chapter 1: health and sanitation

1.1 necessity of water supply (Heber 1985)

Water is one of the basic necessities of life. Without one or two litres of water per day a human being cannot survive. And, to lead a minimal human existence, one needs between 20 litres (in regions with scare water resources) and 50 litres (comfortable plain living standards) of water per day for drinking, the preparation of food, and personal hygiene. For many people, this bare minimum is unattainable, because clean water is scarce. Only 0.8% of the earth surface water is available for human beings to use. More than half the population of the Third World have no adequate access to clean drinking water, three-quarters have no sanitary facilities. The rural population is especially affected.

Table 1.1: Number of people in the Third world (million) without access to clean water and sanitation (excluding China) 1980.(Heber 1985)

1980	**Total Population [million]**	**Population without clean water [million]**	**Population without sanitation [million]**
Urban	703	177 (25%)	331 (47%)
Rural	1612	1143 (71%)	1399 (87%)
Total	2315	1320 (57%)	1730 (75%)

(WHO 1997)The provision of an adequate supply of safe water was one of the eight components of primary health care identified by the International conference on Primary Health Care in Alma-Ata in 1978.

In most countries the principal risks to human health associated with the consumption of polluted water are microbiological in nature (although the importance of chemical contamination should not be underestimated). As indicated in Chapter 18 of "Agenda 21" of UNCED, "An estimated 80% of all diseases and over one-third of death in developing countries are caused by the consumption of contaminated water and on average as much as one-tenth of each person's productive time is sacrificed to water-related diseases."

The risk of acquiring a waterborne infection increases with the level of contamination by pathogenic microorganism. However, the relationship is not necessarily a simple one and depends very much on factors such as infectious dose and host susceptibility. Drinking water is only one vehicle for the disease transmission.

Some agents may be transmitted primarily from person to person and, for bacteria capable of multiplication in food, foodborne transmission may be more important than transmission by drinking-water. Other agents, however, such as *Salmonella typhi, Vibrio cholerae, Giardia lamblia* and hepatitis A virus, are frequently transmitted via contaminated drinking-water and, where this is the case, improvements in drinking-water quality may result in substantial reductions in disease prevalence. Because of this multiplicity of transmission routes, improvements in the quality and availability of water, excreta disposal, and hygiene in general are all important factors in reducing diarrhoea morbidity and mortality.

In the same way that indicators of the quality of water-supply services have been found useful in guiding remedial action, indicators of hygiene practices should also be used. Such indicators should be based on simple, standardized observations, and used to guide hygiene education programmes and the selection of key messages regarding hygiene behaviours.

1.2 water related diseases- an overview (Ghosh, Kamal et al. 1995)

The availability of safe drinking water has a direct bearing on the working conditions and health of the people and their capacity for optimum production. This relationship is evident in the WHO statistics which show that about 80% of all diseases in the developing countries are related to unsafe water supply and inadequate sanitation, causing high infant mortality, low life expectancy and poor quality of life.

In terms of socio-economic development, the resource lost as a result of illness is human labour. The impact of sickness can be measured in terms of death, loss of workers, loss of working time, and loss of productive capacity while at work. In case of water related illness, massive costs are entailed in the share of a nation's resources viz. man-power and material, that are used for the health services and ancillary components.

(WBGU 1997) In the first half of the 20th century, many infectious diseases were thought to be in decline. Unfortunately, many parts of the world are now witnessing a resurgence of this diseases. This situation is a result of numerous and disparate factors:

- rapid population growths
- dense human settlement near forests and swamps
- high mobility
- global trade
- inappropriate use of pesticides and antibiotics
- adaptation of pathogens to environmental conditions
- social and political disintegration
- perturbation of regional climate

In global terms, waterborne infections are still one of the principal causes of disease and death, particularly in developing countries in the tropics and subtropics. Such infections are gaining significance in the industrial nations as well, mainly due to highly resistant parasitic pathogens. About half the world population currently suffers from water-related diseases. For this reason, regulated water supply and sewage disposal meeting the water hygiene criteria of the WHO represent some of the most effective measures for combating these diseases worldwide.

1.2.1 diseases related to water use (WBGU 1997)

In addition to poisoning by contaminants in water, there are numerous infections that can be transmitted by the use of water. A distinction must be made here between infections transmitted

1. by the use of contaminated water or through skin contact with contaminated freshwater or seawater, or

2. by animal hosts or carriers that transmit the pathogens in the area surrounding their freshwater habitats.

Table 1.2 provides an overview of the major waterborne diseases, listed according to a systematic biological classification of pathogens.

Table 1.2: water related diseases (WBGU 1997)

	Pathogen	Disease	Vector	Endangered persons (million)[a]	Incidence (1,000 per year)	Deaths (1,000 per year)	Growth through climate change
Viruses	Polio viruses	Poliomyelitis		no data	110	5	
	Dengue viruses (DEN virus)	Dengue fever	e.g. *Aedes aegypti* (mosquito)	2,400	560	23	++
	Yellow fever viruses (YF virus)	Yellow fever	e.g. *Aedes aegypti* (mosquito)	450	200	30	++
Bacteria	Pathogenic *Escherichia coli*, *Shigella* et al.	Diarrheas		no data	1,200,000 –1,800,000	3,000 –4,000	
	Salmonella typhi	Typhoid		no data	16,000	600	
	Legionella pneumophila	Legionnaire's disease			no data	no data	no data
	Vibrio cholerae	Cholera		no data	380	120	?
Protozoa	*Entamoeba histolytica*	Amoebiasis (amoebic dysentry)		no data	no data	no data	
	Cryptosporidium parvum	Cryptosporidiosis		no data	no data	no data	
	Giardia lamblia	Lambliasis		no data	500		
	Plasmodium sp.	Malaria	*Anopheles* (mosquito)	2,400	300,000 –500,000	2,100	+++
Trematodes	*Schistosoma* sp. (flatworm)	Schistosomiasis or bilharziosis	freshwater snail	600	200,000	20	++
Nematodes	*Wucheria* sp., *Brugia* sp.	Lymphatic filariosis	mosquito	1,094	117,000	no data	+
	Onchocerca volvulus	Onchocerciasis (river blindness)	blackfly	123	17,500	no data	++
	Dracunculus medinensis (guinea worm)	Dracunculiasis	Crustaceans (water flea)	100	100	no data	?

\+ = probable ++ = very probable +++ = highly probable ? = unknown
[a] Projections for population growth, based on 1989 figures.

2.2 Use of contaminated drinking water (WBGU 1997)

Local communities need an infrastructure that is technically and epidemiologically intact in order to ensure an adequate level of water hygiene. Even in developed countries, epidemics are often caused by the consumption of drinking water contaminated with sewage as a result of damage to the pipe system.

Infections transmitted through drinking water are particularly widespread in developing countries where faecal-oral transmission is a consequence not only of poor drinking water quality, but also of insufficient water for sanitation purposes. 25 million people in the developing world die each year from drinking infected or contaminated water. Pathogens or carriers in water are responsible for 99% of the diseases transmitted by drinking water worldwide, while only 1% occurs as a result of chemical pollution. The infections are mainly due to protozoa (*Giardia*, Cryptosporidia), bacteria (e.g. *Escheria coli*, Salmonella, Shigellae, *Campbylobacter* sp., Yersiniae, *Vibrio Cholerae*) or viruses (e.g. rotaviruses). These pathogens are able to enter the drinking water system and cause acute enteric diseases or even systemic infections because drinking water and sewage systems are inadequately separated.

Globally, acute diarrheal diseases are the second most frequent cause of infant mortality, after acute respiratory illness (WHO, 1996).

There is an obvious relationship here between access to clean drinking water and infant mortality. (see. Figure 1.1)

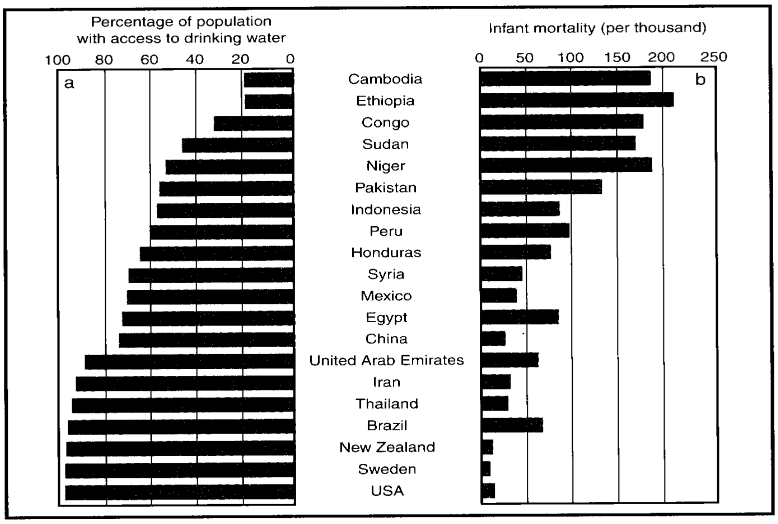

Figure 1.1: relationship between infant mortality and drinking water quality (WBGU 1997)

Cholera alone claims 120,000 lives annually. This infectious disease has re-emerged in many places recently where it was previously assumed to be wiped out. Cholera can be transmitted not only through drinking water, but also through brackish water, when people swim in the sea, or through the ingestion of contaminated fish.

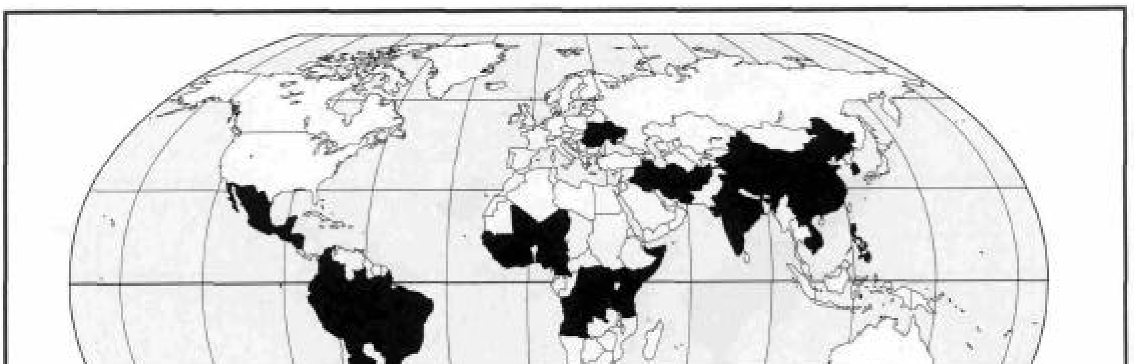

Figure 1.2: outbreaks of cholera in 1995 (WBGU 1997)

1.3 Sanitation concept

For all this reasons it is necessary to have a good sanitation concept with individual solutions. Figure 1.3 shows a sanitation concept for water supply and waste water disposal. Very important is the separation between the water supply and the waste water disposal.

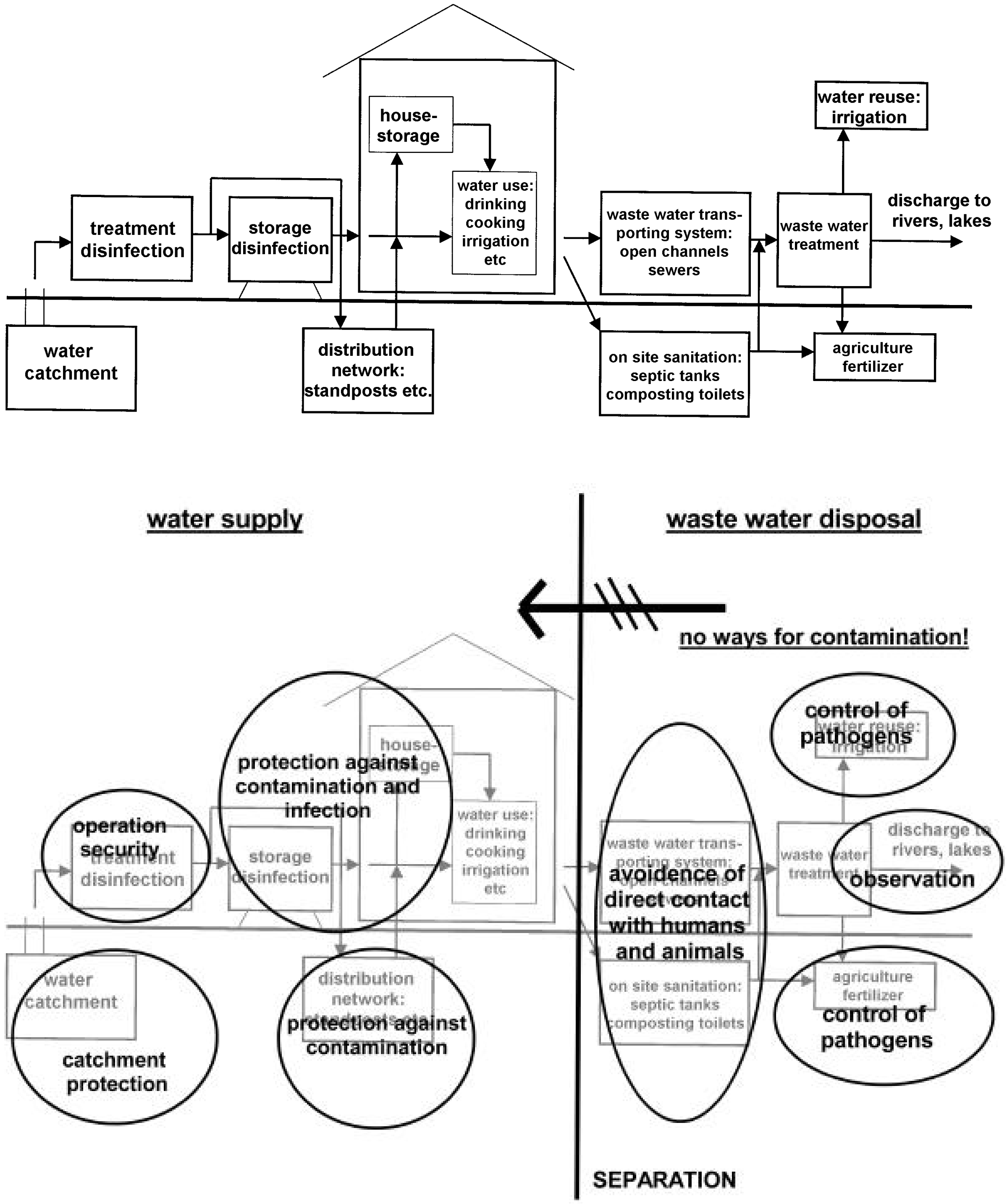

Figure 1.3: sanitation concept

1.4 water withdrawal (WBGU 1997)

Statistical surveys on national water use usually distinguish between agricultural, domestic and industrial withdrawals. Table 1.3 gives an overview on the world-wide water withdrawal.

Table 1.3: Annual domestic and agricultural water withdrawals (WBGU 1997)

		Africa	Asia	Europe	North America	South America	Oceania
	year	1995	1987	1995	1995	1995	1995
total	[km³]	145	1,633	455	608	106	17
Agriculture							
per capita	[m³]	175	460	244	711	196	199
total	[%]	88	85	31	49	59	34
domestic							
per capita	[m³]	199	542	626	1,451	332	586
total	[%]	7	6	14	9	18	19

1.5 water quality standards (WBGU 1997)

- Water for human use (drinking etc.) must meet the highest quality standards. Microbiological parameters are of paramount importance in this context. (see section 1.6).
- Irrigated agriculture has the largest share of global water consumption. The concentration of faecals and certain ions (sodium, chlorine, etc.) is critical in this connection (see lecture 6).
- Water that is used for industry mainly for cooling, transport and power generation. The (low) quality standards are very different.

For some types of use, such as irrigation, fisheries or industry, quality criteria have been defined only roughly! The adaptation of water quality standards is focused world-wide on health protection for the population and on protecting the environment.

1.6 (drinking) water quality

The basic quality requirements of drinking water are that it should be free of pathogens and toxic substances. In addition, water should have a pleasant appearance, and be of a neutral smell and taste. WHO has established guidelines and standards for the quality of drinking water. They include microbiological criteria, chemical and physical aspects. The WHO guidelines on drinking water quality are not legally binding. They can serve only as minimum requirements when developing national standards.
In table 1.4 different drinking water standards are compared.

Table 1.4: Comparison of selected parameters for drinking water standards (WBGU 1997)

	Variable	WHO	EU	Canada	USA	USSR
Physical	Color (color units)	15	20	15	15	
	Turbidity (turbidity index)	5	4			
Chemical	pH value	6.5–8.5	6.5–8.5	6.5–8.5	6.5–8.5	
	Oxygen (mg l^{-1})					4
	Dissolved salts (mg l^{-1})	1.000		500	500	
	Hardness (mg l^{-1} $CaCO_3$)	500				
	Ammonium (mg l^{-1})		0.5			2
	Nitrate-nitrogen (mg l^{-1})	10		10	10	
	Nitrate (mg l^{-1})		50		10	
	Nitrite-nitrogen (mg l^{-1})		1			
	Nitrite (mg l^{-1})		0.1			1.0
	Phosphorus (mg l^{-1})		5			
	Sodium (mg l^{-1})	200	150–175			
	Chloride (mg l^{-1})	250	25	250	250	350
	Sulfate (mg l^{-1})	400	25	500	250	500
	Fluoride (mg l^{-1})	1.5	1.5–0.7	1.5	2	1.5
	Cyanide (mg l^{-1})	0.1		0.2		0.1
	Arsenic (mg l^{-1})	0.05	0.05	0.05	0.05	
	Lead (mg l^{-1})	0.05	0.05	0.05	0.05	0.03
	Cadmium (mg l^{-1})	0.005	0.005	0.005	0.01	0.001
	Chromium (mg l^{-1})	0.05	0.005	0.05	0.05	0.1–0.5
	Iron (mg l^{-1})	0.3	0.3	0.3	0.3	0.5
	Copper (mg l^{-1})	1	0.1	1	1	1
	Nickel (mg l^{-1})		0.05			
	Mercury (mg l^{-1})	0.001	0.001	0.001	0.002	0.0005
	Crude oil (mg l^{-1})		0.01			0.3
	Sum of pesticides (µg l^{-1})		0.5			
	Individual pesticides (µg l^{-1})		0.1			
	Aldrin, Dieldrin (µg l^{-1})	0.03		0.7		
	DDT (µg l^{-1})	1		30		
	Lindan (µg l^{-1})	3		4	0.4	
	Benzene (µg l^{-1})	10			5	
	Hexachlorobenzene (µg l^{-1})	0.01				
	Pentachlorophenol (µg l^{-1})	10				
	Phenols (µg l^{-1})		0.5	2		1
	Detergents (mg l^{-1})		0.2		0.5	0.5
Biological	BOD (mg O_2 l^{-1})					3
	Faecal coliforms (in 100 ml)	0	0	0		
	Coliforms (in 100 ml)	0–3		10	1	

no data: variable not specified

1.6.1 Microbiological aspects (WHO 1997)

Ideally, drinking-water should not contain any microorganisms known to be pathogenic – capable of causing disease – or any bacteria indicative of faecal pollution. To ensure that drinking-water supply satisfies these guidelines, samples should be examined regularly. The detection of *Escherichia coli* provides definite evidence of faecal pollution; in practice, the detection of thermotolerant (faecal) coliform bacteria is an acceptable alternative.

Although developed for large water- supply systems, the values for treated and untreated water supplies are also applicable to community supplies.

The application of any proposed guidelines and procedures must be governed by epidemiological considerations in at least two respects:

- Many parasites have a complex geographical distribution and it may be unnecessary to take precautions against those that do not occur locally.
- The majority of waterborne parasites are also transmissible by other routes, such as food and direct faecal-oral spread, and these routes should also be considered in the formulation of strategies for control.

Species of protozoa known to have been transmitted by the ingestion of contaminated drinking-water include *Entamoeba histolytica* (which causes amoebiasis), *Giardia* spp., and *Cryptosporidium.* These organisms can be introduced into a water supply through human or, in some instances, animal faecal contamination. Coliform organisms do not appear to be a good indicator of *Giardia* or *E. histolytica* in drinking-water: enteroviruses and protozoa are more resistant to disinfection than *E. coli,* so that absence of *E. coli* will not necessarily indicate freedom from these organisms.

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 fertilised egg can cause infection, and such infective stages should be absent from drinking-water. However, the water route is relatively unimportant except in the case of *Dracunculus medinensis* (the guinea worm), which is encountered mainly in unpiped water supplies. While there are methods for detecting this parasite, they are unsuitable for routine monitoring.

1.6.2 Chemical aspects (WHO 1997)

In rural areas of developing countries, the great majority of health-related water- quality problems are the result of bacteriological or other biological contamination. Nevertheless, a significant number of very serious problems (corrosion etc) may occur as a result of the chemical contamination of water resources. In order to establish whether such problems exist, chemical analyses must be undertaken. However, it would be extremely costly to undertake the determination of a wide range of parameters on a regular basis, particularly in the case of supplies that serve small numbers of people. Fortunately, such parameters tend be less variable in source waters than faecal contamination, so that alternative strategies can be employed.

(WBGU 1997) Chemicals in drinking water can be classified into the following groups according to their significance for health:

Type 1: Substances of acute or chronic toxicity. The toxicity rises with increasing concentration. Below a threshold value, however, no impairment to health or long-term damage is detected.

Type 2: Cancerogenic, mutagenic and teratogenic substances without threshold value.. Even minimal quantities increase the likelihood of impairment (especially arsenic and PCB).

Type 3: Essential substances required by the human organism and harmful in high concentrations (fluoride, iodide, copper)

(WHO 1997) Some potentially chronic effects may occur in rural areas where overuse of agrochemicals leads to significant levels of pesticides in water sources. The presence of nitrate and nitrite in water may result from the excessive application of fertilisers or from leaching of wastewater or other organic wastes into surface water and groundwater. Although effects may be difficult to detect in human populations, such contaminants may pose a risk to health.

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, after long- term exposure, affect the mental development of children. Exposure to high levels of naturally occurring fluoride can lead to mottling of teeth and (in severe cases) skeletal fluorosis and crippling. Similarly, arsenic may occur naturally, and long- term exposure via drinking-water may result in a risk to health.

More acute health effects of chemical contamination of small-community supplies include methaemoglobinaemia in infants due to high levels of nitrate, and toxicosis due to accidental and other discharges of solvents and heavy metals from mining activities.

In order to establish whether or not this type of problem exists, a selected number of physicochemical parameters may have to be measured. However, it may be both very costly and physically impractical to cover a large number of parameters, particularly in the case of rural water supplies in developing countries.

If certain chemical contaminants are of special local significance, the levels should be measured and the results evaluated. It should also be noted that 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 goitre caused by iodine deficiency and dental caries resulting from low fluoride intake. No attempt has been made in these guidelines to define a minimum desirable concentration of such substances in drinking-water.

In the following tables (1.5 and 1.6) are given some drinking water standards from the Swiss Center of Appropriate Technology (SKAT).

Table: 1.5: chemical substances, affecting the potability of water (SKAT and Technology 1985)

substance	**max. acceptable concentration**	**max. allowable concentration**
	[mg/l]	[mg/l]
total solids	500	1500
Iron	0.3	1.0
Magnesium	50	150
Manganese	0.1	0.5
Copper	1.0	1.5
Calcium	75	200
Sulphate	200	400
Chloride	200	600
Phenolic substances	0.001	0.002
Carbon Chloroform extract	0.2	0.5
Alkyl Benzyl Sulphonates	0.5	1.0
pH Range	7.0-8.5	<6.5;>9.2

Table 1.6: toxic substances in drinking water (SKAT and Technology 1985)

substance	max. allowable concentration
	[mg/l]
Lead	0.05
Arsenic	0.05
Selenium	0.01
Chromium	0.05
Cyanide	0.2
Cadmium	0.01
Barium	1.0

1.6.3 Physical and aesthetic aspects (WHO 1997)

The chemical and physical quality of water may affect its acceptability to consumers. Turbidity, colour, taste, and odour, whether of natural or other origin, affect consumer perceptions and behaviour.

Although aesthetically unacceptable water normally is contaminated, you cannot say that aesthetically pleasant water guaranties a safe supply.

Although guidelines for drinking-water quality are based on the best available public health advice, there is no guarantee that consumers will be satisfied or dissatisfied by water supplies that meet or fail to meet those 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.

- Turbidity in excess of 5 “nephelometric turbidity unit” (NTU) may be noticeable and consequently objectionable to consumers, because it effects both the acceptability of water to consumers, and the selection and efficiency of treatment processes.
- Colour in drinking-water may be due to the presence of organic matter such as humic substances, metals such as iron and manganese, or highly coloured industrial wastes. Experience has shown that consumers may turn to alternative, perhaps unsafe, sources, when their water displays aesthetically displeasing levels of colour, typically exceeding 15 true colour unit (TCU). Drinking-water should ideally be colourless.
- Odour in water is due mainly to the presence of organic substances. Some odours are indicative of increased biological activity, while others may originate from industrial pollution. Sanitary surveys should include investigations of sources of odour when odour problems are identified.

The combined perception of substances detected by the senses of taste and smell is often called “taste“. “Taste“ problems in drinking-water supplies are often the largest single cause of consumer complaints. 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. Water should be free of tastes and odours that would be objectionable to the majority of consumers.

1.6.4 Critical parameters of drinking-water quality in community supplies (WHO 1997)

The principal risks to human health associated with community water supplies are microbiological, and it has been traditional to rely on relatively few water- quality tests to establish the safety of supplies. Some agencies refer to this strategy as “minimum monitoring’, while others use the term “critical-parameter testing“.

The approach is based on the assumption that health authorities will be aware of other specific sources of risk in each region, such as chemical contamination, and will include these in the monitoring scheme. It is much more effective to test for a narrow range of key parameters as frequently as possible (in conjunction with a sanitary inspection) than to conduct comprehensive but lengthy and largely irrelevant analyses less frequently.

The parameters recommended for the minimum monitoring of community supplies are those that best establish the hygienic state of the water and thus the risk (if any) of waterborne infection. The critical parameters of water quality are thus:

- E. coli; thermotolerant (faecal) coliforms are accepted as suitable substitutes;
- chlorine residual (if chlorination is practised).

These should be supplemented, where appropriate, by:

- pH (if chlorination is practised: where the pH exceeds 8.0, disinfection is less effective!);
- turbidity (in case of surface- and spring waters and if any treatment is effected).

However, an advantage worth noting here is that these critical parameters may be measured on site using relatively unsophisticated testing equipment. On-site testing is essential for the determination of turbidity and chlorine residual, which change rapidly during transport and storage; it is also important for the other parameters where laboratory support is lacking or where transportation problems occur would render conventional sampling and analysis difficult or impossible. Water suppliers need to carry out a wider range of analyses relevant to the operation and maintenance of water-treatment and distribution systems, in addition to the health-related parameters laid down in national water-quality standards.

Other health-related parameters of local significance should also be measured. It may sometimes be useful to include total coliforms in the bacteriological analysis, e.g. if chlorination is practised and there is an extensive distribution network.

1.7 Water sampling and analysis (WHO 1997)

Ideally, a laboratory infrastructure should be established which will enable all samples to be returned to a central or regional laboratory within a few hours. However, this depends on the availability of a good road system and of reliable motorised transport for all sampling officers, and these are not available in many countries. Thus, although it may be possible to establish well-equipped central and even regional laboratories for water analysis, at the provincial and district levels it may be necessary to rely on a relatively small number of simple tests. This approach is sometimes called critical-parameter water testing.

The most important factor to take into account is that, in most communities, the principal risk to human health derives from faecal contamination. In some countries there may also be hazards associated with specific chemical contaminants such as fluoride or arsenic, but the levels of these substances are unlikely to change significantly with time. Thus, if a full range of chemical analyses is undertaken on new water sources and repeated thereafter at fairly long intervals, chemical contaminants are unlikely to present an unrecognised hazard. In contrast, the potential for faecal contamination in untreated or inadequately treated community supplies is always present. The minimum level of analysis should therefore include testing for indicators of faecal pollution (thermotolerant (faecal) coliforms), turbidity, and chlorine residual and pH (if the water is disinfected with chlorine).

Wherever possible the community should be involved in the sampling process. Where water is disinfected, primary health workers, schoolteachers, and sometimes community members can be trained to carry out simple chlorine residual testing. The same people could also collect samples for physicochemical analysis and arrange for their delivery to the regional laboratory. The use of community members in this way has significant implications for training and supervision but would be one way of ensuring more complete surveillance coverage.

1.7.1 Indicator organisms (WHO 1997)

In the following, a summary of the properties and significance of the commonly used faecal indicator bacteria is provided.

Escherichia coli (E. coli) is a member of the family Enterobacteriaceae. It grows at 44 – 45°C on complex media, ferments Lactose and mannitol with the production of acid and gas, and produces indole from tryptophan. However, some strains can grow at 37’C but not at 44 – 45’C, and some do not produce gas. E. coli does not produce oxidase or hydrolyse urea.

Escherichia coli is abundant in human and animal faeces; in fresh faeces it may attain concentrations of 10^9 per gram. It is found in sewage, treated effluents, and all natural waters and soils subject to recent faecal contamination, whether from humans, wild animals, or agricultural activity. Recently, it has been suggested that E. coli may be present or even multiply in tropical waters not subject to human faecal pollution. However, even in the remotest regions, faecal contamination by wild animals, including birds, can never be excluded. Because animals can transmit pathogens that are infective in humans, the presence of E. coli or thermotolerant coliform bacteria must not be ignored, because the presumption remains that the water has been faecally contaminated or that treatment has been ineffective.

Thermotolerant coliform bacteria

Thermotolerant coliform bacteria are the coliform organisms that are able to ferment lactose at 44 – 45°C; the group includes the genus Escherichia and some species of Klebsiella, Enterobacter, and Citrobacter. Thermotolerant coliforms other than E. coli may also originate from organically enriched water such as industrial effluents or from decaying plant materials and soils. For this reason, the term “faecal“ coliforms, although frequently employed, is not correct, and its use should be discontinued.

Regrowth of thermotolerant coliform organisms in the distribution system is unlikely unless sufficient bacterial nutrients are present, unsuitable materials are in contact with the treated water, the water temperature is above 13°C, and there is no free residual chlorine. In most circumstances, concentrations of thermotolerant coliforms are directly related to that of E. coli. Their use in assessing water quality is therefore considered acceptable for routine purposes, but the limitations with regard to specificity should always be borne in mind when the data are interpreted. If high counts of thermotolerant coliforms are found in the absence of detectable sanitary hazards, additional confirmatory tests specific for E. coli should be carried out.

Because thermotolerant coliform organisms are readily detected, they have an important secondary role as indicators of the efficiency of water-treatment processes in removing faecal bacteria.

Coliform organisms (total coliforms)

Coliform organisms have long been recognized as a suitable microbial indicator of drinking-water quality, largely because they are easy to detect and enumerate in water. The term "coliform organisms" refers to Gram-negative, rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth-inhibiting properties and able to ferment lactose at 35 – 37°C with the production of acid, gas, and aldehyde within 24 – 48 hours.

Traditionally, coliform bacteria were regarded as belonging to the genera Escherichia, Citrobacter, Enterobacter, and Elebsiella. However, as defined by modern taxonomical methods, the group is heterogeneous. It includes lactose- fermenting bacteria, such as Enterobacter cloacae and Citrobacter peundii, which can be found in both faeces and the environment (nutrient-rich waters, soil, decaying plant material) as well as in drinking-water containing relatively high concentrations of nutrients, as well as species that are rarely, if ever, found in faeces and may multiply in relatively good-quality drinking-water.

The existence both of non-faecal bacteria that fit the definitions of coliform bacteria and of lactose-negative coliform bacteria limits the applicability of this group as an indicator of faecal pollution. Coliform bacteria should not be detectable in treated water supplies and, if found, suggest inadequate treatment, post- treatment contamination, or excessive nutrients. The coliform test can therefore be used as an indicator both of treatment efficiency and of the integrity of the distribution system. Although coliform organisms may not always be directly related to the presence of faecal contamination or pathogens in drinking-water, the coliform test is still useful for monitoring the microbial quality of treated piped water supplies. If there is any doubt, especially when coliform organisms are found in the absence of thermotolerant coliforms and E. coli, identification to the species level or analyses for other indicator organisms may be undertaken to investigate the nature of the contamination. Sanitary inspections will also be needed.

Faecal streptococci

Faecal streptococci are those streptococci generally present in the faeces of humans and animals. They can generally be regarded as specific indicators of human faecal pollution for most practical purposes. Faecal streptococci rarely multiply in polluted water, and they are more persistent than E. coli and coliform bacteria. Their primary value in water-quality examination is therefore as additional indicators of treatment efficiency. Moreover, streptococci are highly resistant to drying and may be valuable for routine control after new mains are put to operation or distribution systems are repaired, or for detecting pollution of groundwaters or surface waters by surface run-off.

Table 1.7: Guideline values for bacteriological quality (WHO 1997)

Organisms	Guideline value
All water intended for drinking	
E.coli or thermotolerant coliform bacteria	Must not be detectable in any 100ml sample
Treated water entering the distribution system	
E.coli or thermotolerant coliform bacteria	Must not be detectable in any 100ml sample
Total coliform bacteria	Must not be detectable in any 100ml sample
Treated water in the distribution system	
E.coli or thermotolerant coliform bacteria	Must not be detectable in any 100ml sample
Total coliform bacteria	Must not be detectable in any 100ml sample In the case of large supplies, where sufficient samples are examined, must not be present 95% of samples taken throughout any 12-month period

1.8 Hygiene behaviours

The provision of a good drinking-water supply alone is insufficient to ensure health. There are many stages in the collection, storage, and handling of food, the disposal of excreta, and the care of children at which drinking-water can become contaminated and the community exposed to pathogens in excreta. Children, especially those under 5 years of age, are particularly vulnerable to diarrhoea. A common belief is that children’s faeces are harmless, whereas in fact they are the main source of infection of other children. Parents may not dispose of their young children’s faeces hygienically, young children may not use latrines, and the yards surrounding homes are often contaminated. There are many transmission routes for water-related and sanitation-related diseases, and hygiene education can therefore cover a wide range of actions. The most important behaviours from the point of view of health will depend on the community, the disease pattern, and the climate.

9 Behaviours to be recommended in hygiene education

Water source:

- All children, women, and men in the community should use safe water sources for drinking and food preparation.
- Adequate water should be used for hygiene purposes such as bathing, household cleanliness, and clothes washing.
- Water should be efficiently used and not wasted. Wastewater should be properly drained away. (re-using only under controlled conditions!)

- water-sources should be used hygienically and be well maintained.
- There should be no risk of contamination of water sources from nearby latrines, wastewater drainage, cattle, or agricultural chemicals.

Water treatment:

- Simple purification procedures, e.g. chlorination, should be carried out on the water source if necessary.
- If necessary, water should be filtered to remove any solid material, guinea worm, etc.

Water collection:

- Drinking-water should be collected in clean vessels without coming into contact with hands and other materials.
- Water should be transported in covered containers.

Water storage:

- Water should be stored only in vessels that are covered and regularly cleaned.
- Drinking-water should be stored in a separate container from other domestic water wherever possible.

Water drinking:

- Drinking-water should be taken from the storage vessel in such a way that hands, cups, or other objects cannot contaminate the water.

Water use:

- Adequate amounts of water should be available and used for personal and domestic hygiene. (It is estimated that a minimum of 20 – 50 litres per person per day are needed for personal and domestic hygiene.)

Food handling:

- Hands should be washed with soap or ash before food is prepared or eaten.
- Vegetables and fruits should be washed with safe water, and food should be properly covered.
- Utensils used for food preparation and cooking should be washed with safe water as soon as possible after use and left in a clean place.

Excreta disposal:

- All men, women, and children should use latrines at home, at work, and at school.
- The stools of infants and young children should be safely disposed of.
- Household latrines should be sited in such a way that the pit contents cannot enter water sources or the groundwater table.
- Hand-washing facilities and soap or ash should be available, and hands should always be washed after defecation and after helping babies and small children.

Wastewater disposal:

- Household wastewater should be disposed of or reused properly. Measures should be taken to ensure that wastewater is not allowed to create breeding places for mosquitoes and other disease vectors or to contaminate safe water.

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