

# How safe is safe?

**A concise review of the health impacts  
of water supply, sanitation and hygiene**

A WELL study produced under Task 509  
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## Summary

The WHO / UNICEF JOINT MONITORING PROGRAMME (JMP), to whose Year 2000 Global Assessment WELL provided technical support, has collected and reviewed population-based water supply and sanitation coverage data for most of the countries in the world. The programme is however, no longer reporting on 'safe' drinking water and 'adequate' sanitation. Instead, 'improved' water and sanitation technology types are now reported. This change in terminology reflects both the past misrepresentation, and the future uncertainty, in judging and defining services as 'safe' in terms of human health.

The Year 2000 Global Assessment estimates that 2.4 billion people are without access to improved sanitation and 1.1 billion are without access to improved water supply. The United Nations Millennium Summit adopted a target to halve the proportion of people who are unable to reach, or to afford, safe drinking water by the year 2015. It is hoped that the United Nations system will also adopt a similar target for access to hygienic sanitation facilities. Activities are planned to enable monitoring towards these and other goals. The degree to which existing monitoring is able to report upon *safety* of services is unclear. This review therefore seeks to inform monitoring in the sector by providing a review of the evidence of the health risks associated with water supply and sanitation services. As such this document aims to inform policy makers, donor support agencies, government bodies and NGOs.

Models of understanding of the health impact of water supply, sanitation and hygiene practices are presented. The first model, classifications of water-related and excreta-related infections show how quantity of water for hygiene, quality of water and access to, and hygienic use, of sanitation are vital to help reduce the enormous, avoidable health burden from faecal-oral disease transmission. Diarrhoeal diseases are the cause of greatest health impact associated with water supply and sanitation. Approximately two million children die every year because of diarrhoeal diseases. The second model, the F-diagram graphically presents the many routes of faecal-oral disease transmission. It illustrates the importance of sanitation and hygienic practices as the primary barriers to diarrhoeal disease. The model also highlights the need for integrated solutions to address multiple transmission routes. The third model, that of public and private domains, reminds us that we need to better understand the mechanisms of disease transmission in different settings and to tailor interventions accordingly. The private (household) and the public domains are characterised by different levels of immunity and differing practices and responsibilities.

The main science behind the understanding of these health impacts, epidemiology, suffers from a number of methodological difficulties in this context. When combined with the extreme complexity of diarrhoeal disease aetiology, understanding health risks can be difficult. The epidemiological studies reviewed in this report were designed, in many instances, to look at health impact of existing services by comparing served to unserved populations. The use of such observational studies can make investigating the relationship between water supply, sanitation and hygiene and health difficult. For instance, if some people have access to sanitation, does this mean that they are different in some aspect to those that do not? Do they have more resources? Do they have more 'healthy practices' (for instance, good hygiene)? If so, these factors are likely to make them healthier overall and so it becomes difficult to compare them to people without sanitation.

Other problems include definitions and recall of health events, such as episodes of diarrhoea. Several types of bias also present a problem in these studies. Asking a parent or guardian if a child has had diarrhoea over the last two or four-week period may not always lead to accurate

responses. A further problem is that studies often do not attempt to measure *use* of services, which is the 'exposure' that many of the studies investigate.

The studies reviewed point to a large number of determinants of health impact of water supply and sanitation. In each local setting specific conditions and people's practices especially, play a role in the health impact of services. For instance, do children *use* available sanitation? Are their faeces safely disposed of? Can people afford sufficient access to water supply and sanitation? How susceptible are children, the elderly and others to diarrhoeal disease? Which season of the year is it? If many people use open ground for defecation, does the area have a high or a low density of population? How likely are people to come into contact with faeces that are not safely disposed of? How regular are water supplies? Is water supply affected by intermittence or seasonality?

These are just a few questions which are important in determining health impact. The level and type of services are two further factors. They are not therefore the only, or necessarily the most important, determinants of health impact associated with services. The amount of epidemiological evidence for *level* and *type* of service varies. On the whole, more is known about the level of service (largely for water supply). Water supply within the house or the yard is known to be associated with much higher levels of water consumption (and therefore greater hygienic use of water for washing and cleaning) than are shared or public water supplies. The positive health impact of household (or private) water supply is therefore clear.

In the case of *technology types*, the evidence for health impact is both less available and less clear. In the majority of cases, only a small amount of published evidence exists. Review of the body of literature overall suggests that technology type is less important when compared to *how* a service is *used* and *by whom*.

It is also clear that although services provided at household level are optimal for health impact, a piped water supply and sewered sanitation are not necessarily always the best technology types. It is therefore important not to rely on the idea of a hierarchy of service technology with implied safety that can be applied equally in all settings. We need to have more evidence, in many cases, of what health impacts are associated with some types of service, but it is also important to consider the many other factors that determine health impact.

Monitoring of service coverage is needed in order to improve accountability and advocacy for the sector. It is also needed to help to work towards the goals of access to services for all. This monitoring though, will not necessarily always provide a good proxy for health impact. One possibility for monitoring health impact of services is to carry out smaller scale investigation of high risk groups (such as the poor, the young, the old and the immunosuppressed) that seeks to better understand what services are accessible to whom, and how they are used and maintained.

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## 1. Introduction

The WHO / UNICEF JOINT MONITORING PROGRAMME (JMP), to whose Year 2000 Global Assessment WELL provided technical support, has collected and reviewed population-based water supply and sanitation coverage data for most of the countries in the world. The programme is however, no longer reporting on 'safe' drinking water and 'adequate' sanitation. Instead, access to 'improved' water supply and sanitation technology types are now reported. This change in terminology reflects both the past misrepresentation, and the future uncertainty, in judging and defining services as *safe* in terms of human health.

The aim of this piece of work is to review, where available, the epidemiological and other associated literature exploring the safety of different levels of service (e.g. private, shared and public) and different technologies providing service (e.g. pit latrines, dug-wells). In doing so, a number of established models of understanding of health impact are described. The methodological difficulties in estimating health risk are introduced, and the numerous other determinants of health impact associated with water supply, sanitation and hygiene are considered.

The product of the WHO / UNICEF JOINT MONITORING PROGRAMME (JMP) Year 2000 Global Assessment, the Global Water Supply and Sanitation Assessment 2000 Report presents findings on the status of the sector. Coverage estimates for the first time are derived from consumer-based data from large nationally representative household sample surveys such as the Demographic and Health Survey (DHS).

Almost two and a half billion people worldwide are without access to improved sanitation and just over one billion do not have access to improved water supply. Asia and Africa have the lowest levels of service coverage. In Asia, less than half the region's population have access to adequate sanitation. When comparing individual countries, the African region has the highest proportion of countries with less than 50% water supply and sanitation coverage. In all regions, apart from Northern America, rural coverage is lower than urban coverage for both water supply and sanitation.

Urban populations in Asia and Africa are predicted to almost double over the next thirty years. Against this trend, meeting the International Development Target of halving the proportion of those unserved by 2015 would mean providing services to 292, 000 additional people every day over the fifteen years and for sanitation 397, 000 additional people per day.

What the WHO/Unicef Joint Monitoring Programme at present cannot provide us with is sub-national data that might give us an insight into the situation of the poor in different countries, the quality of services, the costs that households pay for them or anything about household hygiene practice, such as handwashing. The scale of the JMP, working to provide data at national, regional and global levels also means that it cannot provide representative local-level information for local decision-making. The nature of work involved in carrying out a large survey such as the DHS also means that surveys are unlikely to be undertaken in countries or regions within countries experiencing conflict or natural disasters.

The United Nations Millennium Summit adopted the target to halve the proportion of people who are unable to reach, or to afford, safe drinking water by the year 2015. It is hoped that the United Nations system will also adopt a similar target for access to hygienic sanitation facilities.

Activities are underway to enable monitoring of progress towards these targets.<sup>1</sup> The degree to which existing monitoring is able to report upon *safety* of services is unclear. This review therefore seeks to inform monitoring in the sector by providing an updated review of the evidence of the health risks associated with water supply and sanitation services. As such this document aims to inform policy makers, donor support agencies, government bodies and NGOs.

The document begins by introducing some of the main conceptual models through which our understanding of the health impact of water supply, sanitation and hygiene practice is interpreted.

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<sup>1</sup> The UK Department for International Development supported a meeting held in February 2001 to discuss better monitoring for the sector. The meeting was attended by representatives from several United Nations organisations and was backed by the Water Supply and Sanitation Collaborative Council.



## 2. Models of understanding of how water supply, sanitation and hygiene affect health

### 2.1 Classifications of water-related and excreta-related infections

This model has evolved from earlier work, grouping water-related infectious diseases by broad routes of transmission.<sup>1</sup> The categories are therefore defined by the types of intervention which can control them, rather than by the types of organisms which cause them. As such this model has helped engineers and public health professionals towards working together.<sup>2</sup>

There are four categories;

- faecal-oral (water-borne **and** water-washed),
- strictly water-washed,
- water-based intermediate host
- and, water-related insect vector.

The first category, faecal-oral includes infections which are transmitted by swallowing faecally contaminated matter containing pathogens (organisms causing disease). They can be caused by drinking contaminated water **as well as** through lack of sufficient water for washing. Diseases in this group include diarrhoeal diseases, typhoid, cholera and hepatitis A and E.

The second category is strictly water-washed. These are conditions that are exacerbated by lack of water for washing and hygiene. Diseases are largely related to skin and eyes, such as scabies, trachoma and conjunctivitis.

The third category is water-based, with aquatic intermediate hosts. Aquatic organisms such as snails act as hosts to parasites, which then infect humans either by being swallowed or through contact in water (for example through entering the skin). Diseases include guinea worm and schistosomiasis.

The last category is diseases that are transmitted by water-related insect vectors. Insect vectors, such as mosquitoes and flies breed in or near water. They transmit disease to humans, for instance through bites. Diseases include malaria, filariasis, yellow fever, dengue and onchocerciasis (river blindness).

A similar classification exists for excreta-related diseases.<sup>3</sup> There are five categories of excreta-related diseases;

- faecal-oral,
- soil-transmitted helminths,
- beef and pork tapeworms,
- water-based helminths
- and, excreta-related insect vectors.

Faecal-oral diseases represent the largest health burden associated with water supply, sanitation and hygiene, and are discussed in more detail below.

Soil-transmitted helminths include roundworm, whipworm and hookworm. These parasitic worm infections are transmitted when eggs are passed in human faeces (eggs often need time in moist soil to mature and become infective).

Beef and pork tapeworms live in animal hosts and humans are infected when eating animal meat that is not sufficiently cooked. The cycle continues when animals eat food contaminated with faeces.

Water-based helminths are the same category as the water-based intermediate host group described above, including schistosomiasis.

The last group, excreta-related insect vectors, includes mosquitoes, flies and cockroaches. The *Culex* mosquito, which transmits filariasis, breeds in septic tanks and flooded latrines. Flies and cockroaches are responsible for causing some transmission of faecal-oral disease.

Sanitation and hygiene interventions have differing impacts for each of these categories.<sup>4</sup> In general improved hygiene practices are thought to have a greater impact on faecal-oral disease than the provision of sanitation hardware alone.

Faecal-oral diseases, in the form of diarrhoeal diseases, are responsible for the greatest number of episodes of illness and deaths worldwide as shown in Table 1 below (data are presented for WHO member state countries). It has been estimated that diarrhoeal disease represents 90% of the health impact associated with water supply and sanitation<sup>1</sup>. Diarrhoeal diseases are estimated to kill more than two million people every year worldwide. The majority are children. There is some reason to believe that the number of deaths has fallen over the 1990s possibly in part due to increased use and success of oral rehydration therapy in preventing deaths.<sup>5</sup> However, it appears that the number of episodes of diarrhoeal disease has remained constant.

Routine data for diarrhoeal disease morbidity and mortality often represent substantial under-reporting. Problems of underreporting are significant in all settings. A recent large study in the UK found that infectious intestinal disease occurs in 1 in 5 people every year, but only 1 in 6 of these presents to a general practitioner.<sup>6</sup>

**Table 1. Water and sanitation related diseases**

	<b>Mortality estimates for 1999</b>	<b>DALYs estimates for 1999</b>
<b>Faecal-oral</b>		
Diarrhoeal disease	2,213,000	72,063,000
Poliomyelitis	2,000	1,725,000
<b>Water-washed</b>		
Trachoma		1,239,000
<b>Water-based</b>		
Schistosomiasis	14,000	1,932,000
<b>Water-related vector</b>		
Malaria	1,086,000	44,998,000
Lymphatic filariasis		4,918,000
Dengue	13,000	465,000
<b>Intestinal nematode infections</b>		
	16,000	2,653,000

Source; WHO World Health Report. WHO; Geneva. 2000

Approximately 90% of diarrhoeal disease cases are estimated to be attributable to environmental factors.<sup>7</sup> Apart from water supply, sanitation and hygiene, diarrhoeal disease is also associated with a number of other risk factors including age, nutrition, lack of breast-feeding and seasonality.

Faecal-oral disease pathogens include bacteria, viruses, protozoa and helminths. The likelihood of infection by these pathogens relies on several factors. Firstly the persistence of the pathogen is important, i.e. whether it can survive and / or multiply in the environment. Bacteria for instance are able to multiply in the environment and inside their hosts. In contrast, viruses can only multiply inside their hosts. Secondly, infective dose is a key factor about which relatively little is known. The infectious dose refers to the number of organisms necessary to cause infection. Viruses and protozoa for instance have very low infective doses, and in some cases just one protozoan cyst can cause infection. This makes transmission by water-washed routes relatively easy, as only a small number of organisms are needed to pass on infection from person to person. In contrast, many bacterial pathogens are thought to have much higher infective doses. In their case, direct consumption from either water supply or food may be the most likely route of transmission. A further factor is human host response, i.e. how well a host fights infection and whether they develop immunity. This is often related to factors such as age and general health status.

### 2.2 The F-diagram

The F-diagram, depicted by Wagner & Lanoix<sup>8</sup> has been widely used as a model of faecal-oral disease transmission (Figure 1). Without removing faeces from potential contact with humans, animals and insects, pathogens may be carried on unwashed hands, in contaminated water or food, or via flies and other insects on to further human hosts. The first way in which to stop or reduce transmission is to ensure the safe disposal of faeces, through sanitation. Children’s faeces in particular are known to be especially infective and are also most likely not to be safely disposed of<sup>3</sup>. The secondary barriers to faecal-oral disease transmission are based on hygienic practices, such as washing hands following defecation and handling children’s faeces and before storing and preparing food and water.

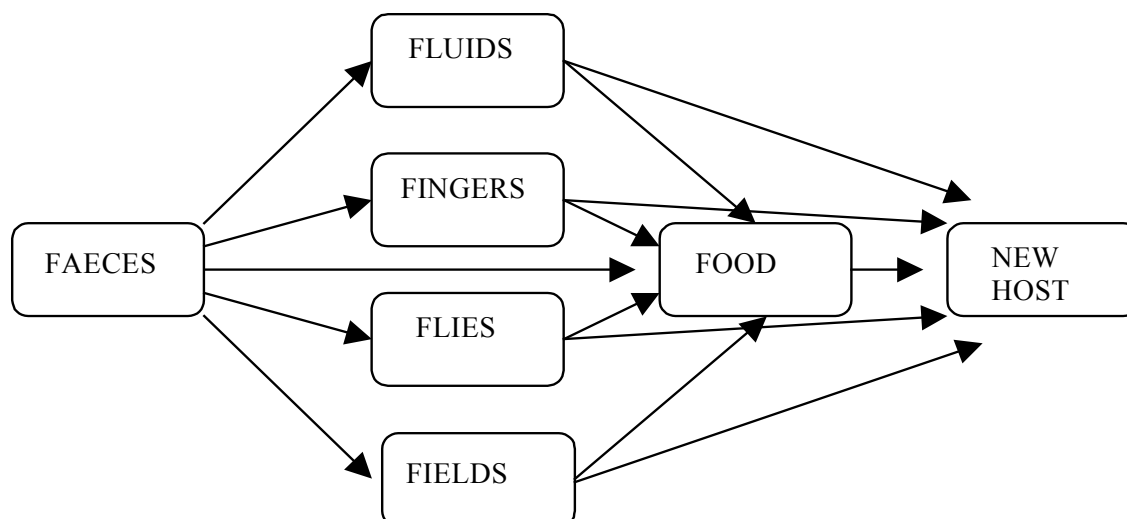


Figure 1. The F-diagram

Source: Wagner & Lanoix 1958

The F-diagram graphically presents multiple routes of transmission (of multiple pathogens). Numerous commentators have advocated integrated measures to control diarrhoeal disease by combating multiple routes of transmission.<sup>9</sup> The greater the variation in interventions, the greater the chance in successfully reducing diarrhoeal disease transmission.

### 2.3 Public and private domains

A third model of understanding, that of public and private domains, complements the move away from the traditional, engineering approach to public health.<sup>10</sup> It brings the focus towards *private* health at household level. The concept of the domestic *domain* encompasses the decisions and actions taken at household level and their relation to environmental health, and is distinguished from the public domain in which the intervention of public authority is required to prevent disease transmission. This model acknowledges the importance of household practices and behaviour. A household-centred approach to environmental health has been advocated.<sup>4</sup>

Many studies have investigated the links between public water supplies and household contamination of stored water.<sup>11</sup> Findings have been rather mixed. There is a growing consensus that diarrhoeal disease pathogens originating within the home, as found in household water storage vessels, are less of a threat to household health than pathogens found in source water supplies (for example from public wells).<sup>12</sup> There appear to be degrees of immunity to pathogens commonly found within the household. These complexities are acknowledged and explored within the public-private domain model.

Several studies have looked at the impact of interventions at household level when the neighbourhood is faecally contaminated.<sup>13</sup> Others have logically argued that interventions should be targeted at those in most need. For instance, it has been suggested that children who are not breast-fed are more susceptible to diarrhoeal disease and as such may benefit more from water supply and sanitation interventions than would breast-fed infants.<sup>14</sup> The logistical difficulties in carrying out this approach may however make it impracticable. Research findings suggest that as neighbourhood levels of faecal contamination improve, the conditions and practices within households become more important.

### 2.4 Areas of present and future focus

An increasing amount of published work in the sector over the last ten years has looked at hygiene behaviour. There has been a quest to better understand and evaluate the impact of hygiene interventions.<sup>15</sup> Another area of particular focus is the cost-effectiveness of interventions.<sup>16</sup> This area, along with hygiene behaviour, appears likely to remain a key issue of interest for the sector for some time. A further area of research development is that of risk assessment and hazard analysis approaches to water quality. Work is related to guideline development and will no doubt continue to be pushed forward by the increasing concern over recently recognised water borne pathogens and the legal responsibilities of a changing water industry.

### 3. Assessment methodologies and difficulties

Most of the difficulties in assessing health impact have been summarised elsewhere.<sup>17</sup> The majority of the epidemiological studies investigating the relationship between water supply, sanitation, hygiene and health are observational. This means that many of the factors that affect both exposure and health outcomes are not controlled for in the design of the study. For instance socio-economic status is strongly related to health status. It also often determines access to water supply and sanitation. Socio-economic status in this case is known as a *confounder* and information needs to be collected and used in the design of the study and / or the analysis of the results. This is often a further issue in case-control studies where the control group is not similar enough to cases in terms of socio-economic status to enable valid comparison.

Another difficulty is recall bias. Many of the studies rely on mothers or guardians of young children recalling episodes of diarrhoea over periods of up to two weeks. It appears that recall over periods longer than 48 hours is unlikely to be accurate.

The choice of health outcomes or indicators used can also pose difficulties. For instance in the case of diarrhoeal disease, there is no accepted standardised definition of diarrhoea.<sup>18</sup> There are also advantages and disadvantages to using morbidity or mortality data. One review suggested that studies which used mortality data were more robust than those using morbidity data.<sup>19</sup> In general, mortality data are more complete than morbidity data.

The choice of exposure under study is also extremely important. Many studies look at water quality as this is relatively easy to measure and because many researchers have started from the assumption that water quality, rather than quantity and hygiene, is the key determinant of health impact. However, they do not always fully acknowledge and design for the multiple causes of diarrhoeal disease. Studies often only look at one part of a relationship between water supply or sanitation and health and as such can not allude to the full impact upon health. For instance, looking only at water quality discounts the existence and impact of secondary transmission from water-washed routes. Similarly, not enough studies investigate each of the steps within the casual pathway such as; use of certain facilities leads to exposure to pathogens and that in turn exposure to these pathogens leads to an identified health outcome. Commentators have highlighted such shortfalls of epidemiology in determining true transmission routes.<sup>20</sup>

A further important factor is that actual *use* of services is seldom investigated. This is especially true for the children under five for whom risks are highest (for instance, are their faeces disposed of safely? Is water treated before consumption?) Another often-overlooked aspect of study design is the unit of observation. When an entire village receives an intervention, the village itself should then be the unit of observation rather than individuals within it.<sup>21</sup> Another problem is publication bias. Studies with negative findings are less likely to be submitted (and accepted) for publication than positive studies.

The body of scientific evidence illustrates that a large number of factors influence the health impact of services. The specific local conditions in which studies are carried out therefore often make it difficult to generalise the results of individual studies.

## 4. Determinants of health impact of water supply and sanitation

The level and type of service both have the potential to influence health. However, numerous other factors affect health risk, in some cases to a greater extent than levels or types of service, by influencing the use and nature of the service. These factors include access to, and *use*, of services, maintenance and treatment and seasonality, water source and pathogen specific factors. Poverty is very often a key variable behind many of the factors listed above, most notably access to services. Most epidemiological studies attempt to measure and control for socio-economic status in order to investigate putative risk factors. This should of course not detract from the importance of poverty in determining access to services and poor health status.

### 4.1 Access and use

Distance to water source has been studied to look at the relationship between distance to source and consumption of water. Consumption of water is used as an indicator of hygiene (and therefore health impact). Research based on several African studies suggests that a water source within one kilometre roughly approximates a thirty-minute round trip.<sup>22</sup> At distances less than that, the amount of water collected plateaus at around 15 litres per person per day. This consumption level can only be improved by introducing water supply within the household. This would have the potential to double or treble the amount of water consumed per person per day.

Distance to sanitation can be a problem of personal security in some places where women wait until dark to use latrines.<sup>23</sup>

Cost of services is another key factor which influences access to services and therefore health impact. Sanitation can be prohibitively expensive to build and / or to upgrade. In the case of water, high costs are often paid out of the low-income household's food budget,<sup>24</sup> with resulting health impacts. Studies have found that cost can be a critical factor in the take up and success of sanitation programmes.<sup>25</sup> Engineering solutions need to be matched with local demand.

Access to services can also be affected by local power dynamics. In some settings, a system of patronage exists around water supply. Villagers have to provide favours to secure access to water.<sup>26</sup>

Another important determinant of health impact is *who* uses services and *how*. For instance do children use sanitation? How are infants' stools disposed of safely away from potential human contact? Are communal latrines well maintained? These factors are all important in faecal-oral transmission as they relate to the safe disposal of faeces.

### 4.2 Treatment and maintenance

Treatment and maintenance are also key factors for the safety of water supply. Common challenges that face many piped water supply systems include contamination of source by industry, agriculture and municipal activities, old and deteriorating treatment works and distribution systems, demand for water outstripping supply, the increasingly recognised problem of treatment-resistant pathogens such as cryptosporidium and fear over toxicity of disinfection by-products.<sup>27</sup> A further factor is the development of biofilms within the distribution network. These are nutrient rich collections of micro-organisms which provide an environment favourable to pathogen survival inside pipes.

Intermittent water supplies can result in water being effectively unavailable for hygiene purposes. Often households need to store water. Domestic water storage vessels are the main breeding sites for *Aedes Aegypti* mosquitoes, the vectors of dengue and dengue haemorrhagic fever. There is some evidence in the UK that disconnections of water supply may influence both the

size of infectious disease outbreaks, as well as secondary infection rates.<sup>28</sup> Intermittence is also associated with changes in pressure within distribution networks which can lead to materials being drawn in through fractures in the pipes. This can then lead to secondary contamination of the water supply, depending on levels of residual chlorine.

Similarly, where water is collected from non-piped sources, the nature of water storage and treatment are both important. As discussed above, in section 2.3, the literature suggests that pathogens from outside the immediate household are more hazardous than those routinely found within the household. Therefore it appears more important for water quality interventions to safeguard the quality of the water source rather than to attempt to improve domestic water storage.<sup>12</sup> Other commentators have suggested treatment of water within the household to improve quality of often-contaminated source water.<sup>29</sup> Routine household treatment of water in many cases often involves boiling. Boiling water will kill off most pathogens. Boiling, however, can be a rather expensive and time consuming activity. It has been estimated that one kilogram of wood is needed to boil one litre of water for one minute.<sup>29</sup> This may not be a choice for lower-income households where resources are limited.

### 4.3 Seasonality

Seasonality is a fairly well established determinant of the health impact of water supply and sanitation facilities. Many studies investigating health risk take seasonality into account in their design. In many tropical and sub-tropical areas, the summer months are associated with peaks in bacterial diarrhoeal disease. These are believed to relate to enhanced bacterial pathogen multiplication in the summer because of moist, warm conditions, and possibly also because of increases in levels of water supply contamination associated with storms and heightened surface run-off along with changes in food availability.<sup>12</sup> In contrast, cooler months, especially in temperate climates, are associated with peaks in viral disease infections.

Seasonality can also be associated with functional problems of both water supply and sanitation services. For instance, floods may also cause problems for both sewered and on-plot sanitation.<sup>30</sup> Flooding can increase the likelihood of direct faecal contamination through overwhelming of on-plot sanitation, sewerage or contaminated storm-water drainage systems. They can also force people to use other forms of sanitation or open ground. Seasonality is also associated with use of services. Households may change their source of water depending on seasonal availability of supply for instance.

### 4.4 Pathogen specific factors

Further determinants of health impact will be pathogen specific. The broad differences between bacteria, viruses, protozoa and helminths have been introduced in section 2.1 above, in terms of infectious dose and environmental viability. Within these broad categories there are exceptions. *Shigella* for instance is thought to be relatively unusual as a bacterium, in its successful ability to transmit infection from unwashed hands.<sup>19</sup>

There are further hypotheses about pathogen virulence and route of transmission. For instance, it has been suggested that pathogens which rely on water-washed transmission routes are less virulent because they need each human to be able to remain mobile and survive to pass on the infection.<sup>30</sup> In contrast, pathogens which transmit infection via host ingestion of water may be more virulent as they do not rely on water-washed transmission routes.

Certain emerging pathogens are receiving increasing attention and are leading to questions about the adequacy of previously accepted standards of water treatment and monitoring. For example, *Cryptosporidium parvum* is receiving increasing publicity as a threat to water supplies in both the North and the South.<sup>31</sup>

The age and susceptibility of the population at risk are further key determinants of the health risk associated with water supply and sanitation. As was seen above in section 2.1, the majority of cases of illness and death due to diarrhoeal disease are in children under five. Another group at heightened risk are the immunosuppressed. AIDS patients are very susceptible to diarrhoeal disease risk and the consequences of infection are often extremely serious. The 1993 US cryptosporidium outbreak in Milwaukee showed how serious the risk can be, with 85% of all those who died being AIDS patients.<sup>32</sup> AIDS victims in the South, and especially in Sub-Saharan Africa are a large group at risk. Displaced populations are often at heightened risk, as discussed in more detail in section 4.7 below.

#### **4.5 Source of water**

The source of water, i.e. either from the ground, surface or rain, may influence health risk. Several studies have collected microbiological water quality data to compare different types of source and technology.<sup>33</sup> It is often difficult to compare such studies, as water samples are not all collected and analysed in a standardised manner. In the future the WHO / Unicef Joint Monitoring Programme aims to introduce water quality sampling. Such an activity should provide large representative, systematically collected and analysed data sets.

Surface water on the whole tends to be at greater risk of large-scale microbiological contamination than does ground water. Untreated groundwater can nonetheless be the cause of disease outbreaks. Geology and land use patterns affect chemical and microbiological quality of ground water as do water abstraction techniques. The nature of contaminants is also important. Most pesticides for instance are in the form of insoluble emulsions. This means that it is easier for them to stick to physical matter in surface water than it is for them to travel and remain in ground water. Chemical contaminants in ground water will often be detectable by taste and as such this will often influence whether or not they are consumed. Arsenic and fluoride are naturally occurring exceptions to this rule and are the cause of serious contamination in a number of countries including Argentina, Bangladesh, Chile, China, India, Mexico, Taiwan, Thailand and the United States of America.

Attention is often focused on pit latrines and their impact on ground water quality. In general, a decision to protect ground water quality at the expense of sanitation is likely to have a negative impact on health.<sup>34</sup>

#### **4.6 Urban-rural differences**

Urban-rural differences in diarrhoeal disease prevalence, incidence and severity are not often investigated. Some evidence suggests that few differences exist between rural and urban diarrhoeal disease prevalence rates. For instance, a review of data from Demographic and Health Surveys from eight countries, reported that diarrhoeal disease prevalence in children under three years was similar in rural and urban areas, with one child in six experiencing diarrhoea.<sup>35</sup> The same study found that children's nutritional status was worse in rural areas. This may suggest that as well as differences in nutritional intake, diarrhoea may be more severe in rural areas. Differentials in access to health care between urban and rural areas are likely to play a role.

In urban areas there may be higher levels of environmental faecal contamination because of high-density populations living without adequate sanitation facilities. In addition, the much higher reliance on piped water supplies in urban areas may represent a higher risk of common source water-borne disease outbreaks. Events in Bangladesh and elsewhere have however, shown the devastating effects of chemically contaminated groundwater for large rural populations.



Differences in reporting systems and completeness of data often make direct comparison of diarrhoeal disease burden between and within countries difficult. Work on disability-adjusted life years (DALYs) calculations suggest that the burden of disease for infectious and parasitic diseases in 1990 was just 2.7% of total DALYs for developed countries compared to 25.6% for developing countries.<sup>36</sup> The figure for Sub-Saharan Africa was 42.5%. Clearly there are enormous disparities between and within regions. More work is needed to better understand urban and rural differences in terms of both risk and health outcomes.

#### **4.7 Situations of conflict and natural disasters**

The vast majority of research referred to in this report has not been carried out in places experiencing conflict or other emergencies. Natural disasters and conflict have devastating effects on public health. The impact of diarrhoeal disease can be particularly extreme. One of the worst recent documented examples has been in the refugee camps of Zaire during the 1994 Rwandan conflict.<sup>37</sup> An estimated one tenth of all refugees died of cholera within their first month in the North Kivu region. Between 58 000 and 80 000 people are believed to have died of cholera. The outbreak was associated with drinking contaminated lake water, overcrowding, a lack of facilities for sanitation and hygiene coupled with the general debilitated state of the refugees. There are many other examples of emergency situations where public health impacts have been extreme.<sup>38</sup>

International efforts to respond to these situations have led to the development of guidelines for emergency fieldworkers. Examples can be found in the Sphere Project,<sup>39</sup> a recent example of collaboration between non-governmental organisations, the International Red Cross, donor support agencies and other actors to set standards for humanitarian assistance in disasters.

Water supply has been a main focus for international efforts in the past. Sanitation and hygiene practices have tended to have been a lower priority within relief efforts. This balance is being redressed by work such as the DFID-funded research project 'Assessment and programme design for emergency sanitation', carried out by WEDC.

## 5. Summarised evidence of health impacts of water supply, sanitation and hygiene

One review calculated the expected reductions in diarrhoeal disease from a range of interventions, as presented in Table 2.<sup>40</sup> According to the review, sanitation is the single most important intervention for the reduction of diarrhoeal morbidity, producing an expected reduction of 36%. Sanitation is closely followed by hygiene interventions which are expected to reduce diarrhoeal morbidity by 33%. The provision of both water supply and sanitation were seen to reduce illness by 30%. As an intervention, water quantity was found to be more effective in reducing illness than was water quality. The review article does not attempt to try to explain all of these findings. However, the models of understanding, as described earlier, do provide suggestion of how such results might come about. For instance, the F-diagram provides an understanding of how faecal-oral disease transmission can be reduced. Sanitation and hygiene practises are the main barriers to disease transmission.

**Table 2. Expected reduction in diarrhoeal disease morbidity from improvements in one or more components of water and sanitation**

	All studies		Rigorous studies	
	n <sup>1</sup>	Reduction %	n <sup>1</sup>	Reduction %
Water and sanitation	7 / 11	20	2 / 3	30
Sanitation	11 / 30	22	5 / 18	36
Water quality and quantity	22 / 43	16	2 / 22	17
Water quality	7 / 16	17	4 / 7	15
Water quantity	7 / 16	27	5 / 10	20
Hygiene promotion	6 / 6	33	6 / 6	33

<sup>1</sup> The number of studies for which a morbidity reduction could be calculated, divided by the total number of studies that relate the type of facility to diarrhoeal morbidity, nutrition and/or mortality.

Source; Esrey SA, Potash JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis and trachoma. WHO bull. 1991;69(5):609-621

A later review investigated the role of water and sanitation interventions upon specific diseases.<sup>41</sup> The results are presented in Table 3. The majority of studies reviewed investigated diarrhoeal disease morbidity. The largest median reduction identified for the diseases reviewed from rigorous studies was for dracunculiasis, with an expected reduction of 78%. An expected reduction of 77% was calculated for schistosomiasis. Ascariasis and trachoma were expected to have 29% and 55% reductions respectively. Rigorous studies of child mortality and water supply and sanitation interventions suggest an expected 55% reduction. The smallest expected reduction, of 26%, was found for diarrhoeal disease morbidity.

The research reviewed by Esrey et al is largely based on observational studies, with some quasi-experimental studies for water supply. Developing inclusion and exclusion criteria for reviews of this kind is often rather difficult. After extensive work criteria can remain fairly arbitrary.

The effectiveness of interventions to reduce diarrhoeal disease such as breast-feeding and improving weaning practices has recently been reviewed.<sup>42</sup> Despite this, there has not been a

published review of water supply and sanitation health impact studies over the last ten years since Esrey's 1991 work. This is a gap in the literature that should be investigated.

**Table 3. Expected reduction in morbidity and mortality from improved water and sanitation for selected diseases**

	All studies		Rigorous studies	
	n <sup>1</sup>	Median reduction % and range	n <sup>1</sup>	Median reduction % and range
Ascariasis	11	28 (0-83)	4	29 (15-83)
Diarrhoeal diseases				
Morbidity	49	22 (0-100)	19	26 (0-68)
Mortality	3	65 (43-79)	-	-
Dracunculiasis	7	76 (37-98)	2	78 (75-81)
Hookworm infection	9	4 (0-100)	1	4 -
Schistosomiasis	4	73 (59-87)	3	77 (59-87)
Trachoma	13	50 (0-91)	7	27 (0-79)
Child mortality	9	60 (0-82)	6	55 (20-82)

Source; Esrey SA, Potash JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis and trachoma. WHO bull. 1991;69(5):609-621

Further work has been carried out using existing data sets provided by Demographic and Health Surveys (DHS), large representative national sample surveys. A review of data for eight countries was published in 1996.<sup>35</sup> The data suggest that incremental improvements in services produce incremental improvements in diarrhoeal prevalence and anthropometric outcomes in urban areas and just in anthropometric outcomes in rural areas. Overall, greater effects were seen for sanitation than for water supply. Aspects of the study are discussed in more detail in published correspondence to and from the author.<sup>43</sup>

A general methodological problem for a large number of studies has been the inability to separate out hygiene practice from existence of sanitation facilities.<sup>9</sup>

## 6. Level of service and health

The *level* of service refers to the level of access to it. For instance, access to water supply can be *private* (as in an in-house piped supply or a well on the premises), or *shared* (as for instance in a pit latrine shared between householders within one compound or *public* (as in water from public standpipes or the use of public toilets). The level of service is often directly related to distance. Level of service is also often associated with cost. Many observers have noted the inequity of households without private water supply paying much more for a far smaller volume of water.<sup>44</sup> The determinants of health impact, as described in section 4.0, can play a part in the health impact of services in addition to, and despite, levels and types of service.

The relative associated impacts for water supply and sanitation are discussed in turn.

### 6.1 Level of water supply service

As stated above, level of service is directly linked to distance to source. For water supply and health in particular the distance to source is very important as it is related to consumption of water (and by association, hygiene). This has been discussed in more detail in section 2.1 Classifications of water-related diseases. A strong case can be made for siting water supply sources within one kilometre of households, or for the highest levels of consumption, within the household. Many of the health impact studies that show strongly positive results are of in-house provision, for instance those cited in Wagner and Lanoix (1958).

Level of water supply therefore acts as a proxy for distance and in effect use of water. Quantity of supply will still be influenced by how reliable the source is (for example whether it suffers from intermittence). Private supplies of water are assumed to be subject to a narrower range of microbiological contamination than are public supplies, shared by a large number of users from different households (as described in section 2.3). Reliability can also affect the quality of water supply, for instance through secondary contamination within old piped networks exacerbated by intermittence. Cost may have an impact on water use and therefore health if, for example, household connections are subject to metering.

### 6.2 Level of sanitation service

Level of service for sanitation appears to have a less straightforward relationship with health than that for water supply. The health impacts of sanitation are centred on the safe disposal of faeces. The nature of use and maintenance of sanitation are therefore fundamental. Private sanitation should in theory provide an optimal service if faeces are safely removed from human contact. In theory, shared and public sanitation should, and in many cases do, also provide exactly the same role. However, shared and public sanitation can sometimes lack adequate maintenance, which in turn may affect use of services. Some public latrines are inadequate to serve the numbers of people wishing to use them. Examples can be found of people queuing for long periods to use public toilets.<sup>45</sup> There are also additional problems of access, for instance facilities are often locked at night. Cost can be a further barrier.

Private access to well designed and maintained sanitation does not necessarily result in all members of a household using the facilities. If children do not use available sanitation, their undisposed faeces will still represent a potential health hazard.

## 7. Technology type and health

Technology type refers to the design of the facility, such as a borehole or a ventilated improved pit latrine. This type of classification was used in the WHO / Unicef Global Assessment 2000. Certain technologies were included as 'improved' (similar to Esrey's 1996 classifications) while others were not counted as representing service coverage due to their assumed negative impacts on health. Table 4. below lists which technologies were included as improved or unimproved in the Global Assessment 2000. The term improved relates to the technology being optimal in design (largely in terms of reduced microbiological risk). It does not, and indeed cannot, refer to the quality and reliability of such technology types in different settings.

While many of the studies identified in this review investigated level of service (by focusing on household connections as the optimum service), far fewer looked specifically at the health risks associated with types of technology. Literature identified is referred to where relevant. General considerations of the health impact of different types of service are noted.

**Table 4. Water supply and sanitation technologies considered to be improved and unimproved in the WHO Unicef Global Assessment 2000**

The following technologies were considered to be improved;

### **Water supply**

Household connection

Public standpipe

Borehole

Protected dug well

Protected spring

Rainwater collection

### **Sanitation**

Connection to a public sewer

Connection to septic tank

Pour-flush latrine

Simple pit latrine

Ventilated improved pit latrine

The following technologies were considered not improved;

### **Water supply**

Unprotected well

Unprotected spring

Vendor-provided water

Bottled water

Tanker truck provision of water

### **Sanitation**

Service or bucket latrines (where excreta manually removed)

Public latrines

Open latrine

Source: WHO Unicef Global Assessment 2000

### 7.1 Water supply technologies

Piped water supplies (private, shared or public) were taken as improved coverage in the GA2000. This assumption was based on the knowledge that most piped water supply systems receive some form of treatment and that they should in theory provide adequate quantities of water. In reality there are many problems with piped water supplies as discussed in Section 4.2 Treatment

and maintenance. Piped water supplies for large urban areas are often drawn from surface water sources to provide adequate volumes. Surface water as noted in section 4.5 is often more open to microbiological contamination than groundwater is. There are also greater risks of chemical contamination, such as from pesticides. As well as contamination of source, inadequate and ageing treatment facilities often threaten the quality of the water as do deteriorating distribution networks which lead to secondary contamination of water within the piped system. Similarly the quantity of water can be greatly compromised by problems of intermittence which can lead water supplies to be available for only a limited number of hours a day. Piped water supplies do not therefore always represent the optimal form of service in all settings.

Wells were included as *improved* in the GA2000 if they were mechanically excavated or were covered and lined. These criteria were chosen because of the perceived benefits to health of reducing erosion of the sides of wells by lining and removing the possibility of materials being washed into the well by covering. The existence of a windlass to avoid contamination by multiple water vessels is also assumed to help to safeguard water quality. The efficiency of these factors is not often evaluated in studies. Examples found tended to be rather ambiguous.<sup>46</sup>

There are other factors whose importance is increasingly recognised, such as the combination of geological characteristics, land and water use patterns and depth of wells. Fluoride and arsenic are widespread examples. Guidelines are needed to better identify the characteristics that place certain areas in high risk of groundwater contamination. Wells along with springs can be particularly susceptible to seasonal differences with water levels fluctuating in some areas in times of drought and flooding causing contamination. Further factors affecting the health impact of wells includes distance from household. As discussed in section 6.0, distance to source can have a strong influence on how much water is consumed. With concomitant impacts on hygiene.

Distance may also affect the number of other people sharing the well, with implications for time taken to wait at source and chances of cross-contamination. Proximity to on-plot sanitation is a further factor, as noted in section 4.5. Similar to wells, springs were included as *improved* if they were protected (i.e. covered to avoid contamination).

Rainwater collection was also included as *improved* water supply coverage. This decision was based on the assumption that rainwater as a source is of sufficient quality. The quality of rainwater itself appears to be seldom monitored. Rainwater collection and use may well be more prevalent in rural areas. Unlike other supplies of water, the storage of rainwater is always necessary. This in many cases leads to the possibility of contamination. There is bacteriological evidence that this storage can be detrimental to health, as exposure to faeces from birds, lizards and mammals is much more likely than it is in storage containers inside the house.<sup>47</sup> A further concern is the type of roof involved and leachate of chemicals.

Rainwater collection is normally supplementary to existing water supplies, as quantities are usually insufficient for year round supplies.

The following types of water supply were not included as *improved* and therefore were not counted as coverage; surface water (ponds, rivers or lakes), vendor supplied water, tanker truck supplied water and bottled water.

Surface water, as mentioned in section 4.5 above, is often subject to microbiological contamination. Untreated water supplies taken from ponds, rivers, lakes or streams are likely to contain large numbers of faecal indicator organisms.<sup>48</sup> For this reason they were not included as improved coverage. Similarly they are at greater risk of contamination from chemicals such as pesticides.

Water supplies provided by tanker trucks were also not included as improved coverage. This was because cost, quantity and quality are often unknown. It is likely however, that these factors vary greatly between different settings. In some cases tanker truck supply will be treated, piped water supplied to areas beyond the network and should therefore represent good quality water (but of a still unknown quantity).

Water supplied by vendors was not included as improved because of the unknown quality and quantity of water and the often high costs of water which are likely to limit the quantity consumed.<sup>24</sup> Similarly, bottled water was not included for the same reasons.

## 7.2 Sanitation technologies

Sewered sanitation (including also septic tanks) was considered as improved coverage in the Global Assessment 2000. Piped systems of sanitation should remove excreta from the house to be treated and disposed of elsewhere. Systems tend to be expensive and the cost of connection is often prohibitive for lower-income households. Sewerage systems can also be very expensive to operate. Large quantities of water are needed to keep systems working. Conventionally treated sewage is also often of questionable quality in regards to downstream health risk.

Both dry and wet pit latrines were included as improved coverage. Pit latrines can represent safe disposal of faeces if well maintained and not used by many more people than they were designed for. They should not require manual emptying before faecal pathogens have died off. Some aspects such as smell and insects (which should be less of a problem with VIP (ventilated improved pits) and with pour-flush latrines) can affect use of the sanitation and in the case of insects can be implicated in transmission of disease to some degree.

The remaining types of sanitation were not included as improved. Public toilets were not included because of the level of service they provide, as described above in section 6.2, this often makes them an inadequate form of sanitation. This is not therefore a factor related to type of technology. Bucket latrines were also not seen as improved as they require manual emptying of fresh faeces which puts those carrying out the work at risk as well as potentially contaminating the local neighbourhood environment. "Kutchas" (temporary) latrines, often in the form of structures that empty into streams or ponds, were also excluded as they do not effectively safely separate excreta from human contact and can be unstable structures. The use of open ground was also excluded as faeces remain in the local environment where people, animals and insects can come into contact with them (this is likely to be a much more important factor in high density urban areas). 'Open' latrines where excreta are effectively left out in the open were also excluded, as they do not represent a safe form of faeces disposal.

Further types of sanitation are not at present used in large enough numbers to be included in the large household surveys such as DHS. Consequently, their suitability was not assessed.

## 8. Conclusion

Many of the answers to questions of health impact of water supply, sanitation and hygiene are still not known. Epidemiology has many shortcomings in its ability to answer these questions.<sup>20</sup> Individual studies are capable of both under and over estimating health impact. Some commentators believe that the general bias is towards under-estimation.<sup>19</sup>

At present an estimated 2.4 billion people lack access to *improved* sanitation and 1.1 billion people lack access to *improved* water supply.<sup>49</sup> The associated health burden is expected to be substantial and without doubt falls largely on the poor. Water supply and sanitation do not only provide direct benefits to health, they are also a basic right and provide privacy, dignity and greater convenience to those who use them.

This report has detailed some of the many factors which influence health impact of water supply and sanitation services; access, nature of use, operation and maintenance of services and seasonality amongst others. These factors affect the safety of services for human health. It is important therefore not to rely on the idea of a hierarchy of service *safety* that applies equally in all settings. Technology type may therefore not be the best proxy for health impact. It is obviously very difficult to estimate quality and reliability of service by technology type alone. There will be an enormous range of quality of service within each group. It is also clearly not feasible to quantify all of the determinants of health impact in routine monitoring on a large scale. The importance of each of these factors will vary widely across different settings.

Evaluating individual water supply and sanitation programmes on the basis of health impact is also rather difficult. Many of the factors outlined in this report play a role, for instance how representative those who receive services are compared to those that do not, and the difficulty in measuring diarrhoeal disease incidence or prevalence. We do not have sufficient information to model the relative importance of each of the risks factors associated with water supply, sanitation and hygiene practices.

The change in terminology from 'safe' water supply and 'adequate' sanitation to 'improved' water supply and sanitation reflects the uncertainty around health impact. It is clearly extremely difficult to answer the question 'how safe is safe?' even within one specific location. It is much harder to attempt to generalise across different settings.

Despite these problems it remains vital to know who has access to 'improved' or adequate services and who does not. Information is needed for both accountability within, and advocacy for, the sector. The Year 2000 Global Assessment represents a vast improvement in the quality of information available for service coverage. Information compiled by Unicef and WHO on an ongoing basis should enable monitoring towards achievement of the Millennium Development Goals.

What is also needed is local information for local decision-making and targeting of high-risk groups to gain better understanding of local priorities and access to, and use of, services.



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