates the presence of faecal material and, hence, that intestinal pathogens could be present. Conversely, their absence indicates that pathogens are probably also absent.

Thousands of organic and inorganic chemicals have been identified in drinking-water supplies around the world, many in extremely low concentrations. The chemicals selected for the development of guideline values include those considered potentially hazardous to human health, those detected relatively frequently in drinking-water, and those detected in relatively high concentrations.

Some potentially hazardous chemicals in drinking-water are derived directly from treatment chemicals or construction materials used in water supply systems.

Such chemicals are best controlled by appropriate specifications for the chemicals and materials used. For example, a wide range of polyelectrolytes are now used as coagulant aids in water treatment, and the presence of residues of the unreacted monomer may cause concern. Many polyelectrolytes are based on acrylamide polymers and co-polymers, in both of which the acrylamide monomer is present as a trace impurity. Chlorine used for disinfection has sometimes been found to contain carbon tetrachloride. This type of drinking-water contamination is best controlled by the application of regulations governing the quality of the products themselves rather than the quality of the water. Similarly, strict national regulations on the quality of pipe material should avoid the possible contamination of drinking-water by trace constituents of plastic pipes. The control of contamination of water supplies by *in situ* polymerized coatings and coatings applied in a solvent requires the development of suitable codes of practice, in addition to controls on the quality of the materials used.