

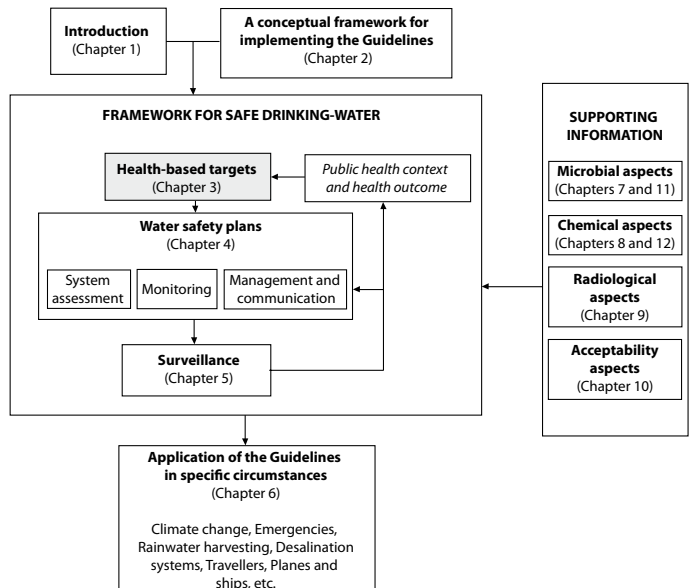
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Health-based targets

Health-based targets are measurable health, water quality or performance objectives that are established based on a judgement of safety and on risk assessments of waterborne hazards. These Guidelines describe four distinct types of health-based targets, applicable to all types of hazards and water supplies:

- 1) health outcome targets (e.g. tolerable burdens of disease);
- 2) water quality targets (e.g. guideline values for chemical hazards);
- 3) performance targets (e.g. log reductions of specific pathogens);
- 4) specified technology targets (e.g. application of defined treatment processes).

These targets are common components of existing drinking-water guidelines or standards that are used to protect and improve drinking-water quality and, consequently, human health. They provide benchmarks for water suppliers and regulators to confirm the adequacy of existing systems or the need for improvement. They underpin the development of water safety plans and verification of successful implementation. Where



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required, health-based targets can be used to support incremental improvement by marking out milestones to guide progress towards water safety and public health goals. This normally requires periodic review and updating of priorities and targets. In turn, norms and standards should also be periodically updated (see [section 2.6.2](#)).

Health-based targets should assist in determining specific interventions appropriate to delivering safe drinking-water, including control measures such as source protection and treatment processes.

3.1 Setting health-based targets

The use of health-based targets is applicable in countries at all levels of development. To ensure effective health protection and improvement, targets need to be realistic, measurable, based on scientific data and relevant to local conditions (including economic, environmental, social and cultural conditions) and financial, technical and institutional resources. Health-based targets should be part of an overall public health policy, taking into account public health status and trends and the contribution of drinking-water to the transmission of infectious disease and to overall exposure to hazardous chemicals both in individual settings and within overall health management.

Although water can be a source of microbial, chemical or radiological hazards, it is by no means the only source. In setting targets, consideration needs to be given to other sources, including food, air, person-to-person contact and consumer products, as well as poor sanitation and personal hygiene. Where the overall burden of disease from multiple exposure routes is very high, there is limited value in setting strict targets for drinking-water. For example, there is limited value in establishing a strict target for a chemical hazard if drinking-water provides only a small proportion of the total exposure to that chemical. The cost of meeting such targets could unnecessarily divert funding from other, more pressing health interventions and is not consistent with the public health objective of reducing overall levels of risk from all sources of exposure to environmental hazards (Prüss et al., 2002; Prüss & Corvalan, 2006).

It is also important to take account of the impact of the proposed intervention on overall rates of disease. For some pathogens and their associated diseases, interventions in water quality may be ineffective and may therefore not be justified. This may be the case where other routes of exposure dominate. For others, long experience has shown the effectiveness of improving drinking-water supply and quality management in the control of waterborne diseases such as typhoid and dysentery.

Meeting health-based targets should be viewed in the context of broader public health policy, including initiatives to improve sanitation, waste disposal, personal hygiene and public education on ways to reduce both personal exposure to hazards and impacts of personal activity on water resources. Improved public health, reduced carriage of pathogens and reduced human impacts on water

The judgement of safety—or what is a tolerable burden of disease 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 health-based targets justifies the cost is for each country to decide.

Table 3.1 Benefits of health-based targets

Target development stage	Benefit
Formulation	Provides insight into the health of the population Reveals gaps in knowledge Supports priority setting Increases the transparency of health policy Promotes consistency among national health programmes Stimulates debate
Implementation	Inspires and motivates collaborating authorities to take action Improves commitment Fosters accountability Guides the rational allocation of resources
Evaluation	Supplies established milestones for incremental improvements Provides opportunity to take action to correct deficiencies and/or deviations Identifies data needs and discrepancies

resources all contribute to drinking-water safety (Howard et al., 2002). Public health prioritization would normally indicate that the major contributors to disease should be dealt with preferentially, taking account of the costs and impacts of potential interventions. However, this does not mean ignoring lesser targets if they can be easily achieved for little cost, as long as this does not divert attention from major targets.

An important concept in the allocation of resources to improving drinking-water safety is the possibility of establishing less stringent transitional targets supported by sound risk management systems in order to encourage incremental improvements of the quality of drinking-water. In this regard, health-based targets can be used as the basis for supporting and measuring incremental progress in water quality improvement. Improvements can relate to progression through increasingly tighter targets or evolution through target types that more precisely reflect the health protection goals (e.g. from specified technology targets to performance targets).

The processes of formulating, implementing, communicating and evaluating health-based targets provide benefits to the overall preventive management of drinking-water quality. These benefits are outlined in Table 3.1.

3.2 Disability-adjusted life years, tolerable disease burden and reference level of risk

At a national level, decisions about risk acceptance and tolerable burdens of disease are complex and need to take account of the probability and severity of impact in addition to the environmental, social, cultural, economic and political dimensions that play important roles in decision-making. Negotiations are an important part of these processes, and the outcome may very well be unique in each situation. Notwithstanding the complexity of these decisions, definitions of tolerable burdens of disease and reference levels of risk are required to provide a baseline for the development of health-based targets and as a point of departure for decisions in specific situations.

Descriptions of tolerable burdens of disease relating to water are typically expressed in terms of specific health outcomes such as maximum frequencies of diarrhoeal disease or cancer incidence. However, these descriptions do not consider the severity of the outcomes. The various hazards that may be present in water are associated with very diverse health outcomes with different impacts ranging from mild diarrhoea to potentially severe outcomes such as typhoid, cancer or skeletal fluorosis.

A common “metric” is needed that can be used to quantify and compare the burden of disease associated with different water-related hazards, taking into account varying probabilities, severities and duration of effects. Such a metric should be applicable regardless of the type of hazard (microbial, chemical or radiological) to enable the use of a consistent approach for each hazard. The metric used in these Guidelines is the disability-adjusted life year, or DALY (Box 3.1). The World Health Organization has used DALYs quite extensively to evaluate public health priorities and to assess the disease burden associated with environmental exposures, particularly for microbial hazards.

A key advantage of using the DALY is its aggregation of different impacts on the quality and quantity of life and its focus on actual outcomes rather than potential risks; hence, it supports rational public health priority setting. DALYs can be used to define tolerable burden of disease and the related reference level of risk.

“Tolerable burden of disease” represents an upper limit of the burden of health effects associated with waterborne disease that is established by national policy-makers. “Reference level of risk” is an equivalent term used in the context of quantitative risk assessments.

In these Guidelines, the tolerable burden of disease is defined as an upper limit of 10^{-6} DALY per person per year. This upper-limit DALY is approximately equivalent to a 10^{-5} excess lifetime risk of cancer (i.e. 1 excess case of cancer per 100 000 people ingesting drinking-water at the water quality target daily over a 70-year period), which is the risk level used in these Guidelines to determine guideline values for genotoxic carcinogens.

Expressing health-based targets for chemical hazards in DALYs has the advantage of enabling comparisons with microbial risks. However, use of the DALY approach for chemicals has been limited in practice due to gaps in knowledge.

The 10^{-6} DALY tolerable burden of disease target may not be achievable or realistic in some locations and circumstances in the near term. Where the overall burden of disease by multiple exposure routes (water, food, air, direct personal contact, etc.) is very high, setting a 10^{-6} DALY per person per year level of disease burden from waterborne exposure alone will have little impact on the overall disease burden. Setting a less stringent level of acceptable risk, such as 10^{-5} or 10^{-4} DALY per person per year, from waterborne exposure may be more realistic, yet still consistent with the goals of providing high-quality, safer water.

3.3 Types of health-based targets

The nature and typical application of health-based targets are presented in Table 3.2. Health-based targets differ considerably with respect to the amount of resources

Box 3.1 Disability-adjusted life years

The various hazards that can be present in water can have very different health outcomes. Some outcomes are mild (e.g. diarrhoea), whereas others can be severe (e.g. cholera, haemolytic uraemic syndrome associated with *Escherichia coli* O157 or cancer). Some are acute (e.g. diarrhoea), whereas others are delayed (e.g. infectious hepatitis or cancer). Some especially relate to certain age ranges and groups (e.g. skeletal fluorosis in older adults often arises from long-term exposure to high levels of fluoride in childhood; infection with hepatitis E virus has a very high mortality rate among pregnant women). In addition, any one hazard may cause multiple effects (e.g. gastroenteritis, Gullain-Barré syndrome, reactive arthritis and mortality associated with *Campylobacter*).

In order to support public health priority setting, a common metric is required that can be applied to all types of hazard and takes into account different health outcomes, including probabilities, severities and duration of effects. The disability-adjusted life year (DALY) provides this metric.

The basic principle of the DALY is to weight each health impact in terms of severity within the range of 0 for good health to 1 for death. The weighting is then multiplied by duration of the effect and the number of people affected. In the case of death, duration is regarded as the years lost in relation to normal life expectancy. Using this approach, a mild diarrhoea with a severity weighting of 0.1 and lasting for 7 days results in a DALY of 0.002, whereas death resulting in a loss of 30 years of life equates to a DALY of 30.

Hence, $DALY = YLL \text{ (years of life lost)} + YLD \text{ (years lived with a disability or illness)}$. In this context, *disability* refers to a condition that detracts from good health.

For example, infection with rotavirus (in developed countries) causes:

- mild diarrhoea (severity rating of 0.1) lasting 7 days in 97.5% of cases;
- severe diarrhoea (severity rating of 0.23) lasting 7 days in 2.5% of cases;
- rare deaths of very young children in 0.015% of cases.

The DALY per case can then be calculated as follows:

$$\begin{aligned} DALY &= (0.1 \times 7/365 \times 0.975) + (0.23 \times 7/365 \times 0.025) + (1 \times 70 \times 0.00015) \\ &= 0.0019 + 0.0001 + 0.0105 \\ &= 0.0125 \end{aligned}$$

Infection with *Cryptosporidium* can cause watery diarrhoea (severity weighting of 0.067) lasting for 7 days with extremely rare deaths in 0.0001% of cases. This equates to a DALY per case of 0.0015.

Further information on the use of DALYs in establishing health-based targets is included in the supporting document *Quantifying public health risk in the WHO Guidelines for drinking-water quality* (Annex 1).

needed for their development and implementation and in relation to the precision with which the public health benefits of risk management actions can be defined. The most precise are health outcome targets, which underpin the derivation of the remaining targets, as shown in Figure 3.1. Each target type is based on those above it in Table 3.2, and assumptions with default values are introduced in moving down between target types. The targets towards the top of the table require greater scientific and technical inputs and are therefore more precisely related to the level of health protection. Target types at the bottom of Table 3.2 require the least interpretation by practitioners in implementation, but depend on a number of assumptions (e.g. establishing specified technology targets in the absence of sufficient source water quality data to apply performance targets for microbial pathogens). Efforts should be made to collect additional information when critical data for applying the next stage of target setting may not be available. This incremental improvement will ensure that the health-based targets will be as pertinent as possible to local circumstances.

Table 3.2 Nature and application of health-based targets

Type of target	Nature of target	Typical applications	Notes
Health outcome	Defined tolerable burden of disease	High-level policy target set at national level, used to inform derivation of performance, water quality and specified technology targets	These Guidelines define a tolerable burden of disease of 10^{-6} DALY per person per year
	No adverse effect or negligible risk	Chemical or radiological hazards	Derived from international chemical or radionuclide risk assessments
Water quality	Guideline values	Chemical hazards	Based on individual chemical risk assessments
		Microbial water quality targets are not normally applied	<i>Escherichia coli</i> is used as an indicator of faecal contamination and to verify water quality
		Radiological water quality targets are not normally applied	Radiological screening levels are applied
Performance	Specified removal of hazards	Microbial hazards (expressed as log reductions)	Specific targets set by water supplier based on quantitative microbial risk assessment and health outcome targets or generic targets set at national level
		Chemical hazards (expressed as percentage removal)	Specific targets set by water supplier based on chemical guideline values or generic targets set at national level
Specified technology	Defined technologies	Control of microbial and chemical hazards	Set at national level; based on assessments of source water quality, frequently underpinned by established or validated performance of the specified technology (e.g. requirement of filtration for surface water)

When establishing health-based targets, care should be taken to account for short-term events and fluctuations in water quality along with “steady-state” conditions. This is particularly important when developing performance and specified technology targets. Short-term water quality can significantly deteriorate, for example, following heavy rain and during maintenance. Catastrophic events can result in periods of very degraded source water quality and greatly decreased efficiency in many processes, or even system failure, greatly increasing the likelihood of a disease outbreak. Events like these provide additional justification for the long-established “multiple-barrier principle” in water safety.

For chemical hazards, health-based targets most commonly take the form of water quality targets, using the guideline values outlined in [section 8.5](#). Performance targets expressed as percentage removals or specified technology targets can also be applied to chemical hazards.

3. HEALTH-BASED TARGETS

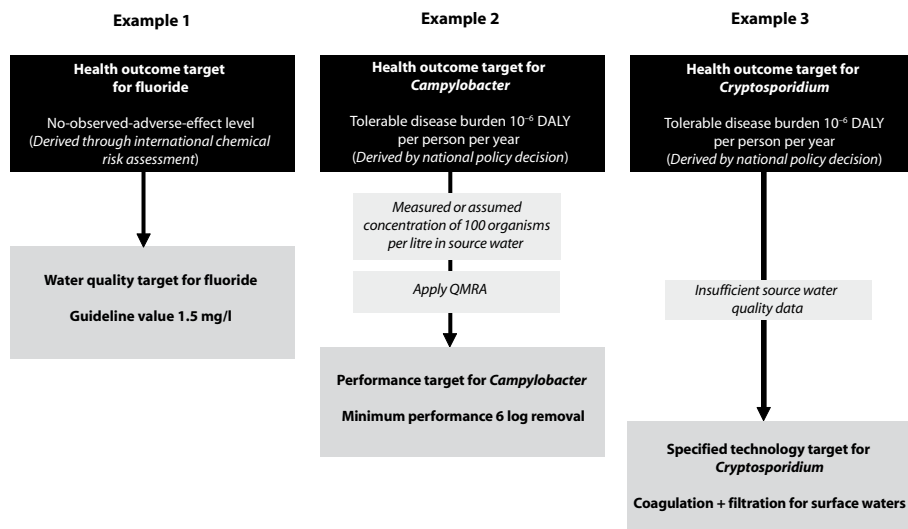


Figure 3.1 Examples of how to set health-based targets for various hazards

For microbial hazards, health-based targets usually take the form of performance or specified technology targets. The choice of target will be influenced by the number of data available on source water quality, with performance targets requiring more information. Water quality targets are typically not developed for pathogens, because monitoring finished drinking-water for pathogens is not considered a feasible or cost-effective option. Concentrations of pathogens equivalent to a health outcome target of 10^{-6} DALY per person per year are typically less than 1 organism per 10^4 – 10^5 litres. Therefore, it is more feasible and cost-effective to monitor for indicator organisms such as *E. coli*.

In practice, risks to public health from drinking-water are often attributable to a single hazard at a time; therefore, in deriving targets, the reference level of risk is applied independently to each hazard.

3.3.1 Health outcome targets

The most direct descriptions of drinking-water safety are health outcome targets, such as upper limits on frequencies of diarrhoeal disease or cancer incidence. These upper limits represent tolerable burdens of disease and are typically set at the national level. They underpin the derivation of water quality, performance and specified technology targets (Figure 3.1). These Guidelines define a tolerable burden of disease of 10^{-6} DALY per person per year. For threshold chemicals, the health outcome target is based on no-observed-adverse-effect levels (see [section 8.2](#)).

Health outcome targets must be translated into water quality, performance or specified technology targets in order to be actioned by the water supplier as part of the water safety plan.

3.3.2 *Water quality targets*

Water quality targets are the most common form of health-based target applied to chemicals that may be found in drinking-water. The guideline values for individual chemicals described in [section 8.5](#) provide water quality targets that can be used to verify that water safety plans have been effective in managing risks from chemicals in drinking-water.

Guideline values are established on the basis of international risk assessments of the health effects associated with exposure to the chemical in water. In developing national drinking-water standards (or health-based targets) based on these guideline values, it will be necessary to take into consideration a variety of environmental, social, cultural, economic, dietary and other conditions affecting potential exposure, as well as the default assumptions that are used to derive the guideline values. Exposure from chemicals in drinking-water is typically minor in comparison with that from other sources (e.g. food, consumer products and air), with a few important exceptions (e.g. arsenic and fluoride). This may lead to national targets that differ appreciably from the guideline values. In some cases, it may be appropriate to take action to prevent exposure to a chemical from sources other than drinking-water (e.g. lead from soldered cans and from petrol).

One example is that of the health-based target for fluoride in drinking-water. A guideline value of 1.5 mg/l is recommended in [Table A3.3](#) of [Annex 3](#), with a comment that “Volume of water consumed and intake from other sources should be considered when setting national standards.” Thus, in a country with a warm climate year-round and where piped water is the preferred source of drinking-water, authorities may select a health-based target for fluoride that is lower than this guideline value, as water consumption is expected to be higher. On a similar note, the health-based target should be reviewed in terms of its impact on the most vulnerable section of the population.

Where water treatment processes have been put in place to remove or reduce specific chemicals (see [section 8.4](#) and [Annex 5](#)), water quality targets should be used to determine appropriate treatment requirements.

It is important that water quality targets are established only for those chemicals that, following rigorous assessment, have been determined to be of health concern or of concern for the acceptability of the drinking-water to consumers. There is little value in undertaking measurements for chemicals that are unlikely to be in the system, that will be present only at concentrations much lower than the guideline value or that have no human health effects or effects on drinking-water acceptability. One example is that of radionuclides in drinking-water, which may be present in such minute quantities that their contribution to the overall health risks from drinking-water will be negligible. Analysis of individual radionuclides requires sophisticated and expensive procedures; hence, in such cases, measurements of gross alpha and gross beta activities may be adopted as the screening tests for the presence of radionuclides in drinking-water, as discussed in [section 9.3](#).

Water quality targets are also used in the certification process for chemicals that occur in water as a result of treatment processes or from materials in contact with water. In such applications, assumptions are made in order to derive standards for materials and chemicals that can be employed in their certification. Generally, allow-

ance must be made for the incremental increase over levels found in water sources. For some materials (e.g. domestic plumbing), assumptions must also account for the relatively high release of some substances for a short period following installation.

Escherichia coli remains an important indicator of faecal contamination for verification of water quality, but measurements of *E. coli* do not represent a risk-based water quality target. The use of *E. coli* as an indicator organism is discussed in more detail in [chapter 7](#).

3.3.3 Performance targets

Although performance targets can be applied to chemical hazards, the most common application is for control of microbial hazards in piped supplies. Performance targets assist in the selection and use of control measures that are capable of preventing pathogens from breaching the barriers of source protection, treatment and distribution systems or preventing growth within the distribution system.

Performance targets define requirements in relation to source water quality. Ideally, this should be based on system-specific data; more commonly, however, targets will be specified in relation to broad categories of source water quality and type (see [section 7.2](#)). The derivation of performance targets requires the integration of factors such as tolerable disease burden (acceptable risk), including severity of disease outcomes, and, for pathogens, quantitative microbial risk assessment (see [section 7.2](#)). There are insufficient data, and it is not realistic, to derive performance targets for all potentially waterborne pathogens. The practical approach is to derive targets for reference pathogens representing groups of pathogens (e.g. bacteria, viruses and protozoa). Selection of reference pathogens should take into account variations in susceptibility to treatment as well as local conditions, including prevalence of waterborne transmission and source water characteristics.

The most common application of performance targets is in identifying appropriate combinations of treatment processes to reduce pathogen concentrations in source water to a level that will meet health outcome targets and hence be safe. This is normally expressed in terms of log reductions. Selection of processes requires evidence that they will meet required performance targets (i.e. validation; see [sections 2.2.2](#) and [4.1.7](#)). Examples of treatment processes and pathogen reductions are given in [section 7.3](#).

Performance targets can be applied to catchment controls that are aimed at reducing pathogen concentrations through preventive measures and to measures to prevent ingress of contamination through distribution systems. Performance targets are also important in certification of point-of-use devices and specified technologies used for drinking-water treatment. Certification of devices is discussed elsewhere (see [section 1.2.9](#)).

Performance targets can be applied to chemical hazards. In comparison with targets for microbial hazards, they are typically applied to specific chemicals, with performance measured in terms of percentage reduction (see [section 8.4](#)).

3.3.4 Specified technology targets

Specified technology targets typically take the form of recommendations concerning technologies applicable in certain circumstances (e.g. filtration and disinfection of

surface water). Selection of technologies is usually based on qualitative assessments of source water type and quality (e.g. impacted surface water, protected groundwater). Specified technology targets are most frequently applied to small community supplies and to devices used at the household level. They can be applied to both microbial and chemical hazards.

Smaller municipal and community drinking-water suppliers often have limited resources and ability to develop individual system assessments and health-based targets. National regulatory agencies may therefore directly specify technology requirements or approved options. These may include, for example:

- specific and approved treatment processes in relation to source types and characteristics;
- providing guidance on requirements for protection of well heads;
- requirements for protection of drinking-water quality in distribution systems.

It is important to review specified targets on a regular basis to ensure that they are kept up to date in terms of the prevailing scientific knowledge about the technology and its application.