Water and Public Health

Session Objectives

- To demonstrate the link between water and health and show the profound influence of water supply and quality on public health.

- To describe the basic classification of water-related disease.

- To describe the concept of the faecal-oral route of disease transmission and the classic water-borne disease cycle.

- To describe how improvements in water supplies will lead to improvements in health and a reduction in morbidity and mortality rates.

Water and Public Health

Introduction

Water has a profound influence on human health. At a very basic level, a minimum amount of water is required for consumption on a daily basis for survival and therefore access to some form of water is essential for life. However, water has much broader influences on health and well-being and issues such as the quantity and quality of the water supplied are important in determining the health of individuals and whole communities.

The first priority must be to provide access for the whole population to some form of improved water supply. However, access may be restricted by low coverage, poor continuity, insufficient quantity, poor quality and excessive cost relative to the ability and willingness to pay. Thus, in terms of drinking-water, all these issues must be addressed if public health is to improve. Water quality aspects, whilst important, are not the sole determinant of health impacts.

The quality of water does, however, have a great influence on public health; in particular the microbiological quality of water is important in preventing ill-health. Poor microbiological quality is likely to lead to outbreaks of infectious water-related diseases and may causes serious epidemics to occur.

Chemical water quality is generally of lower importance as the impact on health tend to be chronic long-term effects and time is available to take remedial action. Acute effects may be encountered where major pollution event has occurred or where levels of certain chemicals are high from natural sources, such as fluoride, or anthropogenic sources, such as nitrate.

Microbiological drinking-water quality and human health

The microbiological quality of drinking-water has been implicated in the spread of important infectious and parasitic diseases such as cholera, typhoid, dysentery, hepatitis, giardiasis, guinea worm and schistosomiasis.

Many other diseases are associated with water in other ways. Water may act positively in the control of some through its use in hygiene, and may act as a source or vector for others where contact with water is required for disease transmission or where agents of disease or insect vectors require water in which to complete their life cycle. The various relationships between water and disease are summarized in Table 1.

Water-related disease incidence worldwide

Water-related disease places an excessive burden on the population and health services of many countries worldwide and in particular those in developing countries. Table 2 shows estimates of the morbidity and mortality rates of some major water-related diseases worldwide, figures which are likely to be conservative estimates.

Table 1: Diseases related to water and sanitation

Group	Disease	Route leaving host	Route of infection
Diseases which are often water-borne	Cholera	faeces	oral
	Typhoid	faeces/urine	oral
	Infectious hepatitis	faeces	oral
	Giardiasis	faeces	oral
	Amoebiasis	faeces	oral
	Dracunculiasis	cutaneous	percutaneous
Diseases which are often associated with poor hygiene	Bacillary dysentery	faeces	oral
	Enteroviral diarrhoea	faeces	oral
	Paratyphoid fever	faeces	oral
	Pinworm (Enterobius)	faeces	oral
	Amoebaisis	faeces	oral
	Scabies	cutaneous	cutaneous
	Skin sepsis	cutaneous	cutaneous
	Lice and typhus	bite	bite
	Trachoma	cutaneous	cutaneous
	Conjunctivitis	cutaneous	cutaneous
Diseases which are often related to inadequate sanitation	Ascariasis	faecal	oral
	Trichuriasis	faecal	oral
	Hookworm (Ancylostoma/Necator)	faecal	oral/ percutaneous
Diseases with part of life cycle of parasite in water	Schistosomiasis	urine/faeces	percutaneous
Diseases with vectors passing part of their life cycle in water	Dracunculiasis	cutaneous	percutaneous

adapted from Bradley, D J, London School of Hygiene and Tropical Medicine, various

Forty per cent of mortality in children under five years of age is related to diarrhoeal disease and it has been estimated that in 1995 more than 1,500,000,000 episodes of diarrhoea occurred in children under five years of age in the developing world (excluding China) and that some 4,000,000 of these resulted in death.

Table 2: Morbidity and mortality rates of some important water-related diseases (after WHO, 1995)

Disease	Cases per year (thousands)	Deaths per year (thousands)
Cholera	384	11
Typhoid	500	25
Giardiasis	500	low
Amoebiasis	48,000	110
Diarrhoeal disease	1,500,000	4,000
Ascariasis	1,000	20
Trichuriasis	100	low
Ancylostoma	1,500	60
Dracunculiasis (Guinea worm)	> 5,000	-
Schistosomiasis	200,000	800
Trachoma	360,000 (active)	9,000 (blind)

These diseases are caused by the ingestion of contaminated faecal material transmitted by the transmitted by the faecal - oral route. Infectious agents of all types may be transmitted by the faecal - oral route via water, including viruses (such as infectious hepatitis, rotavirus and Norwalk agent); bacteria (such as cholera, typhoid and dysentery); and parasites (such as *Giardia*, *Cryptosporidium* and *Entamoeba*).

Faecal pollution of drinking-water may be sporadic and the degree of faecal contamination may be low or fluctuate widely. In communities where contamination levels are low, supplies may not carry life-threatening risks and the population may have used the same source for generations. However, where contamination levels are high, consumers (and especially the visitors, the very young, the old and those suffering from immuno deficiency-related disease, for instance through malnutrition or AIDS) may be at a significant risk of infection.

Improving water and sanitation and improvements in health

Results of epidemiological studies into the relationship between the quality of water supply and sanitation versus human health vary widely and there are severe methodological difficulties involved in undertaking such studies. Nevertheless there is sufficient evidence to support the conclusion that improving water supply and sanitation can have a significant impact on human health. Table 3 summarizes the findings of an extensive review of studies of this type.

Table 3: Percentage reduction in the diarrhoea morbidity rate attributed to improvements in water supply or excreta disposal

Type of Intervention	Number of Studies	Percentage reduction Median	Range
All	53	22	0-100
Water quality improvements	9	16	0-90
Improvements in availability	17	25	1-100
Improvements in availability *and* quality of water	8	37	0-82
Improvements in excreta disposal	10	22	0-48

Source: after Esrey, Feachem and Hughes, 1985

One of the reasons for the difficulty in undertaking studies on the health impact of improvements in water supply quality is that the faecal - oral route includes several and multiple routes to infection as summarized in Figure 1 below.

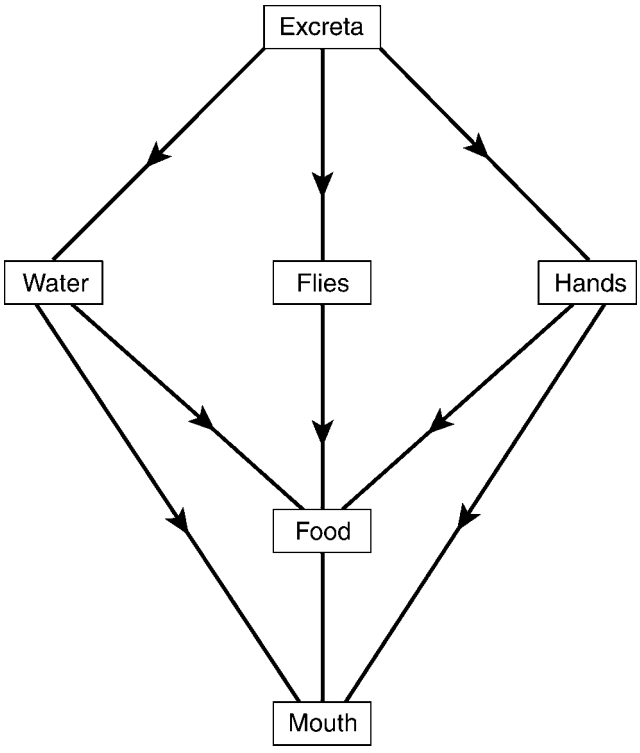

Figure 1: Principal elements of faecal - oral disease transmission

This complexity of routes also demonstrates the importance of various aspects of hygiene as complementary actions to water quality improvements.

Clearly, the likelihood of acquiring a waterborne infection increases with the level of contamination by pathogenic (disease-causing) microorganisms. However, the relationship is not necessarily a simple one and depends very much on factors such as infectious dose and host susceptibility.

Moreover there remains some doubt as to the relative importance of drinking-water quality and other aspects of water supply on the prevalence of infections with a faecal-oral route of transmission. For example, some agents with a low infectious dose may be transmitted primarily from person to person and thus improving the quality of drinking-water may not make a dramatic impact on their prevalence in the community. Human rotavirus and some species of *Shigella* fall into this category. Bacteria which are capable of multiplication in food may follow a food-borne transmission route more readily than waterborne.

Conversely there are other agents for example *Salmonella typhi, Vibrio cholerae, Giardia lamblia* and hepatitis A virus which are frequently transmitted via contaminated drinking-water. Where this is the case, improvements in water quality may result in substantial reductions in prevalence.

In those cases where transmission is not primarily water borne, improvements in water availability and personal hygiene may be much more important in reducing morbidity from diarrhoea and other water-borne infections.

The relative importance of drinking-water quality to the maintenance of public health may vary with respect to a number of geographical, social, seasonal and microbiological factors. It is not possible to state with any confidence which aspect of water supply is the most important at any one time or in any one location. What is becoming increasingly clear however is that *all* factors relating to the quality and availability of drinking-water are potentially important and must be taken into consideration. In this context it is worth emphasizing that one of the few general conclusions that may be drawn about drinking-water quality is that if faecally-derived pathogens are not present, then endemic or epidemic waterborne disease will not occur.

Other aspects of microbiological quality

As noted above, water borne disease is not exclusively transmitted by the faecal-oral route, although this route of disease transmission is of overwhelming importance globally. Some other microbiological aspects of importance are as follows:

Opportunistic and other water-associated pathogens

Opportunistic pathogens are naturally present in the environment and normally present no risk to human health. They are able to cause disease in people with impaired local or general immune defences. These people include the elderly and the very young; persons with extensive burns; persons undergoing immuno-suppressive therapy (such as following transplant surgery) and those with immuno deficiency-related diseases (such as AIDS). Examples of opportunistic pathogens of this type include *Pseudomonas aeruginosa*, certain species of *Flavobacterium, Acinetobacter, Klebsiella, Serratia, Aeromonas* and some 'slow growing' mycobacteria.

Inhalation of water containing certain infectious agents may also cause disease. This is the case with, for example, *Legionella spp* (Legionnaire's disease) and *Naeglaria fowleri* (an occasional cause of primary amoebic meningoencephalitis).

Cyanobacterial Toxins

Some cyanobacteria ('blue-green algae') are capable of producing toxins, including hepatotoxins, neurotoxins and lipopolysaccharides. Few epidemiological studies have been undertaken and little information is available regarding the true importance of this problem. Where blooms of cyanobacteria occur in lakes and reservoirs used for drinking-water supply a potential risk to health exists and therefore impounded surface waters used for drinking-water supply should be protected from contamination with nutrients.

Nuisance organisms

A number of organisms of no public health significance are undesirable because they produce turbidity, taste or odour or because they are visible to consumers of drinking-water. Their presence indicates that water treatment and supply system maintenance may be defective. These include: tastes and odours from *Actinomyces* and *Cyanobacteria*; and infestation of water mains by animal life feeding upon microbial films, such as the crustacean *Gammarus pulex, Nais* worms and the larvae of chironomids.

Chemical contamination and health

Chemical contamination of drinking-water may also have effects on health, although in general these tend to be chronic rather than acute, unless a specific pollution event has occurred and are therefore generally considered of lower priority than microbiological contamination.

Chemical pollutants which affect health include nitrate, arsenic, mercury and fluoride. In addition, there are an ever-increasing number of synthetic organic compounds released into the environment whose effect on human health is poorly understood, but which it appears may be carcinogenic.

Some details are given below on the four substances noted above, however, it must be recognized that raised concentrations of any chemical known to have an impact on human health may lead to long-term problems. In general, water sources used for drinking-water supply should be protected from chemical contamination through land-use control, definition of protection zones and application of adequate wastewater treatment.

Nitrate

Excess nitrate in drinking-water has been linked to methaemaglobinamenia in infants, the so-called ‘blue-baby’ syndrome. Nitrate leads to the oxidation of normal haemoglobin to methaemoglobin which is unable to transport oxygen to the tissues. This may result in cyanosis (a dark blue coloration) and in some cases, asphyxiation and death.

The Guideline Value (GV) for nitrate of 50 mg/l has been set on the basis of the acute health risk to infants and is unusual for this reason as most GVs are set for long-term risks. Many countries are now experiencing problems with elevated nitrate, particularly in groundwaters caused through poor treatment and disposal of excreta, intensification of animal husbandry and large-scale applications of inorganic and organic fertilizers.

In some countries, notably in the Countries of Central and Eastern Europe (CCEE) such as Moldova and Romania, levels have been recorded in shallow groundwater at up to 1000 mg/l, whilst in India anecdotal evidence suggest levels of up to 1500 mg/l. At these levels, more widespread chronic effects are likely to be noted including a possible greater likelihood of gastric cancer.

Nitrate is a conservative element in natural groundwaters and therefore once large-scale nitrate contamination has occurred, it will take a considerable period of time before it is naturally attenuated through de-nitrification or diluted. In these circumstances, short term measures will include identifying alternative sources of water, for instance deeper boreholes, or through blending with low-nitrate waters. Removal of nitrate by ion exchange in treatment plants is expensive as most anion exchangers are non-selective for nitrate and therefore nitrate specific resins must be used.

Long-term solutions must involve the reduction in the release of nitrate into the environment through, for example, control of fertilizer application and improvements in human and animal excreta treatment and disposal.

Arsenic

A provisional GV of 0.1 mg/l has been set for arsenic on the basis of an excess cancer risk of $6x10^{-4}$. In some parts of the world, natural sources of arsenic may contaminate water supplies and lead to poisoning of the users. The most well-documented cases of arsenic poisoning from drinking-water have come from India, where there is arsenic contamination of large numbers of rural water supplies. Common symptoms include inflamed eyes and skin lesions. Arsenic contamination has also been noted in southern Thailand and the CCEE.

Most natural arsenic comes from the reduction of arsenic complexes caused through changing redox and pH conditions and from the oxidation of arsenic containing minerals exposed by falling groundwater tables induced through over abstraction or reduced recharge.

There is also increasing evidence that there is a tendency for arsenic levels to increase in shallow groundwaters under urban areas. This has been particularly noted where conditions become anoxic, organic rich sediments are present and arsenate compounds associated with iron are common. This has significant implications for water supply in these areas, particularly in low-income areas where community-based water projects may involve the sinking of dug and wells and shallow tube wells. Arsenic may also be discharged in effluent from a variety of industrial processes.

Control options for arsenic contamination will vary according to the source. Arsenic derived from industrial effluents should be controlled through proper treatment of wastes and monitored by the pollution control agency. The control of arsenic from natural sources must include sustainable groundwater resource management. Many of the problems noted in India result from over-

abstraction of groundwater, primarily by the agricultural sector. Arsenic problems noted under urban areas may be more difficult to control given the range of factors which influence whether arsenic is released.

In all cases, short-term options will include treatment of water in home using, use of alternative sources or a switch to an alternative source, such as deep groundwater unaffected by arsenic contamination. Arsenic may be removed at treatment plants through a variety of processes, although like most treatment aimed at chemical removal, increase the costs of producing drinking-water.

Fluoride

Fluoride in drinking-water can have toxic effects in both excess and deficiency, although WHO only set a GV of 1.5 mg/l for excess fluoride as susceptibility in deficiency is highly dependent on nutritional status.

Excess fluoride may lead to dental or skeletal fluorosis, the latter being a crippling disease which affects a number of areas including the Rift valley of East Africa and parts of India, Mexico and the former Soviet Union. However, a lack of fluoride may cause dental caries, a weakening of the teeth, thus in some circumstances fluoride may be added to the drinking-water supply.

The acceptable concentration of fluoride in water is in part related to climate, as in warmer climates the quantities of water consumed are higher thus leading to a greater risk of fluoride related problems as overall intake increases. Susceptibility of individuals to fluorosis may also be determined by renal impairment.

Control options for fluoride contamination of water include blending of fluoride-rich waters with waters of low fluoride content, selection of low-fluoride sources and removal of fluoride by treatment at public water supply or household level. Fluoride can be successfully removed by precipitation by use of coagulants (commonly an alum-lime mix), adsorption on activated carbon substrates, osmosis or ion exchange. Fluoride removal is often more effective at a water supply level and the Nalgonda technique, developed in India, has been proven as a low-cost techniques which can operate on a variety of water supply options ranging from piped water supplies to handpump units.

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Water and Public Health

Presentation Plan

Section	Key points	OHP
Introduction	• water has a profound influence on health, at the most basic level this means that a minimum amount is required for consumption each day for survival • the influence of water on health goes far beyond this as water is a principal medium for disease prevention • WHO recognises that access to adequate water supplies is a fundamental human right • this was confirmed at the Mar del Plata conference in 1977	**1**
Water-related disease incidence	• water-related diseases account for over 80 per cent of all deaths in developing countries • infectious and parasitic diseases are the major cause of morbidity in developing countries and cause important outbreaks world-wide • many of the water-related diseases lead to epidemics which may have relatively high mortality/morbidity ratio	**2**
Water supply improvements	• improved water supply and sanitation will lead to reduced incidence of morbidity and mortality • this may be up to 100 per cent for some diseases such as typhoid or dracunculiasis • need improvements in water supply and sanitation to achieve these objectives as improvement in one aspect aloe will not produce the full health benefits expected • water quality is only one aspect of water supply that should be improved • increased coverage, continuity of supply and quantity of water supplied at a reasonable cost are all important • infant mortality rates (a key sentinel community) can be significantly reduced with improved water supply	**3,4**
Water-related disease types	• very many water-related diseases • not all water related diseases are fatal or lead to epidemics, but all debilitating to some degree • water-related diseases may be classified on the basis of transmission • the principal classes are: water-borne; water-washed; water based; and water-related insect vectors • many infectious diseases can be classified in more than one group, for instance most diarrhoeal disease may be transmitted by a classic water-borne route, but are also related to inadequate quantities of water (hygiene)	**5**

Section	Key points	OHP
Disease transmission	• many diseases may be transmitted via the faecal-oral route • these include infectious diseases such as cholera and hep A • transmission occurs when human faecal matter is ingested through drinking contaminated water or eating contaminated food • water is an important medium for transmitting disease as contamination with excreta can lead to ingestion of faecal matter (see infection cycle)	**6,7**

Water Quality

"All people, whatever their stage of development and social and economic condition, have the right to have access to drinking water in quantities and of a quality equal to their basic needs."

(UN Conference at Mar del Plata, 1977)

Global Morbidity and Mortality Rates

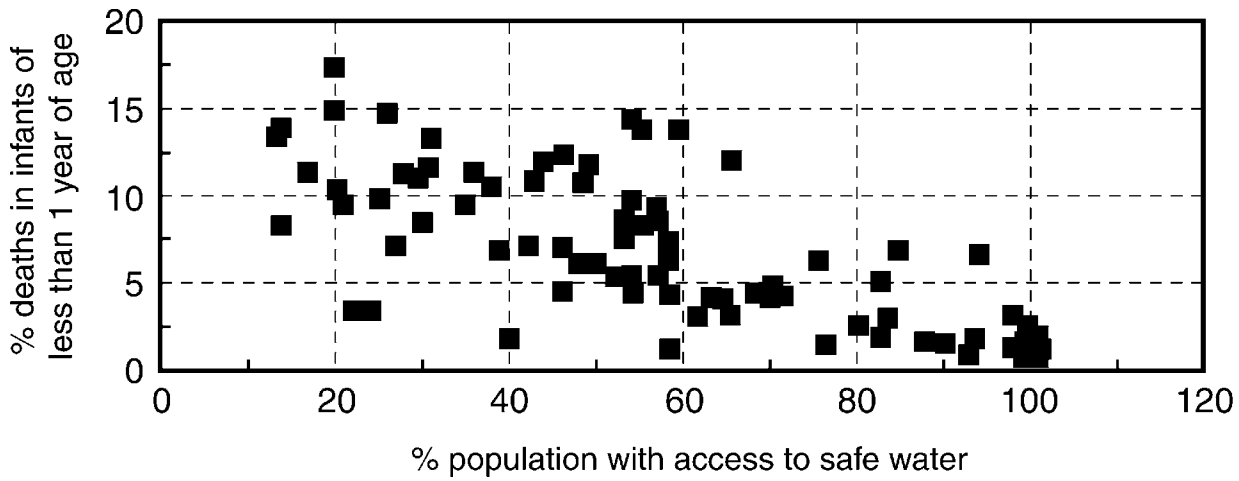
	Number/Year or Total Reported	
	Cases of disease	Deaths
Cholera	384 000	11 000
Typhoid	500 000	25 000
Giardiasis	500 000	low
Amoebiasis	48 000 000	110 000
Diarrhoeal disease	1 500 000 000	4 000 000
Dracunuliasis (guinea-worm)	> 5 000	-
Schistosomiasis	200 000 000	800 000

World Health Report, 1995

Potential Reductions in Morbidity for Different Diseases as a Result of Improvements in Water Supply and Sanitation

Diseases	**Projected reduction in morbidity (%)**
Cholera, thyphoid	80 – 100
Diarrhoeal diseases, dysentery, gastroenteritis	40 – 50
Dracunuliasis	100
Schistosomiasis	60 - 70

Infant Mortality versus Access to Safe Water

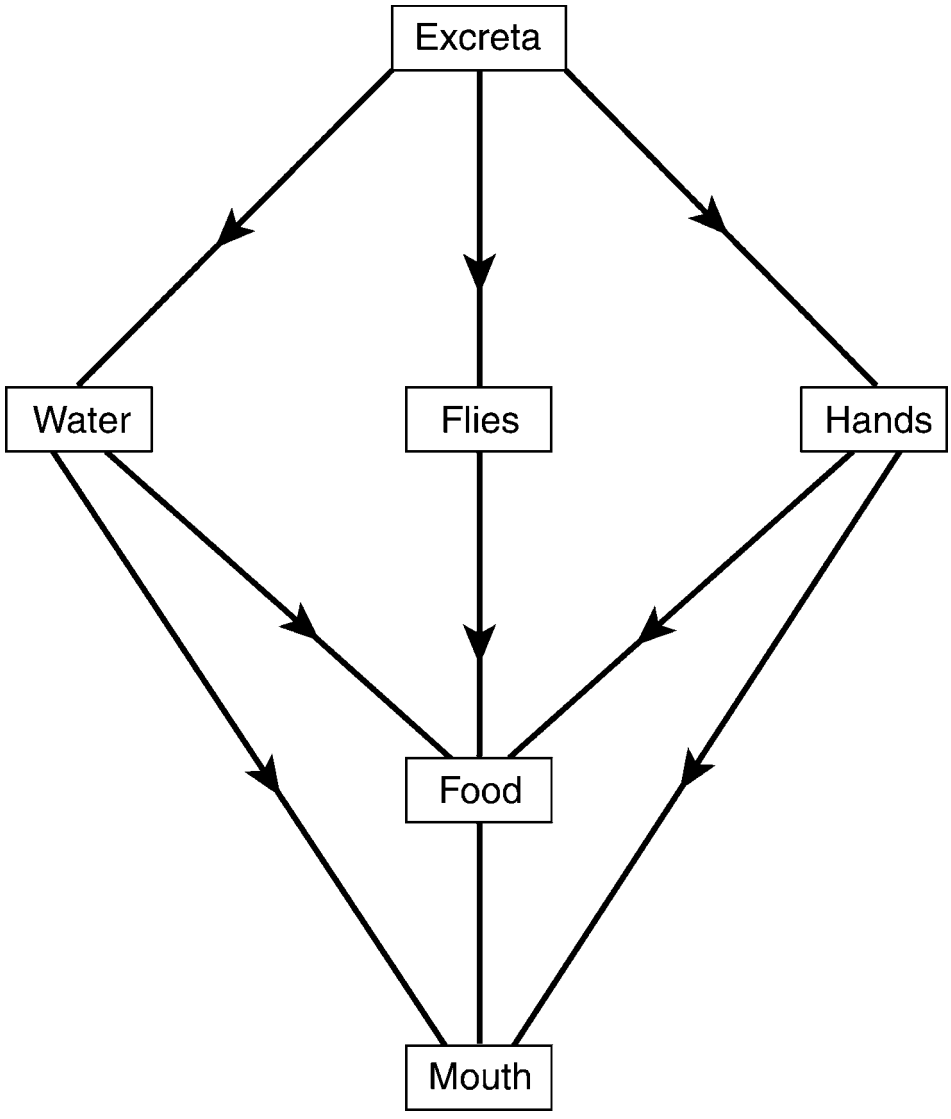


Source: Regli et.al 1993

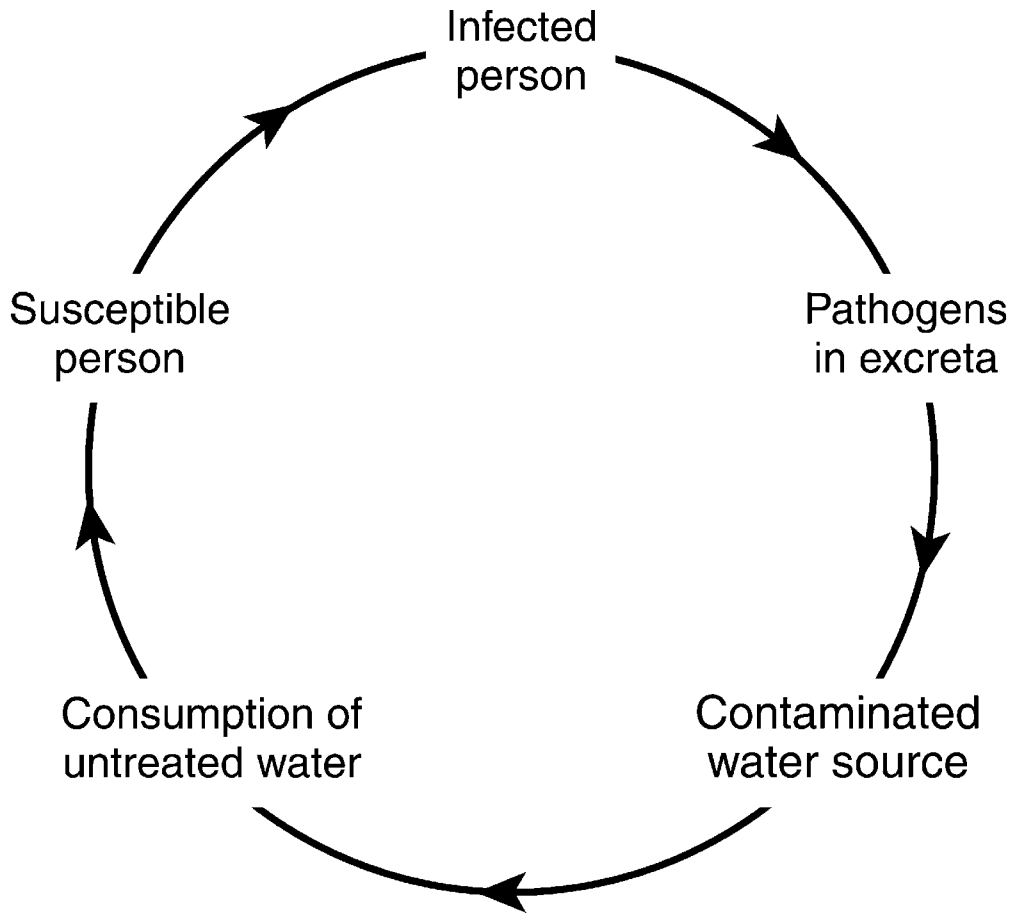
Water and Sanitation-related Diseases

Group	**Diseases**
Water-borne diseases (diseases transmitted by water)	Cholera; Typhoid; Bacillary dysentery Infectious hepatitis; Giardiasis
Water-washed diseases (caused by lack of water)	Scabies; Skin sepsis and ulcers; Yaws; Leprosy; Lice and thypus; Trachoma; Dysenteries; Ascariasis; Parathphoid
Water based diseases	Schistomiasis; Dracunuliasis; Bilharziosis; Filariasis; Threadworm
Water-related insect vector diseases	Yellow fever Dengue fever Bancroftian filariasis Malaria Onchocerciasis

The Faecal-Oral Route of Disease Transmission



The Classical Waterborne Infection Cycle



Source: Tebbutt, T.H.Y., 1992