3. HEALTH-BASED TARGETS

3.1 Role and purpose of health-based targets

Health-based targets should be part of overall public health policy taking into account status and trends and the contribution of drinking-water in the transmission of infectious disease and to overall exposure to hazardous chemicals. To ensure effective health protection and improvement, the implementation of health-based targets should be achievable within available financial, technical and institutional resources. This normally implies periodic review and updating of priorities and targets, and in turn that norms and standards should be periodically updated to take account of these factors and the changes in available information (see section 2.3).

Health-based targets should assist in determining interventions appropriate to deliver safe drinking-water, including control measures such as source protection and treatment processes. They should also be used in evaluating the adequacy of existing installations and policies and assist in identifying appropriate auditing and schemes.

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

Health-based targets are typically national in character. Using information and approaches in these Guidelines, national authorities should be able to establish health-based targets that will improve drinking-water quality, and consequently human health, and also support the best use of available resources in specific national and local circumstances.

In order to minimise the likelihood of outbreaks of disease, care is required to account properly for water supply performance both in steady-state and during maintenance and periods of unusual load. Performance of the system during short-term events (such as variation in source water quality, system challenges and process problems) must therefore be factored into development of health-based targets. Both short-term and catastrophic events can result in periods of very degraded source water quality and greatly decreased efficiency in many processes, both of which provide a logical and sound justification for the long established 'multiple barrier principle' in water safety.

The processes of establishing, implementing monitoring and evaluation of health-based targets provides benefits to the overall preventive management of drinking-water quality. These benefits are outlined in table 3.1.

Table 3.1 Benefits of establishing Health-based Targets

Target development stage	Benefit
Formulation	Insight into the health of the population Reveals gaps in knowledge Supports the priority-setting process Increases the transparency of health policy Ensures consistency among national health programmes Stimulates debate
Implementation	Inspires and motivates collaborating authorities to undertake action Improves commitment Fosters accountability Guides the 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

3.2 Types of health-based targets

[NB first section i.e. up to and including numbers and following first paragraph repeats 2.1.1 – pending insert]

Health-based targets are required as a ‘benchmark’ for water suppliers. They provide information with which to evaluate the adequacy of existing installations and assist in identifying the level and type of inspection and analytical verifications appropriate. Health-based quality targets underpin the development of WSPs and verification of their successful implementation. They should lead to improvements to public health outcomes.

Ideally water quality targets should be set using quantitative risk assessment and take into account local conditions and hazards. However, in practice they may evolve from historical precedent or be adapted from international practice and guidance. The assessment of risk is a basis for decision-making with exclusive emphasis upon health.

Establishing health-based targets should take account not only of ‘steady-state’ conditions but also the possibility of short-term events (such as variation in environmental water quality, system challenges and process problems) which may lead to significant risk to public health.

For microbial pathogens, health-based targets will employ selected index pathogens that combine both control challenges and health significance in terms of health hazard and other relevant data. More than one pathogen is required in order to assess the diverse range of challenges to the safeguards available. While health-based targets may be expressed in terms of exposure to specific pathogens (i.e. water quality targets, WQTs), care is required in relating this to overall population exposure, which may be focused on short periods of time. WQTs must therefore account for potentially ‘catastrophic’ events with the potential to (lead to large-scale outbreaks of disease) in addition to background rates of disease during normal conditions of supply performance and efficiency. These different conditions relate to the recognised phenomenon of short periods of very decreased efficiency in many processes and provide a logical justification for the long established ‘multiple barrier principle’ in water safety.

For chemical constituents of drinking-water, health-based targets can be established using the guideline values outlined in Chapter 8. These values have been established on the basis of the health effect of the chemical in water. In developing national drinking-water standards (or health-based targets) based on these guidelines values, it will be necessary to take into consideration a variety of geographical, socioeconomic, dietary and other conditions affecting potential exposure. This may lead to national targets that differ appreciably from the guideline values. There are a large number of chemicals included in these Guidelines, setting targets, or including all chemicals into national standards or monitoring programmes is neither feasible or desirable. Further information on the prioritisation of chemicals is available in WHO *Chemical Safety for Drinking-water: Assessing Priorities for Risk Assessment.*

An overview of the targets is provided in table 3.2.

Management of toxic microbial contaminants, notably cyanobacteria in drinking-water is best managed through the implementation of appropriate assessment, monitoring and management practices (see Chapter 8).

Table 3.2 – Health-based targets

Type of Target	Typical applications	Nature of Target	Assessment
Health outcome (epidemiology based)	Microbial or chemical hazards with high measurable disease burden largely water-associated	Reduction in detected disease incidence or prevalence	Public health surveillance
(risk assessment based	Microbial or chemical hazards in situations where disease burden is low and cannot be measured directly	Tolerable level of risk by contaminants in drinking water, absolute or as a fraction of the total burden by all exposures	Quantitative risk assessment
Water Quality Targets	Chemical constituents with effects on health typically after long-term exposure.	Guideline Value applied to water quality	Periodic measurement of key chemical constituents to assess compliance with relevant guideline values (see chapter 8).
	Chemical additives and by-products	Guideline Values applied in testing procedures for materials and chemicals	Testing procedures applied to the materials and chemicals to assess their contribution to drinking-water exposure taking account of variations over time (see chapter 8.).
Performance targets	Microbial contaminants	Generic performance target for removal of group of microbes	Compliance assessment through system assessment and operation monitoring (see Chapter 4)
		Customised performance targets	Individually reviewed by public health authority; assessment would then proceed as above
	Threshold chemicals with acute affects on health which vary widely (e.g. nitrate and cyanobacteria)	Guideline values applied to water quality	Compliance assessment through system assessment and operation monitoring (see Chapter 4)
Directly specified requirements	Constituents with acute health affect in small municipalities and community supplies	National authorities specifies specific processes to adequately address constituents with acute health affects (e.g. generic WSPs for an unprotected catchment)	Compliance assesses through system assessment and operation monitoring (see Chapter 4)

N.B. each target type is based on those above it in this table and assumptions with default values are introduced in moving down between target types. These assumptions simplify the application of the target and introduce potential inconsistencies.

3.2.2 Water Quality Targets

Adverse health consequences arising from exposure to chemicals primarily occur following long-term exposure, with exceptions such as nitrate/nitrite. Management through periodic analysis of drinking water quality and comparison with WQTs such as GVs is therefore commonly applied to such chemicals in drinking water. While a preventive management approach to water quality should be applied to all drinking-water systems, the guideline values for individual chemicals described in chapter 8 provide health targets for chemicals in drinking-water.

Concentrations of most chemicals in drinking-water do not normally fluctuate widely over short periods of time and this approach is therefore appropriate to these.

While a preventive management approach to water quality should be applied to all drinking-water systems, the guideline values for individual chemicals described in chapter 8 are considered appropriate health targets for threshold chemicals in drinking-water.

Concentrations of most chemicals in drinking-water do not normally fluctuate widely over short periods of time. Where water treatment processes have been put in place to remove specific chemicals (see chapter 4), WQTS should be used to determine treatment requirements, monitoring of process operation will be appropriate and where concentrations in raw water are not expected to change rapidly, chemical monitoring is only necessary periodically. For those chemicals that are considered to be of sufficient concern in particular supplies to warrant chemical monitoring, the frequency of measurements should relate to the behaviour of the chemical. However, in most cases, the necessity will be for relatively infrequent measurement.

It is important that WQTs are only established for those chemicals which, following rigorous assessment, have been determined to be of health concern or of concern for the acceptability to consumers. There is little value in undertaking measurements for chemicals that are unlikely to be in the system, which will only be present at concentrations much lower that the guideline value or have no human health effects.

WQTs are also used as part of the certification process for those chemicals that occur in water as a result of treatment processes or from materials in contact with water. For large systems and other circumstances,for example desalination plants, itmay be appropriate to establish WQTs for microbial contaminants. In such applications assumptions are made regarding the presence of hazardous chemicals in raw materials in order to estimate resulting human exposure.

3.2.3 Performance and Safety Targets

In situations where short-term exposure is relevant to public health, because water quality varies rapidly or it is not possible to detect hazards between production and consumption, it is necessary to ensure control measures are in place and operating optimally, and to verify their effectiveness in order to secure safe drinking-water.

Performance and safety targets are designed to assist selection and use of control measures which are capable of preventing pathogens breaching the barriers of the same protection treatment and distribution systems, or from regrowth within the distribution system.

Target-setting agencies should identify performance and safety targets which may include requirements for source protection, nature and extent of treatment and protection of water quality in distribution. Most commonly, targets for removal of pathogen groups through water treatment processes will be specified in relation to broad categories of source water quality, as presented in Table 3.3. The derivation of performance and safety targets requires the integration of factors such as tolerable disease burden (acceptable risk), including severity of disease outcomes and dose response relationships for specific pathogens (target microbes) see Chapter 7.

Performance and safety targets should be developed to be achievable for selected index pathogens that combines both control challenges and health significance in terms of health hazard and any other relevant data. In practice, more than one pathogen will normally be required in order to properly reflect diverse challenges to the safeguards available. While performance and safety targets may be expressed in terms of exposure to specific pathogens, care is required in relating this to overall population exposure, which may be concentrated into short periods of time.

Performance and safety targets should be established to define performance requirements in relation to source quality with prime emphasis on processes and practice that will ensure the targets can be routinely achieved.

The principal practical application of performance and safety targets for pathogen control is in assessing the adequacy of drinking-water treatment infrastructure. This is achieved by using information on performance targets with knowledge concerning pathogen removal (table 3.4).

Table 3.3 – Performance and safety targets for pathogen group and indicator reduction by source type

Catchment Type	**Health Target**		
	Bacteria (log reduction)	**Protozoa (incl Cryptosporidium and Giardia)** (log reduction)	**Viruses** (log reduction)
Rivers and Streams	4 log	6 log	8 log

Table 3.4 Estimated removals of enteric pathogens in treatment systems using multiple barriers

Enteric organisms	Estimated reduction in numbers of enteric pathogens				Estimated overall removal[b]
	Watershed protection	**Reservoir detention**	**Filtration**	**Disinfection[a]**	
Bacteria	0.5–1 log removal	~ 1 log removal per 10 days storage Retention for over 60 days will provide almost complete removal.	0.5–1 log removal	Complete inactivation can be achieved by a range of disinfectants including chlorine, chloramines, UV providing sufficient doses and contact times are applied to clarified water.	Complete removal Achievable
Viruses	Complete removal of most human enteric viruses if human waste excluded.	1–2 log removal Long-term detention (1–6 months)	Conventional 2 log removal Direct 1 log removal Membrane > 4 log removal	Chlorine, UV light, ozone and chlorine dioxide 3 log removal	Removal of 5 log achievable
Giardia	0.5–1 log removal	1.5–2.5 log removal Long-term detention (1–6 months)	Conventional 2.5 log removal Direct 2 log removal Membrane[c] > 4 log removal	Chlorine 1–2 log removal Ozone and chlorine dioxide 2 log removal	Removal of 5.5–8 log achievable
Cryptosporidium	0.5–1 log removal	1–2 log removal Long-term detention (1–6 months)	Conventional 2 log removal DAFF 2 log removal Direct Filtration 2 log removal Membrane[c] > 4 log removal	Ozone 0.5–2 log removal Chlorine dioxide 0.5–1 log removal UV light 3 log removal Chlorine and chloramines ineffective	Removal of 3.5–7 log achievable

DAFF = dissolved air flotation and filtration
[a] Log removals based on standard doses and minimum contact times of 30 minutes
[b] Using standard technology (catchment control, detention, conventional filtration, chlorination)
[c] Depending on pore size
(Adapted from the NHMRC *Australian Drinking Water Guidelines* (2002))

Table 3.5 – Categorisation of drinking-water system based on compliance with performance and safety targets

Quality of water system	Population size <5 000	5 000 to 100 000	>100 000
Excellent	90%	95%	99%
Good	80%	90%	95%
Fair	70%	85%	90%
Poor	60%	80%	85%

3.2.4 Directly Specified Requirements

Smaller municipal and community water suppliers often have limited resources and ability to develop individual system assessments and/or management plans. National regulatory agencies may therefore directly specify requirements/approved options. This may imply for example defining guidance notes for protection of well heads, specific and approved treatment processes in relation to source types and requirements for protection of drinking-water quality in distribution.

In some circumstances national or regional authorities may wish to establish model water safety plans to be used by local suppliers either directly or with limited adaptation. This may be of particular importance when supplies are community-managed. Where an approach focusing on ensuring operators receive adequate training and support to overcome management weaknesses may be more effective than enforcement of compliance.

Model WSPs are available in publications accompanying these guidelines for the following types of water supply and household management of water:

- Groundwater from protected boreholes/wells with mechanised pumping
- Conventional treatment of water
- Multi-stage filtration
- Storage and distribution through utility managed piped systems
- Storage and distribution through community managed piped systems
- Water vendors
- Water on vessels (ships, trains, planes)
- Tubewell from which water is collected by hand

Model WSPs are also available for household collection and treatment of water and water hygiene. These should be used in conjunction with hygiene education programmes to support health promotion to reduce diarrhoeal disease.

- Spring from which water is collected by hand
- Simple protected well
- Rainwater catchment
- Household handling and storage of water
- Household disinfection
- Household filtration systems
- Household combined systems (coagulation-flocculation, filtration and disinfection)

Performance requirements are also important in certification of devices, for drinking-water treatment and for pipe installation that prevent ingress. Enforcement of minimum design criteria by manufacturers of water treatment technologies is discussed elsewhere (see also 1.2.8*). (For further information – see WHO Water Safety Plan)*

3.3 General Considerations in Establishing Health-based Targets

Health based targets need to be realistic, relevant to local conditions and reflect the relative importance of drinking water as a source of hazards in individual settings. While water can be a major source of enteric pathogens and hazardous chemicals it is by no means the only source. In setting targets consideration needs to be taken of other sources of hazards including food, air and person-person contact and the impact of poor sanitation and personal hygiene. There is no point in establishing extremely strict target concentrations for a chemical for example such as acrylamide, "a threshold" chemical, if drinking water only provides a small proportion of total exposure. The cost of meeting such targets could unnecessarily divert funding from other more pressing health interventions.

Health-based targets and water quality improvement programs should also be viewed in the context of a broader holistic program of public health promotion. These broader programs should include initiatives to improve sanitation, waste disposal, personal hygiene and public education on mechanisms for reducing both personal exposure to hazards and the impact of personal activity on water quality. Improved public health, reduced carriage of pathogens and reduced human impacts on water resources will contribute to the preventive management strategy for assuring drinking-water quality.{Cross reference healthy cities, healthy villages, school hygiene}.

3.3.1 Assessment of risk in the overall framework

In the framework for water quality management, assessment of risk is not a goal in its own right but rather a basis for decision-making and is the starting point in the first iteration of the cycle. For the purposes of these Guidelines, emphasis is upon health and, as such, it is considered an assessment of health risk. In applying the Guidelines to specific circumstances other non-health factors should be taken into account as these may have a considerable impact upon both costs and benefits.

In developing strategies for control of drinking-water quality as part of wider public health protection measures it is 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 therefore are not justified in health terms. This may be the case where other routes of exposure dominate (drinking-water treatment with the sole aim to reduce zoonotic pathogens endemic in domestic animals, e.g. *Cryptosporidium parvum*, in a community where the human population is exposed to the pathogen through direct contact with their domestic animals and their faeces). For others, long experience has shown the effectiveness of management strategies at the level of water supply and quality (e.g. typhoid, dysentery caused by *Shigella*).

3.3.2 Reference level of risk

Descriptions of a "reference level of risk" in relation to water are typically expressed in terms of specific health outcomes (such as cancer, diarrhoeal disease, etc.), e.g. a maximum frequency of diarrhoeal disease incidence.

Given the diverse range of water related infections and the severity of immediate and delayed health outcome with some infections, a common exchange unit is essential in order to account for acute, delayed and chronic effects (including both morbidity and mortality). These include diverse effects; varied severity weightings; and acute versus delayed effects such as adverse birth outcomes, cancer, cholera, dysentery, infectious hepatitis, intestinal worms, skeletal fluorosis, typhoid, association of Guillain-Barré syndrome with campylobacteriosis, (mild self-limiting diarrhoea through to significant case mortality rates). This is done in order to maximise relevance to policy development and decision-making.

A reference level of risk is used, expressed in disability adjusted life-years (DALYs), to enable the comparison of water-related diseases to one another. For these purposes, only the public health effects of waterborne disease are taken into account. For the purpose of guideline derivation, the preferred option is to define an absolute upper level of tolerable risk, which is the same for exposure to each individual hazard.

Decisions about risk acceptance are highly complex and need to take account of different dimensions of risk. In addition to the 'objective' dimensions of probability and severity of an effect, there are important socio-cultural, economic, environmental and political dimensions that play an important role in decision-making. Negotiations play an important role in these processes, and the outcome may very well be unique in each situation. Notwithstanding the complexity of decisions about risk, there is a need for a baseline definition of tolerable risk for the development of guidelines and as a departure point for decisions in specific situations.

For the purposes of these Guidelines, the reference level of risk is 10^{-6} DALYs per person per year which is approximately equivalent to a lifetime cancer risk of 10^{-5} (i.e. one excess case of cancer per 100,000 of the population ingesting drinking-water containing the substance at the guideline value for a lifespan of 70 years). For a pathogen causing watery diarrhoea with a low case fatality rate (e.g. 1 in 100,000) this reference level of risk would be equivalent to 1/1000 annual risk of infection and disease to an individual (approximately 1/10 over a lifetime).

Disability Adjusted Life Years (DALYs)
For guideline derivation, the preferred option is to define an absolute upper level of tolerable risk, which is the same for exposure to each individual contaminant. As waterborne disease be of widely different nature, severity and duration, a common unity is necessary. This is needed to compare health effects of micro-organisms and carcinogens for example. DALYs is the preferred metric.

The basic principle of the DALY approach is to weigh each health effect for its severity with (usually) death as the most severe outcome (weight 1), multiply this weight with the duration of the health effect ('duration' of death being the remaining group life expectancy), and with the number of people affected by the particular outcome. Summarizing over all the health outcomes caused by a certain agent, this results in an estimate of the burden of disease attributable to this agent.

Thus, Disability Adjusted Life Years combine years of life lost by premature mortality (YLL) with years of life lived with a disability (YLD), that are standardized by means of severity weights. Thus:

$$\mathbf{DALY = YLL + YLD}$$

DALYs have been extensively used to compare the health of different populations and to define public health priorities, both at an international and national level. DALYs can be used to integrate the health effects of different illnesses associated with one agent (e.g. gastroenteritis, Gullain-Barré syndrome, reactive arthritis and mortality associated with *Campylobacter*), to compare the health impact of different agents in water (e.g. *Cryptosporidium parvum* and bromate and the net health benefits of ozonation in drinking-water treatment). DALYs can be used to define reference level of tolerable risk, to be applied to all waterborne agents of disease and related to both pathogens and to levels accepted for chemical agents.

Example of the application of the DALYs approach
Different cancers have different severity, manifested mainly by different mortality rates. A typical example is renal cell cancer, associated with exposure to bromate in drinking-water. The health burden of renal cell cancer, taking into account an average case-fatality ratio of 60% and average age at onset of 65 years is 11.4 DALYs per case (Havelaar et al., 2000). This value can be used to convert the tolerable lifetime cancer risk in a tolerable annual loss of DALYs. 10^{-5} cancer cases / 70 years of life x 11.4 DALYs per case = 1.6×10^{-6} DALYs per personyear or a tolerable loss of 1.6 healthy life years in a population of a million over a year. For the purposes of these guidelines this reference level of risk is rounded to 10^{-6} DALYs/person/year. For countries that use a stricter definition of the level of acceptable risk of carcinogens (usually 10^{-6}) the tolerable loss will be proportionately lower (i.e. 1.6×10^{-7} DALYs per personyear).

Further information on the use of DALYs in establishing health-based targets is included in “Quantifying Public Health Risks in the WHO Guidelines for Drinking-water Quality.