WHO Guidelines for Drinking-water Quality (2003)

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Preface

Access to safe drinking-water is essential to health, is a basic human right and an essential component of effective policy for health protection.

The importance of water, sanitation and hygiene for development and health has been reflected in their inclusion in a series of international policy forums. These have included health-orientated conferences such as the Alma Ata Conference 19XX on primary health care. They have also included water-orientated conferences such as the Mar del Plata Declaration in 1979 which launched the water supply and sanitation decade 1981-1990; the Millenium Declaration goals and the outcome of the Johannesburg World Summit for Sustainable Development in 2002.

At a national level access to safe drinking water is important as a health and development issue. In some regions it has been shown that investments in water supply and sanitation for health can yield a net economic benefit, since the reductions in adverse effects and health care costs outweigh the costs of undertaking the intervention. This is true for some water quality investments such as water treatment in the home. Experience has also shown that interventions in improving access to safe water favour especially the poor, whether in rural or urban areas, and can be an effective part of poverty alleviation strategies.

Drinking-water quality continues to be a concern for health in countries at all levels of development and targets for access to safe water have been incorporated in a number of international declarations and policy statements including the Millennium Declaration goals and targets and the outcome of the World Summit on Sustainable Development, Johannesburg, 2002.

Since finalisation of the second edition of WHO's Guidelines for Drinking-water Quality in 1992 there have been a number of events which have highlighted the importance of drinking-water quality and health and which have furthered understanding of aspects of drinking-water quality and health. These are reflected in this third edition of the Guidelines.

In 1984-5 and in 1993-7, WHO published the first and second editions *of Guidelines for Drinking-water Quality* in three volumes. In 1995? the decision was made to pursue the further development of the Guidelines through a process of rolling revision. This lead to the publication of addenda on chemical and microbial aspects to the second edition of the Guidelines in 1998, 1999 and 2002; of a text on "Toxic Cyanobacteria in Water"; and to the preparation of expert reviews on key issues preparatory to the development of a third edition of the Guidelines.

In 2000 a detailed plan of work was agreed for development of the third edition of the Guidelines. As with previous editions, this work was shared between WHO Headquarters and the WHO Regional Office for Europe (EURO). Within Headquarters the Programme on Water Sanitation and Health and within EURO the European Centre for Environment and Health, Rome, lead the process of their development. Within WHO Headquarters the Programme on Chemical Safety provided inputs on some chemical hazards and the Programme on Radiological Safety contributed to the section dealing with radiological aspects. All six WHO Regional Offices participated in the process.

This revised Volume 1 of the Guidelines is accompanied by:

- A series of publications providing background to the assessment and management of risks associated with microbial hazards and by reference to internationally peer reviewed risk assessments for specific chemicals. These replace the corresponding parts of the previous "Volume 2".
- Volume 3 provides guidance on good practice in surveillance, monitoring and assessment of drinking water quality.
- The guidelines are also accompanied by other publications explaining the scientific basis of their development and providing guidance on good practice in implementation.

The preparation of the current edition of the Guidelines for Drinking-water Quality covered a period of six years and involved the participation of numerous institutions and over …X. experts from …Y… developing and developed countries. The work of those individuals listed in Annex 1 was central to the completion of the Guidelines and is much appreciated.

This volume of the Guidelines for Drinking-water Quality explains requirements to ensure drinking-water safety, including minimum procedures and specific Guideline Values; and how those requirements are intended to be used. This volume also describes the approaches used in deriving the guidelines, including Guideline Values. It includes summary statements on significant microbial and chemical hazards. The development of this Third edition of the Guidelines for Drinking-water Quality includes a substantive revision of approaches to ensuring microbial safety. This takes account of important developments in microbial risk assessment and its linkages to risk management. The development of this orientation and content was lead over an extended period by Dr Arie Havelaar (RIVM, Netherlands) and Dr Jamie Bartram (WHO).

These Guidelines supersede those in previous editions (1983-4; 1992-7 and addenda); and previous International Standards (1958, 1963 and 1971). This edition of the Guidelines further develops concepts, approaches and information in previous editions:

- Experience has shown that microbial hazards continue to be the primary concern in both developing and developed countries and the value of a systematic approach towards securing microbial safety. This edition includes significantly expanded coverage of this, builds on principles such as the multiple barrier principle and importance of source protection considered in previous editions. The Guidelines are accompanied by comprehensive documentation describing the approaches towards fulfilling requirements for microbial safety; and providing guidance to good practice in ensuring that safety is achieved.
- Revised information on many chemicals. This includes information on chemicals not considered previously; revisions to take account of new scientific information; and in some cases lesser coverage where new information suggests a lesser priority.
- Experience has also shown the necessity of recognising the important roles of many different stakeholders in ensuring drinking water safety. This edition includes discussion of the roles and responsibilities of key stakeholders in ensuring drinking-water safety.
- The need for different tools and approaches in supporting safe management of large utility versus community supplies remains relevant and this edition describes the principal characteristics of the different approaches.
- There has been recognition that few chemicals cause large-scale health effects through drinking-water exposure. These include fluoride and arsenic. Other chemicals may also be significant in certain conditions. Interest in chemical hazards in drinking-water was

highlighted by recognition of the scale of arsenic exposure through drinking-water in Bangladesh and elsewhere. The revised Guidelines and associated publications provide guidance on identifying local priorities and on management of the chemicals associated with more large-scale effects.

- WHO is frequently approached for guidance on the application of the *Guidelines for Drinking-water Quality* to applications other than community supplies on managed utilities. This revised edition includes information on application of the Guidelines to several specific circumstances and is accompanied by texts dealing with some of these in greater detail.

The *Guidelines for Drinking-water Quality* are kept up to date through a process of rolling revision which leads to periodic release of documents which may add to or supersede information in this volume.

The Guidelines are addressed primarily to water and health regulators, policy makers, and their advisors; mainly to assist them in the development of national standards. The Guidelines and their associated documents are also used by many others as a source of information on water quality and health and on effective management approaches.

Acknowledgements

The work of the following Working Groups was crucial in the development of the third edition of the *Guidelines for Drinking-water Quality:*

Microbial Aspects Working Group

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

Many individuals and representatives from various countries have provided expert input into the development of these *Guidelines* and supporting documentation. The efforts of all who helped in the preparation and finalization of the *Guidelines for Drinking-water Quality* are gratefully acknowledged. A list of all participants is listed in Annex 1.

Acronyms and Abbreviations used in text

ADI	Acceptable daily intake
AFRO	WHO Regional Office for Africa
AMRO	WHO Regional Office for the Americas
CICAD	Concise International Chemical Assessment Document
DALY	Disability Adjusted Life Year
DWQC	WHO Drinking-water Quality Committee
EHC	(IPCS) Environmental Health Criteria document
EMRO	WHO Regional Office for Eastern Mediterranean
EURO	WHO Regional Office for Europe
FAO	Food and Agriculture Organization of the United Nations
GDWQ	(WHO) Guidelines for Drinking-water Quality
GV	(WHO Drinking-water Quality) Guideline Value
HACCP	Hazard Assessment Critical Control Point
HAV	Hepatitis A Virus
HCB	Hexachlorobenzene
HEV	Hepatitis E Virus
IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
ILO	International Labour Office
IPCS	International Programme on Chemical Safety
IQ	Intelligence Quotient
ISO	International Organisation for Standardisation
JECFA	(FAO/WHO) Joint Expert Committee on Food Additives
JMPR	(FAO/WHO) Joint Meeting on Pesticide Residues
JTU	Jackson Turbidity Unit
LOAEL	Lowest Observed Adverse Effect Level
NOAEL	No Observed Adverse Effect Level
NTU	Nephelometric Turbidity Unit
PAHs	Polyaromatic hydrocarbons
PCBs	Polychlorinated Biphenyls
PCS	(WHO) Programme on Chemical Safety
PGV	(WHO Drinking-water Quality) Provisional Guideline Value
PIC	Prior Informed Consent
PMTDI	Provisional maximum tolerable daily intake
POP	Persistent Organic Pollutant
PTWI	Provisional tolerable weekly intake
SEARO	WHO Regional Office for South-east Asia
TCU	True Colour Unit
TDI	Tolerable Daily Intake
UF	Uncertainty Factor
UNEP	United Nations Environment Programme
WHO)	World Health Organization
WPRO	WHO Regional Office for West Pacific
WSP	Water Safety Plan
YLL	Years of Life Lost

1 INTRODUCTION

1.1 General considerations

The primary purpose of the Guidelines for Drinking-water Quality is the protection of public health.

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.

Safe drinking-water, as defined by the Guidelines is such that it does not represent any significant risk to health over a lifetime of consumption. It is suitable for all usual domestic purposes, including personal hygiene. The Guidelines are applicable to packaged water and ice intended for human consumption. However, water of higher quality may be required for some special purposes, such as renal dialysis, cleaning of contact lens, or for certain purposes in food production. There may also be special requirements for those who are significantly immunocompromised to take other additional steps, such as boiling all drinking-water, due to their extreme susceptibility to organisms that would not normally be of concern through drinking-water. The Guidelines may not be suitable for the protection of aquatic life.

The Guidelines are derived so as to take account of the needs of an individual through a normal lifetime, including changes in sensitivity that may occur between life stages. Those at greatest risk of waterborne disease are infants and young children, people who are debilitated or living under insanitary conditions and the elderly. Exclusions, such as particularly sensitive sub-populations, (including the sick and immuno-compromised), may be specifically defined in some sections of the Guidelines.

The Guidelines are intended to support the development and implementation of risk management strategies which if properly implemented will ensure the safety of drinking-water supplies. These may include national or regional standards developed from the scientific basis provided in the Guidelines. Such strategies, if properly implemented, will ensure the safety of drinking-water supplies, through the control of constituents of water hazardous to health. The Guidelines may describe reasonable minimum requirements of safe-practice to protect the health of consumers and/or may derive numerical “Guidelines Values” for constituents of water or indicators of water quality. Neither the minimum safe practices nor the numeric Guideline Values of constituents are mandatory limits and do not directly translate into legal requirements. In order to define such limits, it is necessary to consider the guidelines 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. Further, the Guidelines are best used as an integrated preventive management for safety applied from catchment to consumer. In developing standards and regulations, care should be taken to ensure that scarce resources are not necessarily diverted to the development of standards and the monitoring of substances of relatively minor importance to public health. The approach followed in these Guidelines intends to lead to national standards and regulations that can be readily implemented and enforced and are protective of public health.

The nature and form of drinking-water standards may vary among countries and regions. There is no single approach that is universally applicable. It is essential in the development and implementation of standards that the current and planned legislation relating to the water, health and local government is taken into account and that the capacity of potential regulators in the country is assessed. Approaches that may have worked in one country or region do not necessarily transfer to other countries or regions. It is essential that each country review its needs and capacities in developing a regulatory 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 as national or local standards justifies the cost is for each country to decide. What must be emphasized is that the guidelines be adaptable to take account of socio-cultural, economic and environmental conditions of the settings in which they are applied.

An important concept in the allocation of resources to improving drinking-water safety is that of incremental improvements towards long-term quality targets. Priorities set now to remedy the most urgent problems (e.g. safety from pathogens, see Section 1.1.1) may be linked to long-term targets of further water-quality improvements (e.g. improvements of aesthetic parameters, see section 1.1.4).

The community has a right to water of appropriate quality, but also adequate quantity. Adequate quantity of water for basic hygiene is a pre-requisite for health protection and improving access to safe drinking-water can result in tangible health improvements.

The basic and essential requirements to ensure the safety of drinking-water are health based quality or safety targets established by a competent health authority; adequate and properly managed systems (adequate infrastructure, proper monitoring and effective planning and management) and a system of independent surveillance.

A holistic risk management approach to drinking-water supply increases confidence in the safety of drinking-water and reduces reliance on end-point testing. These plans systematically assess risks throughout a drinking-water supply, from the catchment, aquifer and its source water, through to the consumer's tap, and identify the ways that these risks can be managed including methods to ensure that barriers and control measures are working effectively. A risk management plan assesses the integrity of the entire water supply system and is able to incorporate strategies to deal with day-to-day management of water quality, including the inevitable upsets and failures.

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.

The Guidelines include:

- a drinking-water safety framework
- a quality management approach for drinking-water systems from catchment to tap
- assessment of the health risk presented by;

  - microorganisms
  - chemicals
  - radiological constituents
- an explanation of the criteria used to select the various constituents addressed;
- approaches used in deriving Guidelines, including Guideline Values;
- explanation on how the Guidelines are intended to be used; and
- summary statements either supporting the Guidelines recommended, or explaining why no health-based guideline is required, or possible, at the present time.

The Guidelines are applicable to large metropolitan and small community piped and to non-piped drinking-water systems in communities and in individual dwellings. The Guidelines are also applicable to a range of specific circumstances, including large buildings, water quality for travelers, and conveyances.

The great majority of health-related water-quality problems are the result of microbial (bacteriological viral, protozoal or other biological) contamination. Nevertheless, an appreciable number of serious health concerns may occur as a result of the chemical contamination of drinking-water.

1.1.1 Microbial aspects

Securing the microbial safety of drinking-water supplies is based on the use of multiple barriers operating from catchment to consumer, to prevent contamination of drinking-water or reduce if negligible levels not injurious to health. Safety is increased if multiple barriers are in place including protection of water resources and sources and a properly selected and operated series of treatments and measures to control contamination in distribution. The preferred strategy to ensure compliance with the Guidelines, is a management approach which places the primary emphasis on preventing or reducing the entry of pathogens to drinking-water and to reduce reliance on treatment processes for removal of pathogens. As far as possible, water sources should be protected from contamination by human and animal waste, which can contain a variety of bacterial, viral, and protozoan pathogens and helminth parasites.

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

Microbial water quality may vary rapidly and over a wide range. Short-term peaks in pathogen occurrence may increase disease risks considerably and may also trigger outbreaks of waterborne disease. For these reasons reliance cannot be placed on water quality measurements, even when made frequently, to determine the microbial safety of drinking-water as it is unable to provide timely indication of water quality.

Management of drinking-water requires a system-wide assessment to determine potential hazards in the system and to identify the control measures being used to reduce or eliminate the hazards (see Section 4.1); monitoring to ensure barriers within the system are functioning efficiently (see Section 4.2) and the development of management plans to describe actions taken under both normal and incident conditions.

End-product testing is an important quality-control or verification procedure to ensure water quality targets are being met and that management plans are appropriate for the system, however, it should not be considered as a step in the determination of water quality from a public health view point.

Failure to provide adequate protection and effective treatment and protection of drinking-water throughout the distribution system to the consumer will expose the community to the risk of outbreaks of intestinal and other infectious diseases. Outbreaks are particularly to be avoided because of their capacity to result in the simultaneous infection of a large number of persons and potentially a high proportion of the community.

In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with human and animal faeces. Faecal waste can be a source of pathogenic bacteria, viruses, protozoa and helminths. Verification of microbial quality of drinking water includes testing for *Escherichia coli* as an indicator of faecal pollution. *E. coli* provides conclusive evidence of faecal pollution and should not be detected. In practice, the detection of thermotolerant coliform bacteria can be an acceptable alternative. While *E. coli* is a useful indicator it has limitations. Enteric viruses and protozoa are more resistant to disinfection and consequently the absence of *E. coli* will not necessarily indicate freedom from these organisms. That is why particular attention should be directed to protecting sources of drinking-water from contamination, installing and operating appropriate treatment technologies and implementing comprehensive water safety plans.

In addition to faecally borne pathogens other hazards, e.g. guinea worm, cyanobacteria and *Legionella* may be of public health importance under specific circumstances.

The infective stages of many helminths such as parasitic roundworms and flatworms can be transmitted to humans through drinking-water. A single mature larva or fertilized egg can cause infection, and should be absent from drinking-water. However, the water route is relatively unimportant except in the case of *Dracunculus medinensis* (the guinea worm).

Legionella bacteria are ubiquitous in the environment and can proliferate at the higher temperatures experienced at times in piped distribution systems and more commonly in hot and warm water systems supplied with drinking water. Exposure from drinking-water is preventable through the implementation of basic water quality management measures in buildings and/or through the maintenance of disinfection residuals throughout the piped distribution system.

Public health concern regarding cyanobacteria relates to the ability of many species and strains of these organisms to produce cyanotoxins which are toxic when ingested. These toxins pose a challenge for management. Unlike most toxic chemicals, high concentrations of cyanotoxins rarely occur dissolved in the water as these toxins are usually contained within cyanobacterial cells. Exposure to high concentrations usually result from ingestion of accumulated cell material. In contrast to pathogenic bacteria, these cells do not proliferate within the human body after uptake, only in the aquatic environment before intake.

It is important to recognize that while water can be a very significant source of infectious organisms that many of the diseases that are waterborne are also transmitted by person-to-person contact, aerosols, and food intake. Depending on circumstance and in the absence of water-borne outbreaks, these routes may be more important than waterborne transmission.

Some microorganisms will grow as biofilm on surfaces in contact with water. With one or two exceptions, such as *Legionella,* most of these organisms do not cause illness but they can cause nuisance through generation of tastes and odours or discolouration of water supplies. Growth following drinking-water treatment is normally referred to as 'regrowth'. Growth is typically reflected in measurement of increasing heterotrophic plate counts (HPC) in water samples. Elevated HPC levels occur especially in stagnant parts of piped distribution systems, in domestic plumbing, in some bottled water and in plumbed-in devices such as softeners, carbon filters, and vending machines.

1.1.2 Disinfection

Disinfection is of unquestionable importance in the supply of safe drinking-water. The destruction of microbial pathogens is essential and very commonly involves the use of reactive chemical agents such as chlorine. Chlorine can be easily monitored and controlled as a drinking-water disinfectant, and frequent monitoring is recommended wherever chlorination is practised.

In drinking-water treatment, disinfection is an effective barrier to many pathogens in drinking-water, especially bacteria and should be used for surface waters and for groundwater subjected to faecal contamination. Residual disinfection is used to provide a partial safeguard against low level contamination and regrowth within the distribution system.

Chemical disinfection of a water supply that is faecally contaminated will reduce the overall risk of disease but may not necessarily render the supply safe. Chlorine disinfection of drinking-water has limitations against the protozoan pathogens - in particular *Cryptosporidium* - and some viruses. Disinfection efficacy may also be unsatisfactory against pathogens within flocs or particles, which protect them from disinfectant action. It is essential that an overall management strategy is implemented where multiple barriers including source water protection and appropriate treatment processes as well as protection in distribution are used in conjunction with disinfection to prevent or remove microbial contamination.

The use of chemical disinfectants in water treatment usually results in the formation of chemical by-products. 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.

Disinfection should not be compromised in attempting to control disinfection by-products

High levels of turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria, and give rise to a significant chlorine demand.

1.1.3 Chemical aspects

The health risk due to toxic chemicals in drinking-water differs from that caused by microbial contaminants. The problems associated with chemical constituents of drinking-water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure. There are few chemical constituents of water that can lead to health problems resulting from a single exposure, except through massive accidental contamination of a

supply. Moreover, experience shows that, in many such incidents, the water generally becomes undrinkable owing to unacceptable taste, odour, and appearance.

As chemical contaminants are normally associated with adverse health effects only after long-term exposure, they are considered a lower priority category than microbial contaminants.

Where short-term exposure is not likely to lead to health impairment, it is often most effective to concentrate the available resources for remedial action on findings and eliminating the source of contamination, rather than on installing expensive drinking-water treatment for its removal.

There are many chemicals that may occur in drinking-water, however only a few are of immediate health concern in any given circumstance. Chemical contaminants in drinking-water should be prioritised both for monitoring and for remedial action to ensure scarce resources are not unnecessarily directed towards those of no health concern (See *Chemical Safety of Drinking-water: Assessing Priorities for Risk Assessment*).

Exposure to high levels of naturally occurring fluoride can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis. Similarly, arsenic may occur naturally, and excess exposure to arsenic in drinking-water may result in a significant cancer risk. Other naturally-occurring chemicals of health concern include uranium and selenium.

The presence of nitrate and nitrite in water, causing methaemoglobinaemia in infants, may result from the excessive application of fertilizers or from leaching of wastewater or other organic wastes into surface water and groundwater.

In areas with aggressive or acidic waters, the use of lead pipes and fittings or solder can result in elevated lead levels in drinking-water, which may cause adverse neurological effects in children.

Some health effects may occur as a result of specific chemical deficiencies in the diet, of which water forms a part. Important examples are ophthalmic goiter caused by iodine deficiency and dental caries resulting from low fluoride intake. No attempt has been made in the Guidelines to define a minimum desirable concentration of such substances in drinking-water because it is assumed that the diet would usually be the principal source of beneficial substances.

1.1.4 Acceptability aspects

Water should be free of tastes and odours that would be objectionable to the majority of consumers.

In assessing the quality of drinking-water, consumers rely principally upon their senses. Microbial, chemical and physical 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. In extreme cases, consumers may avoid aesthetically unacceptable but

otherwise safe supplies in favour of more pleasant but potentially unsafe sources of drinking-water.

Although the Guidelines are based on the best available public health evidence, there is no guarantee that consumers will be satisfied or dissatisfied by water supplies that meet or fail to meet these Guidelines. It is therefore wise to be aware of consumer perceptions and to take into account both health-related guidelines and aesthetic criteria when assessing drinking-water supplies.

Changes in the normal taste of a public water supply may signal changes in the quality of the raw water source or deficiencies in the treatment process and should be investigated.

1.1.5 Radiological aspects

The radiological health risk associated with the presence of naturally occurring radionuclides in drinking-water should also be taken into consideration as part of overall system assessment, although the contribution of drinking-water to total exposure to 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.

1.2 Roles and responsibility in drinking-water safety management

Preventive management is the preferred approach to drinking-water safety and must take account of the characteristics of the water supply from catchment and source to its use by consumers. The Guidelines have been developed towards this approach. As many aspects of water quality management are often outside the direct responsibility of the water supplier, it is essential that a collaborative multi-agency approach is adopted to ensure that agencies with responsibility for specific areas within the water cycle are involved in the management of water quality. One example is where catchments and source waters are beyond the drinking-water supplier's jurisdiction. Consultation with other authorities is necessary for many other elements of drinking-water quality management, such as monitoring and reporting requirements, emergency response plans and communication strategies.

A preventive integrated management approach with collaboration from all relevant agencies is the preferred approach to drinking-water safety.

All major stakeholders that could affect or be affected by decisions or activities of the drinking-water supplier should be identified. These could include, for example, health or resource management agencies and consumers, industry and plumbers respectively

The various agencies and other stakeholders involved should be encouraged, to coordinate their planning and management activities where appropriate. Appropriate mechanisms and documentation should be established for stakeholder commitment and involvement.

1.2.1 Surveillance and Quality Control

In order to protect public health a dual role approach, differentiating the roles and responsibilities of service providers from those of regulatory public health oversight has proven to be effective.

Organizational arrangements for the maintenance and improvement of water-supply services should therefore take into account the vital and complementary roles of the agency responsible for surveillance and of the water supplier. The two functions of surveillance and quality control, are best performed by separate and independent entities because of the conflict of interests that arises when the two are combined. In this:

- national agencies provide a framework of targets, standards and legislation to enable and require suppliers to meet their obligations;
- agencies involved in supplying water for consumption by any means should be required to verify that the systems they administer are capable of delivering safe water and that they routinely achieve this;
- a surveillance agency is responsible for independent (external) surveillance through periodic audit of all aspects of safety and/or verification testing.

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In practice, there may not always be a clear division of responsibilities between the health and water-supply sectors. In some cases, the range of professional, governmental, non-governmental, and private institutions may be wider and more complex than that discussed above. Whatever the existing framework, it is important that clear strategies and structures are developed for implementing surveillance and quality control, collating and summarizing data, reporting and disseminating the findings, and taking remedial action. Similarly, clear lines of accountability and communication are essential.

> ***Surveillance of drinking-water quality can be defined as "the continuous and vigilant public health assessment and overview of the safety and acceptability of drinking-water supplies*** (WHO, 1976)

Surveillance is an investigative activity undertaken to identify and evaluate risk factors associated with drinking-water which could pose a risk to health. Surveillance contributes to the protection of public health by promoting improvement of the quality, quantity, coverage, affordability, and continuity of water supplies. The surveillance authority must have the power to determine whether a water supplier fulfilling its obligations.

In most countries the agency responsible for the surveillance of drinking-water supply services is the ministry of health (or public health) and its regional or departmental offices. In some countries, it may be an environmental protection agency; in others, the environmental health departments of local government may have some responsibility.

Surveillance requires a systematic programme of surveys that typically combine auditing, analysis, sanitary inspection, and institutional and community aspects. It should cover the whole of the water-supply system including sources, and activities in the catchment, transmission infrastructure (whether piped or unpiped), treatment plants, storage reservoirs, and distribution systems.

Timely action to prevent problems and ensure the correction of faults should be an aim of the surveillance programme. There may at times be a need for penalties to encourage and ensure compliance. The surveillance agency must therefore be supported by strong and enforceable legislation if it is to be effective. However, it is important that the agency develops a positive and supportive relationship with suppliers.

The surveillance agency should be empowered by law to compel the water suppliers to post notices recommending the boiling of water when microbial contamination that could threaten public health is detected.

Water suppliers are responsible at all times for the quality and safety of the water that they produce.

Water suppliers are responsible at all times for the quality and safety of the water that they produce, and they achieve this by development and implementation of a water safety plan.

The responsibility of the supplier is distinguished from that of the surveillance agency on the basis of institutional responsibilities and the frequency of the monitoring activities conducted.

A water safety plan is designed to ensure that water services meet agreed national standards and institutional targets and has three principal components: a system assessment; identification of control measures and associated operational monitoring; and a management plan.

1.2.2 Public Health Authorities

In order to effectively support the protection of public health from water borne disease, a national entity with responsibility for public health will normally act in four areas

1. *Surveillance of health status and trends* including outbreak detection and investigation, generally directly but in some instances through a decentralized body.
2. Directly establishing *norms and standards*. National public health authorities often have the primary responsibility for setting norms on drinking-water supply, which may includes the setting of water quality targets, performance and safety targets and directly specified requirements (e.g. treatment). Normative activity is not restricted to water quality but also includes for example regulation of materials and chemicals used in the production and distribution of drinking-water (see section 8.10) and establishing minimum standards in areas such as domestic plumbing (see section 1.2.10). Neither is it a static activity, since as changes occur both in water supply and in technologies and materials available (e.g. from plumbing materials and treatment processes) so health priorities and responses to them will also change.
3. Representing health concerns in *wider policy development*, especially health policy and integrated water resource management (see section 2.7.1). Health concerns will often suggest a supportive role towards resource allocation to those concerned with water supply extension and improvement; will often involve lobbying for the primary requirement to satisfy drinking-water needs above other priorities and may imply involvement in conflict resolution.
4. Direct action, generally though subsidiary bodies (such as regional and local environmental health administrations) or by providing guidelines to other local entities (such as local government) in surveillance of drinking-water supplies. These roles vary widely according to national and local structures and responsibilities. They frequently

include a supportive role to community supplies, where local authorities often intervene directly.

Public health surveillance i.e. surveillance of health status and trends is an essential process to verify drinking-water safety. It takes into consideration disease outbreaks in the entire population who may be exposed to pathogenic microorganisms from a range of sources, not just drinking-water. National public health authorities may also undertake or direct research to evaluate the role of water as a risk factor in disease, for example through case-control, cohort studies or intervention studies. Public health surveillance teams typically operate at national, provincial, and district levels, as well as in cities or at rural health centres.

The Guidelines provide the scientific point of departure for national authorities to develop drinking-water regulations and standards relevant for the national situation, taking account of local, regional or national environmental, economic, and socio-cultural conditions.

The public health authority acts against the background of overall public health policy, and in interaction with all stakeholders. In accounting for public health context, priority will normally be afforded to disadvantaged groups. This will generally entail balancing drinking-water quality safety management and improvement with the need to ensure universal access to reliable supplies of safe drinking-water in adequate quantities.

In order to develop an understanding of the national drinking-water situation, the national public health authority should periodically produce reports outlining the national water quality and highlight public health concerns and priorities in the context of overall public health priorities. This implies the need for effective transfer of information between local, regional and national agencies.

National Authorities should formulate and implement a policy to assure that the community has access to some form of organized, reliable drinking-water supply. Where such targets have not been met, appropriate tools and education should be made available to implement individual or household treatment.

1.2.3 Local Authorities

Local environmental health authorities play a key role in managing water resources and drinking-water supplies. This begins with catchment inspection and authorising activities in the catchment which may impact on source water quality. It further includes verifying and auditing the management of formal supply systems. Local environmental health authorities will also give specific guidance to communities or individuals in designing and implementing community and household supplies and correcting deficiencies, and they may also be responsible for verification and auditing. They have an important role in educating consumers where household water treatment is necessary.

Household and small community drinking-water supplies generally require integrated education programs about water supply and water quality. Such programmes should normally include:

- water hygiene awareness raising;
- basic technical training and technology transfer in water supply and management;
- consideration of and approaches to overcoming socio-cultural barriers to acceptance of water quality interventions;

- motivation, mobilization and social marketing activities; and
- a system of continued support, follow-up and dissemination of the water quality program to achieve and maintain sustainability.

These programs can be administered at the community level by local health authorities or other entities, such as NGOs and the private sector. If the programme arises from other entities, the involvement of the local health authority in the development and implementation of the water-quality education and training program is strongly encouraged.

Approaches to such participatory hygiene and sanitation education and training programs are described in other WHO documents, (see *PHAST Step-by-Step Guide: A Participatory Approach for the Control of Diarrhoeal Disease* (SIDA - UNDP - WB -WHO, 2000, 137 p; Operation and Maintenance of Rural Water Supply and Sanitation Systems - A Training Package for Managers and Planners (IRC - WHO, 2000, 302 p.).).

1.2.4 Water Resource Management

Water resource management is an integral aspect of preventive management of drinking-water quality. Prevention of microbial and chemical contamination of source water is the first barrier against contamination of drinking-water of public health concern.

Water resource management and potentially-polluting human activity in the catchment will influence water quality downstream or in aquifers. This will impact on treatment steps required to ensure provision of safe water, and preventive action may be preferable to upgrading treatment.

The influence of land use on water quality should be assessed as part of water resource management. This assessment is usually not accomplished by the health authorities or water supply agencies alone, and should take into consideration:

- land cover modification;
- extraction activities;
- construction/modification of waterways;
- application of fertilisers, herbicides, pesticides and other chemicals;
- stock density and application of manure
- road construction, maintenance and use;
- various forms of recreation;
- urban or rural residential development with particular attention to excreta disposal, sanitation, landfill and waste disposal; and
- other potentially polluting human activity such as industry, mining, military sites, etc.

Water resource management may be the responsibility of catchment management agencies and/or other entities controlling or impacting source water resources, such as industrial, agricultural, navigation and flood control entities.

The extent to which health or water supply agencies' responsibility includes water resource management varies greatly between countries and communities. Regardless of government structures and sector responsibilities, it is important that health authorities liaise and collaborate with sectors managing the water resource and regulating land use in the catchment.

Establishing close collaboration between the public health authority, water supply agency and the resource management agency is essential to understanding the disease agents potentially occurring in the system. It is also important for introducing the protection of drinking-water resources in decisions for land use or regulations to control contamination is water resources i.e. to ensure an integrated management approach for effective drinking-water quality management. Depending on the setting, this may include involvement of further sectors, such as agriculture, traffic, tourism or urban development.

To assure the adequate protection of drinking-water sources, national authorities will normally interact with other sectors in formulating national policy for integrated water resources management. A regional and local structure for implementing the national policy will be set up, and the national authorities will guide regional and local authorities by providing tools to audit formalized water supply systems, and by providing general guidelines for community supplies.

Regional environmental or public health authorities have an important task in participating in the preparation of integrated water resources management plans to ensure the best available drinking-water source quality**.** *For further information – See WHO Groundwater and Surface water monographs).*

1.2.5 Water Supply Agencies

Water supply agencies varies from very large urban supplier servicing populations with tens of millions to small community supplies providing water to very small populations. In many countries they include non-piped as well as piped means of supply.

Water supply agencies are responsible for quality control (see section 1.2.1). Their key responsibilities are to prepare and implement drinking-water safety plans, which include three principal components:

- Design and construction of a system that can consistently meet water quality targets.
- Identification of control measures in the supply chain which are of particular importance in securing drinking-water safety and corresponding operational monitoring.
- Preparation, maintenance and implementation of management plans including documenting system assessment, monitoring plan, describing actions to be taken in normal operation and incident conditions, including documentation upgrading and communication plans.

Water supply agencies should develop the infrastructure necessary for quality control of drinking-water. (*For further information – See WHO Water Safety Plan*)

1.2.6 Community Management

The precise definition of a “community water supply” will vary. While a definition based on population size or the type of supply may be appropriate under many conditions, it is often administration and management that set community supplies apart. The increased involvement of ordinary, often untrained and sometimes unpaid, community members in the administration and operation of water-supply systems is characteristic of small communities; this provides a ready distinction between community water supplies and the supply systems of towns and cities. Community managed drinking-water supplies, with both piped and non-piped distribution systems are common worldwide, in both developed and less-developed

countries. However, water supplies in periurban areas in developing countries - the communities surrounding major towns and cities - may also be classified as "community water supplies" .

Ensuring water safety to consumers requires that the needs of community supplies are explicitly considered and addressed. Effective and sustainable programmes for the management of community drinking-water quality require the active support and involvement of local communities. These communities should be involved at all stages of such programmes, including initial surveys; decisions on siting of wells, offtakes or establishing protection zones; monitoring and surveillance of water supplies; reporting faults, carrying out maintenance, and taking remedial action; and supportive actions including sanitation and hygiene practices.

The community may already be highly organized and taking action on health issues or However, it may lack a well-developed structure for water supply, some sections of the community, such as women, may be poorly represented, and there may be disagreements or factional conflicts. In this situation, achieving community participation will take more time and require many visits to bring people together, resolve differences, agree on common aims, and take action. Even after the community starts to become involved, further visits, possibly over several years, will be needed to provide support and encouragement, and ensure that the structures created for safe water supply continue to operate. This may involve setting up comprehensive hygiene and health educational programmes to ensure that the community:

- is aware of the importance of water quality and its relation to health, and of the need for safe water supplies in sufficient quantities for domestic use for drinking, cooking and essential hygiene requirements;
- accepts the importance of surveillance and the need for a community response;
- understands and is prepared to play its role in the surveillance process;
- has the necessary skills to perform that role; and
- Is aware of requirements for the protection of water supplies from pollution

(For further information - see WHO Guidelines for Drinking-water Quality, Volume 3, second edition; Water Safety Plans; PHAST; Operation and Maintenance of Rural Water Supply and Sanitation Systems – A training package for managers and planners (IRC, WHO 2000))

1.2.7 Water Vendors

Water vendors selling water to households or at collection points are common in many parts of the world where scarcity of water, or faults or a lack of infrastructure lead to a failure of conventional water supplies to provide suitable quantities of drinking-water. Water vendors use a range of modes of transport to carry drinking-water for sale directly to the consumer, including tanker-trucks,wheelbarrows/trolleys. In the context of these Guidelines, water vendors do not include bottled water or water sold through vending machines.

There are a number of health concerns associated with water supplied to consumers by water vendors. These include access to adequate volumes and concern regarding inadequate treatment or transport in inappropriate containers which can result in contamination of drinking-water.

Where the source of water is uncertain, or the quality of the water is unknown, water can be treated or retreated in small quantities to significantly improve its quality and safety. The simplest and most important for microbially contaminated water is disinfection. If bulk supplies in tankers are used, sufficient chlorine should be added to ensure that a free residual

concentration of at least 0.5 mg/litre after a contact time of at last 30 minutes is present at the delivery point. Tankers should normally be reserved for potable water use. Before use, tankers should be either disinfected or steam-cleaned.

Local authorities should implement monitoring programmes for water provided by vendors and where necessary develop education programmes to improve the collection, treatment and distribution of water to prevent contamination.

1.2.8 Individual consumers

Everyone consumes water from one source or another and in many places and situations, consumers have important roles in the collection, treatment and storage of water. Consumer actions may help to ensure the safety of the water they consume and may also contribute to improvement or contamination of the water consumed by others. Consumers have the responsibility for ensuring their actions do not impact adversely on water quality. Installation and maintenance of household plumbing systems should be undertaken preferably by qualified and authorised plumbers (See 1.2.10) or other persons with appropriate expertise to ensure cross-connection or back-flow events do not result in contamination of local water supplies.

In most countries there are populations whose water is derived from household sources, such as private wells and rainwater. In households using non-piped water supplies, appropriate efforts are needed to ensure safe collection, storage and perhaps treatment of their drinking-water. In some circumstances, households and individuals may wish to treat water in the home to increase their confidence in its safety, not only where community supplies are absent but also where community supplies are known to be contaminated or causing waterborne disease (see Chapter 6). Public health and local authorities may provide guidance to support households and individual consumers in ensuring the safety of their drinking-water (see chapter 6). Such guidance is best in the context of a community education, training and program (See section 1.2.3 of this document).

1.2.9 Certification Agencies

Certification is used to verify that services and devices and materials used in drinking-water supply meet a given level of quality and safety. Certification is a process in which an independent organization validates the claims of the manufacturers against a formal standard or criteria or provides an independent assessment to possible risks of contamination from a material or process. The certification agency may be responsible for seeking data from manufacturers, generating test results, conducting inspections and audits, and possibly making recommendations on product performance.

Certification as been applied to technologies use at household and community levels, such as hand pumps, and materials used by water supplies e.g. treatment chemicals, and devices used in the household for collection, treatment and storage.

Certification of products or processes involved in the collection, treatment, storage and distribution of water can be overseen by government agencies or private organisations. Certification process will depend on the standards against which the products are certified, criteria and the party that performs the certification.

National or local government certification programmes have a number of possible objectives:

- Certification of products to ensure that they do not cause contamination of drinking-water with toxic substances, substances that could affect consumer acceptability or that support the growth of microorganisms
- Certification of products to ensure that their operation does not threaten the safety of the user or the general public.
- Products testing, to avoid re-testing at local levels or prior to each procurement.
- Ensuring uniform quality and condition of products.
- Certification and accreditation of laboratories

An important step in any certification procedure is the establishment of standards, which must form the basis of assessment of the products. These standards should also - as far as possible contain the criteria for approval. In procedures for certification on technical aspects these standards are generally developed in close co-operation between the manufacturers the certifying institute and the consumers on the basis of consensus. The governmental public health agencies should have responsibility for developing the parts of the approval or criteria relating directly to public health.

(*For further information – see WHO Monograph on the Safety of Materials and Chemicals Used in the Production and Distribution of Drinking-water – also Chapter 8 Chemical Additives Section)*

1.2.10 Plumbing

Significant health consequences have been associated with inadequate plumbing systems within public and private buildings and have arisen from poor design, incorrect installation, alterations and inadequate maintenance.

Numerous factors influence the quality of water within a building's piped distribution system, and may result in microbial or chemical contamination of drinking-water. Outbreaks of gastrointestinal disease within buildings can occur through faecal contamination of drinking-water resulting from cross-connections with wastewater pipes. Poorly designed of plumbing systems can cause stagnation of water, and provide a suitable environment for the proliferation of *Legionella*. Plumbing materials, pipes and fitting, can result in elevated heavy metal concentrations in drinking-water (e.g. lead) and inadequate materials can be conducive to bacterial growth. Potential adverse health effects may not be confined to the individual building. Wider exposure to other consumers is possible through contamination of the local public distribution system, beyond the particular building through cross-contamination of drinking-water and back siphonage.

The delivery of water that complies with relevant national standards into buildings relies on a plumbing system that is not generally directly managed by water suppliers. Reliance is therefore placed on proper implementation of plumbing and, for larger buildings, on building-specific drinking-water safety plans (see 6.1).

To ensure water quality remains safe within the private distribution system, plumbing practice must ensure the prevention of hazards to health of the occupant through;

- pipes carrying either water or wastes are water tight, durable, of smooth and unobstructed interior, and protected against anticipated stresses;
- cross-connection between the water supply and the waste water removal systems do not occur;

- hot and cold water system should be designed to minimise the proliferation of *Legionella* (see also 3.6.4 and 8.2.5);
- appropriate protection is in place to prevent back-siphonage;
- system design of multi-story buildings minimises pressure fluctuations;
- the elements of the plumbing system are durable and protected from accidental damage,
- waste is discharged without contaminating drinking-water; and
- plumbing systems functions efficiently.

It is important that plumbers are appropriately qualified and have the competence to undertake necessary servicing of plumbing systems to ensure compliance with local regulations, and use safe materials approved for use.

Design of the plumbing systems of new buildings should normally be approved prior to construction and be inspected by an appropriate regulatory body during construction and prior to commissioning of the buildings.

1.3 Supporting documentation to the Guidelines

The Guidelines themselves are accompanied by separate texts that provide background information substantiating the derivation of the Guidelines and providing guidance on good practice towards effective implementation.

Water Safety Plans

The improvement of water quality control strategies, in conjunction with improvements in excreta disposal and personal hygiene can be expected to deliver substantial health gains in the population. This document provides information on improved strategies for the control and monitoring of drinking-water quality
[*Davison A., Howard G., Stevens M., Callan P., Kirby R., DeereD., Bartram J.*]

Impact of Treatment on Microbial Water Quality and Occurrence of Pathogens in Surface Water and their relationship with Indicator Parameter

The publication provides a critical analysis of the literature on removal and inactivation of pathogenic microbes in water to aid the water quality specialist and design engineer in making important decisions regarding microbial water quality. It also identifies and reviews research on the occurrence of pathogens in surface waters. It comprises the analyses of measured concentrations of pathogens and the relationship to the concentration of indicator parameters.
[*LeChevallier M., Au K., Dagendorf F., Queste A., Stalleicken I., Kistemann T.*}

Microbial Water Quality in Piped Distribution Systems: A review of Knowledge and Practice

The development of pressurised pipe networks for supplying drinking-water to individual dwellings, buildings and communal taps is a requisite for the continuing development and health of most communities. This publication considers the presence and growth of microorganisms in distribution networks and the practices that influence their presence and growth.
[*Ainsworth R.*]

Evaluation of the H_2S Method for Detection of Fecal Contamination of Drinking-water

This report critically reviews the scientific basis, validity, available data and other evidence for and against H2S tests as measures or indicators of faecal contamination in drinking-water. [*Sobsey M.d., Pfaender F.K.*]

Legionella and the prevention of Legionellosis

This review presents the current state of knowledge affecting survival and growth of Legionella spp. and factors influencing infective dose and occurrence in the environment. It also provides information on prevention and risk assessment/management control strategies. *[Exner M., Pleischl S., Rechenburg A., Hornei B., Wieland A., Kistemann T., Dangendorf F.]*

Chemical safety of drinking-water: assessing priorities for risk management
Provides the tools that allow users to undertake a systematic risk management approach to assess their water supply system(s) locally, regionally, or nationally; to prioritise the chemicals of greatest significance; consider how these might be controlled or eliminated, and to review or implement standards that are appropriate.
[*Thompson T, Fawell J, Kunikane S, Jackson D, Appleyard, S, Kingston P)]*

Safety of Materials and Chemicals Used in the Production and Distribution of Drinking-water

This document is intended to provide information based on best available experience on how to manage the quality and use of materials and chemicals added to drinking-water during its treatment, storage, and the ultimate impact on its quality.
[*Cotruvo J*]

Guidelines on Hazard Characterisation for Pathogens in Food and Water (WHO/FAO)

This document provides a practical framework and structure approach for the characterisation of microbial hazards, to assist governmental and research scientists.

Protecting Surface waters for health – managing the quality of drinking-water sources

As a companion document to Protecting groundwater for health, this document covers scientific evidence for the behaviours of pathogens and chemicals in surface waters, provides guidance on assessment of the potential for surface water contamination from activities in catchments, and proposes management approaches and technical tools available to resource managers.
[Chorus I., Fastner J., Schmoll O.]

Protecting Ground waters for health – managing the quality of drinking-water sources

As the first stage of an integrated approach to water safety management, this document provides scientific background information to transport and attenuation of pathogens and hazardous chemicals in groundwater, guidance on assessing potential groundwater pollution from human activities in the catchment, and strategies for the protection of groundwater

sources used for drinking-water. It is a companion volume to *Protecting Surface-waters for Health*

Toxic cyanobacteria in drinking-water: A guide to their public health consequences, monitoring and management

This book describes the present state of knowledge regarding the impact of cyanobacteria on health through the use of water. It considers aspects of risk management and details the information needed for protecting drinking-water sources and recreational water bodies from the health hazards caused by cyanobacteria and their toxins. It also outlines the state of knowledge regarding the principal considerations in the design of programmes and studies for monitoring water resources and supplies and describes the approaches and procedures used. *[Chorus I., Bartram J.]*

Managing Water in the Home: Accelerated Health Gains from Improved Water Supply

This report describes and critically reviews the various methods and systems for household water collection, treatment and storage. It also assesses the ability of household water treatment and storage methods to provide water with improved microbial quality. *[Sobsey M.]*

Quantifying Public Health Risks in the WHO Guidelines for Drinking-water Quality: A burden of Disease Approach, Havelaar A. and Melse J. RIVM, Bilthoven, The Netherlands.