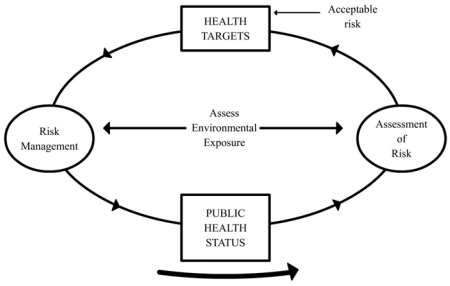

3

The Global Burden of Disease study and applications in water, sanitation and hygiene

Annette Prüss and Arie Havelaar

This chapter introduces the concept of the global burden of disease and its key measure, the Disability-Adjusted Life Year (DALY). It illustrates the use of DALYs both to integrate the effects of a single agent and also to compare the health effects of different agents. It also examines their role in informing the development of guidelines.

3.1 INTRODUCTION

In 1996, in a landmark publication, the Global Burden of Disease and Injury series appeared on our shelves, representing the culmination of over eight years of work (Murray and Lopez 1996 a,b). These volumes outline the Global Burden of Disease (GBD) Study and the associated global health statistics, and

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represent the first global and internally consistent collection of epidemiology information on disease burden. The volumes describe the burden from 107 diseases and injuries and 10 major risk factors or risk groups for various age groups and geographical regions. It represents a unique achievement describing the world's disease burden status and trends in the health of populations.

The project was undertaken in a number of stages, with the first stage initiated by the World Bank in 1988. The initial aims were to assess the significance to public health of individual diseases (or related clusters of disease) and what was known about the cost and effectiveness of relevant interventions for their control (Jamieson 1996). This first phase led to the introduction of a new common measure for examining diverse disease outcomes, the DALY or Disability Adjusted Life Year. Phase two extended the effort by attempting to provide a comprehensive set of estimates for total disease burden by including disability as well as number of deaths. The publication of the Global Burden of Disease and Injury series represents the third phase of the project. The publication of these volumes was undertaken to inform policy analysis, particularly assessment of priorities in terms of health research and development in developing countries (Jamieson 1996). The initial estimates outlined in the Global Burden of Disease and Injury series are constantly undergoing a process of updating and development (WHO 1999).

3.2 MEASURING POPULATION HEALTH

Of key importance to the GBD study was the introduction of a common unit of currency to allow comparisons to be made between different health outcomes and allowing quantification of non fatal outcomes. This section details the development of the DALY. While not without their problems (Anand and Hanson 1997; Barendregt *et al*. 1996; Williams 1999) DALYs and other summary measures of population health do go at least some way towards providing a level playing field from which comparisons can be made.

For the purpose of integrating the health burden of different health effects of one agent, or comparing the effects of different agents, a common measure is necessary. Traditionally, public health policy has concentrated on mortality, and the severity of disease was expressed in death rates or the number of life years lost due to a certain cause. However, many diseases do not lead to premature mortality, but may be a significant cause of morbidity. Healthy life expectancy is increasingly becoming the focus of public health policy (Van der Maas and Kramers 1997). As outlined in the introduction, Murray (1994) and Murray and Lopez (1996a) have developed the DALY. The DALY is part of a family of population health summary measures. It is based on measuring health gaps, as opposed to measuring health expectancies (Murray and Lopez 1999), and as

such it measures the difference between current conditions and a selected target, for example an ideal health state. This integrated measure combines years of life lost by premature mortality (YLL) with years lived with a disability (YLD), standardised by means of severity weights. Thus:

$$DALY = YLL + YLD \tag{3.1}$$

3.2.1 Years of life lost

To estimate YLL on a population basis, the age-specific mortality rates must be combined with the life expectancy of the fatal cases, had they not developed the disease. If mortality affects the population in a random fashion, the life expectancy can be derived from standard life tables. Murray (1996) proposed a table based on the highest observed national life expectancy (for Japanese women), taking into account differences in life expectancy between men and women. The standard life expectancy at birth is 80.0 years for men and 82.5 years for women. For comparison, the life expectancy in the Netherlands in 1994 was 74.6 years for men and 80.3 years for women (Van der Maas and Kramers 1997) while that in Zimbabwe in 1998 was 39 years. If mortality affects a susceptible sub-population, the use of standard life expectancy would lead to a gross overestimation of YLL. In this case, disease-specific information is necessary to estimate the additional loss of life years by the disease under consideration. The total loss of life years is calculated as:

$$YLL = \sum_i e^*(a_i) \sum_j d_{ij} \tag{3.2}$$

where i is an index for different age-classes, d_{ij} is the number of fatal cases per age-class, j is an index for different disease categories and $e^*(a_i')$ is the mean life expectancy in that age class.

3.2.2 Years lived with disability

To estimate YLD on a population basis, the number of cases must be multiplied by the average duration of the disease and a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (dead). If necessary, the disease process can be subdivided into several stages according to duration or severity. Thus,

$$YLD = \sum_j N_j \; L_j \; W_j \tag{3.3}$$

where *j* is an index for different disease categories, N is the number of patients, L is the duration of disease and W is the severity weight.

3.2.3 Measuring disability

Disability needs to be assessed in three different domains: the physical, psychological and social domains. Each of these domains is an aggregate of a number of dimensions, which are usually measured by means of questionnaires. There are three main types of questionnaire for health status measurement: generic, disease-specific and domain-specific (Essink-Bot 1995). Generic instruments cover the three domains of health in a non-disease specific way, assuming that different diseases can be characterised as patterns of physical, psychological and social dysfunction. Several generic instruments have been developed, which differ in the emphasis that each places on each domain. Disease-specific instruments are developed to study changes in health as a consequence of (treatment for) a specific disease. Domain-specific instruments concentrate on the consequences of disease in a specific domain of health or, more specifically, on a specific symptom.

The choice between these three types of instruments depends on the purpose and the perspective of the study. In this case, the objective of the study is to integrate and compare the health effects of very different diseases, which leads naturally to the choice for generic instruments. This choice is further supported by the societal perspective of the study: the objective is to evaluate the impact of disease on a public health level, which leads to the need for non-disease-specific and comprehensive, i.e. generic, measurements.

Information from questionnaires gives a descriptive evaluation of health status, which must be evaluated for further analysis. Different valuation methods are available, such as Standard Gamble (SG), Time Trade Off (TTO), Person Trade Off (PTO) and Visual Analog Scale (VAS) (Brooks 1996; Murray 1996; Torrance 1986). For public health analyses the Person Trade Off and the Time Trade Off methods are the most natural approaches. The Person Trade Off protocol has two variants. In the PTO1-variant, respondents are asked to choose between an intervention that prolongs the life of 1000 individuals in perfect health and an intervention that prolongs the life of N individuals with less than perfect health. In the PTO2-variant, the alternative is to cure N individuals in less than perfect health. The value of N at which the respondent cannot make a choice (the indifference point) is used to calculate the disability weight of the health state under consideration. In the Time Trade Off protocol, respondents are asked to weigh the benefits of an immediate ‘cure’ against possible later loss of health. Nord (1995) has outlined that the PTO protocol is by its nature most suitable for evaluation of health care programmes from a societal perspective.

Societal perspective also requires that the values used be based on public perception rather than on the opinion of patients or health professionals. However, in the GBD study (Murray and Lopez 1996a,b) and in the VTV study (Van der Maas and Kramers 1997), the panels were composed of medical experts, because they were expected to be best able to compare a large number of diseases in an objective manner.

In the GBD study (Murray and Lopez 1996a,b), a set of 22 indicator conditions was described, representing different grades of disability in the dimensions of physical functioning, neuro-psychological conditions, social functioning, pain and sexual/reproductive functions. In a formal procedure, these indicator conditions were assigned disability weights and classified into seven disability classes. In the next step, several hundred outcomes were evaluated with respect to the distribution of each condition across the seven disability classes. From these data, a composite disability weight for each condition was calculated (Table 3.1).

Table 3.1. Disability classes and indicator diseases (Murray 1996)

Class	Weight	Examples
1	0.00–0.02	Vitiligo on face, low weight
2	0.02–0.12	Watery diarrhoea, sore throat
3	0.12–0.24	Infertility, arthritis, angina
4	0.24–0.36	Amputation, deafness
5	0.36–0.50	Down's syndrome
6	0.50–0.70	Depression, blindness
7	0.70–1.00	Psychosis, dementia, quadriplegia

3.3 MAJOR OUTCOMES OF THE GBD STUDY

In the Global Burden of Disease Study (Murray and Lopez 1996a,b), DALYs have been calculated with age-weighting and a three-percent discount rate. The leading causes of mortality and burden of disease for 1990 are shown in Table 3.2.

Table 3.2 shows the importance of accounting for non-fatal outcomes, as can be seen from the change in ranking position for a number of causes and the appearance of illnesses such as unipolar major depression when disability, not just death, is accounted for. A more recent estimation of mortality and disease burden (WHO 1999) shows a similar pattern but with HIV/AIDs taking up fourth position for both deaths and DALYs and malaria being an important cause in terms of DALYs (Table 3.3).

Table 3.2. Leading causes of death and burden of disease estimates for 1990 (adapted from Murray and Lopez 1996a)

Rank	Cause	% of total	Deaths or DALYs (1000s)
Deaths			
1	Ischaemic heart disease	12.4	6260
2	Cerebrovascular disease	8.7	4381
3	Lower respiratory infections	8.5	4299
4	Diarrhoeal diseases	5.8	2946
5	Perinatal conditions	4.4	2443
6	Chronic obstructive pulmonary disease	3.9	2211
7	Tuberculosis	2.1	1960
8	Measles	2.1	1058
9	Road traffic accidents	1.9	999
10	Cancer of trachea/bronchus/lung	1.9	945
DALYs			
1	Lower respiratory infections	8.2	112,898
2	Diarrhoeal diseases	7.2	99,633
3	Perinatal conditions	6.7	92,313
4	Unipolar major depression	3.7	50,810
5	Ischaemic heart disease	3.4	46,699
6	Cerebrovascular disease	2.8	38,523
7	Tuberculosis	2.8	38,426
8	Measles	2.7	36,520
9	Road traffic accidents	2.5	34,317
10	Congenital abnormalities	2.4	32,921

Table 3.3. Leading causes of death and burden of disease estimates for 1998 (adapted from WHO 1999)

Rank	Cause	% of total	Deaths (1000s)
1	Ischaemic heart disease	13.7	7375
2	Cerebrovascular disease	9.5	5106
3	Lower respiratory infections	6.4	3452
4	HIV/AIDS	4.2	2285
5	Chronic obstructive pulmonary disease	4.2	2249
6	Diarrhoeal diseases	4.1	2219
7	Perinatal conditions	4.0	2155
8	Tuberculosis	2.8	1498
9	Cancer of trachea/bronchus/lung	2.3	1244
10	Road traffic accidents	2.2	1171

Table 3.3 (cont'd)

Rank	Cause	% of total	DALYs (1000s)
1	Lower respiratory infections	6.0	82,344
2	Perinatal conditions	5.8	80,564
3	Diarrhoeal diseases	5.3	73,100
4	HIV/AIDS	5.1	70,930
5	Unipolar major depression	4.2	58,246
6	Ischaemic heart disease	3.8	51,948
7	Cerebrovascular disease	3.0	41,626
8	Malaria	2.8	39,267
9	Road traffic accidents	2.8	38,849
10	Measles	2.2	30,255

Table 3.4 examines the DALY data shown in Table 3.2 by developed versus developing region. As might be expected, there are some notable differences between developed and developing as well as between the overall world picture.

Table 3.4. Causes of DALYs by developed and developing regions, 1990 (adapted from Murray and Lopez 1996a)

Rank	Developed regions		Developing regions	
	Cause	%	Cause	%
1	Ischaemic heart disease	9.9	Lower respiratory infections	9.1
2	Unipolar major depression	6.1	Diarrhoeal disease	8.1
3	Cerebrovascular disease	5.9	Perinatal conditions	7.3
4	Road traffic accidents	4.4	Unipolar major depression	3.4
5	Alcohol use	4.0	Tuberculosis	3.1
6	Osteoarthritis	2.9	Measles	3.0
7	Cancer of trachea/bronchus/lung	2.9	Malaria	2.6
8	Dementia etc.	2.4	Ischaemic heart disease	2.5
9	Self-inflicted injuries	2.3	Congenital abnormalities	2.4
10	Congenital abnormalities	2.2	Cerebrovascular disease	2.4

Disease burden is also being assessed at national and regional levels, and for specific purposes such as analysing the importance of certain diseases or risk factors in population subgroups. The disease burden caused by an environmental problem, and the preventable part of it, are major elements in driving the field of decision-making for priority setting and resource allocation in health and the environment. The global burden of disease attributable to various risk factors is shown in Table 3.5.

Table 3.5. Global burden of disease and injury attributable to selected risk factors, 1990 (adapted from Murray and Lopez 1996a)

Risk factor	Deaths (1000s)	As % total deaths	DALYs (1000s)	As % total DALYs
Malnutrition	5881	11.7	219,575	15.9
Poor water supply, sanitation and personal and domestic hygiene	2668	5.3	93,392	6.8
Unsafe sex	1095	2.2	48,702	3.5
Tobacco	3038	6.0	36,182	2.6
Alcohol	774	1.5	47,687	3.5
Occupation	1129	2.2	37,887	2.7
Hypertension	2918	5.8	19,076	1.4
Physical inactivity	1991	3.9	13,653	1.0
Illicit drugs	100	0.2	8467	0.6
Air pollution	568	1.1	7254	0.5

Quantitative assessment of the burden, together with information on effectiveness and cost-effectiveness of interventions within a social and ethical framework, provide a rational basis for research, implementation and policy development. The attributable burden would usually be based upon the burden that would have been observed if the past exposure of concern had been absent or reduced to a plausible level. The preventable burden would be the burden that could be avoided if current levels of exposure were reduced to a minimum or eliminated.

3.4 GBD ESTIMATE APPLICATIONS

GBD estimates can be used in assessing the performance of a country or region in terms of health-supporting conditions and actions, to map out geographical or population-specific differences, and to monitor trends. GBD information is therefore a tool for identifying overall inequalities in a population. It also allows for comparison between regions or comparison with the developmental status of a region.

GBD information may also be used as a basis for identifying control priorities. Alongside information on effectiveness of interventions and their costs, it helps to prioritise action to prevent or reduce problems associated with a high disease burden. Disease burden measurements become essential when an effort will have a benefit proportional to the size of the problem being addressed. This is the case with political attention, allocation of time in training curricula or, to a certain extent, allocation of resources to research and

development. GBD trends permit planning for a shift in priorities rather than reacting to signs of change.

3.5 GBD AND GUIDELINES

Traditionally, guideline values for environmental media (the Drinking-Water Quality Guidelines, WHO 1993, for example) aim to provide the answer to the question:

At which value can we reasonably expect that no or only negligible health impacts will occur in an exposed population?

The question:

How much disease burden will be reduced in a population if the guidelines are implemented?

cannot be answered without additional information. This means that, although the costs of implementation could be estimated, the efficiency of such an intervention in terms of health status improvement of the population concerned remains unresolved.

Ignorance of the effectiveness of an intervention in terms of disease burden can be acceptable provided that the intervention is affordable, and that resource allocation is not in competition with other interventions (or that other aspects such as ethical or considerations are involved). When resource allocation is a problem, informed choices have to be made, at least in the short term. This is not necessarily a problem only in developing countries, but is also a common problem in developed country situations. For example, a significant number of bathing beaches do not meet the bathing water quality requirements. The Recreational Water Quality Guidelines (WHO 1998) therefore propose various levels of recreational water quality, described by the associated burden a population would experience if exposed (see Chapters 2 and 11). The policy maker can, on the basis of such information and population exposure, not only estimate the current burden of disease caused by such an exposure in the population, but also the reduction of the burden if improvement action was taken.

Looking at the normative function from a wider angle, disease burden measurement also provides information on the relative importance of a problem involving an environmental condition. It therefore puts the normative function of a specific type of exposure into a certain perspective concerning the priority that its development deserves.

3.5.1 Use of DALYs in guideline derivation

DALYs can be utilised in a variety of ways. They can be used to integrate the effects of a single agent, compare the health effects of different agents or conditions and to inform the debate on levels of acceptable risk.

3.5.1.1 Disease development – gastrointestinal disease

The first step in disease burden estimation requires an understanding of the natural history of the disease. This is best illustrated by the use of a diagram (see Figure 3.1) and it allows disease development to be broken down into various health outcomes or end points. The host can be in any of a number of possible health states, and the transitions between these states can be described by a set of conditional probabilities, i.e. the chance of moving to a health state, given the present health state.

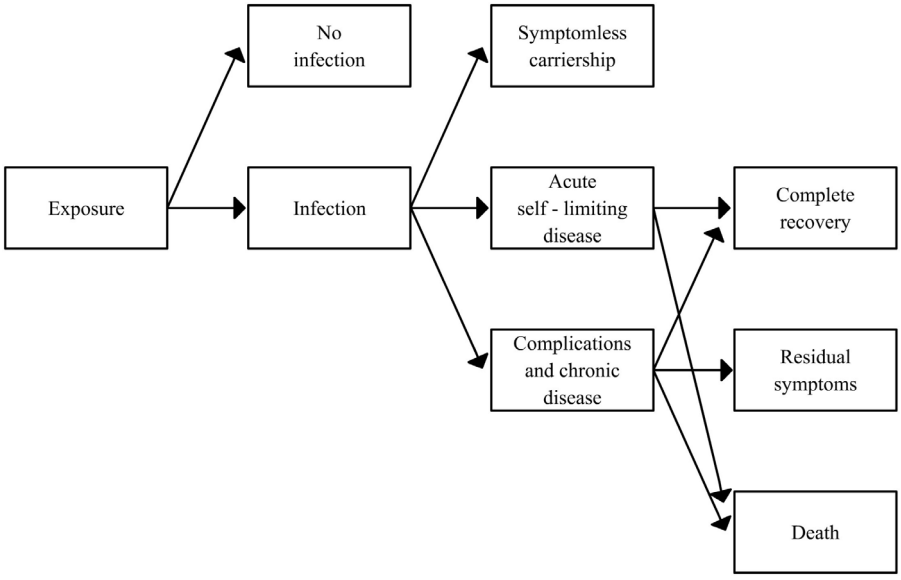

Figure 3.1. Chain model of infectious gastrointestinal disease.

The probability of infection (that is, the ability of the pathogen to establish and multiply within the host) depends on the level of exposure to the organisms in food, water or other environmental factors. Based on data from human feeding studies, statistical dose–response models have been developed to quantify the relationship between the number of ingested organisms and the probability of infection (Havelaar and Teunis 1998; Teunis *et al*. 1996). These

models are empirical and do not explicitly identify the factors that may influence the process of infection. Such factors include:

- the physiological status of the pathogen
- the matrix in which it is presented to the host
- the microbial dynamics in the host
- the aspecific host resistance (e.g. gastric acid, enzymes, bile, peristalsis)
- the specific (cellular and humoral immunity) host resistance.

Thus, generalisation of dose–response models is only possible to a limited extent. There are also experimental data on the probability of acute, gastrointestinal disease after infection. In most human feeding studies, clinical symptoms are also described, but the relationship with the ingested dose is less uniform than for infection (Teunis *et al*. 1997). Additional data may be derived from epidemiological studies, such as outbreak investigations or prospective cohort studies.

Usually, gastroenteritis is a self-limiting disease and the host will generally recover within a few days to a few weeks without any residual symptoms (although this may not be true of susceptible individuals, those with weakened immune systems and those in developing countries). In most cases, symptomatic or asymptomatic infection confers immunity that may protect from infection and/or disease upon subsequent exposure. Usually, immunity against enteric pathogens is short-lived and the host will again enter a susceptible state within a period of months to years. In a small fraction of infected persons (with or without acute gastroenteritis), chronic infection or complications may occur. Some pathogens, such as salmonellae, are invasive and may cause bacteraemia and generalised infections. Other pathogens produce toxins that may be transported by the blood to susceptible organs, where severe damage may occur. An example is the haemolytic uremic syndrome, caused by damage to the kidneys from Shiga-like toxins of some *E. coli* strains. Complications may also arise by immune-mediated reactions, where the immune response to the pathogens is then also directed against the host tissues. Reactive arthritis and Guillain-Barré syndrome are well-known examples of such diseases. The complications from enteritis normally require medical care, and frequently result in hospitalisation. There may be a substantial risk of mortality, and not all patients may recover fully, but may suffer from residual symptoms, which may be life-long. Therefore, despite the low probability of complications, the public health burden may be significant.

3.5.1.2 Integrating the health effects of exposure to one agent

This application of the DALY scale, in terms of exposure to a single agent, is illustrated by the example of the health burden of infection with thermophilic *Campylobacter* spp. in the Dutch population. *Campylobacter* infection may lead to a great diversity of symptoms, but most important in terms of incidence and severity are acute gastroenteritis (in the general population and leading to a general practitioner visit), Guillain-Barré syndrome (clinical phase as well as residual symptoms) and reactive arthritis.

Table 3.6. Health burden due to infection with thermophilic *Campylobacter* spp. in the Netherlands, assuming no age-weighting or discounting* (adapted from Havelaar *et al*. 2000a)

Population	Number of cases	Duration (years)	Severity weight	YLD/ YLL
Morbidity				
General population: gastroenteritis	311,000	0.014	0.067	291
General practitioner: gastroenteritis	17,500	0.023	0.393	159
Clinical phase Guillain-Barré	58.3	1	0.281	16
Residual symptoms: Guillain-Barré	57.0	37.1	0.158	334
Reactive arthritis	6570	0.115	0.210	159
Mortality				
Gastroenteritis	31.7	13.2	1.00	419
Guillain-Barré	1.3	18.7	1.00	25
TOTAL				1403

* based on mean values of the estimated annual incidence, the severity weight and the duration

Table 3.6 shows a summary of results, indicating an annual loss of approximately 1400 DALYs per year in the Dutch population of 15 million. The most significant impact on public health is from gastroenteritis-related mortality and the residual symptoms of Guillain-Barré Syndrome, despite the fact that the incidence is low. Acute gastroenteritis (both patients who do and do not visit their GP), is an additional important source of disease burden.

3.5.1.3 Integrating health effects from exposure to different agents

DALYs can also be used to compare the effects of different agents and allow a balancing of risks. Disinfection of drinking water reduces the risk of infectious disease but oxidants such as chlorine and ozone react with water constituents to produce a wide range of disinfection by-products, with toxic and carcinogenic properties. The dilemma of how to balance these positive and negative health effects has long hampered decision making with regard to implementing or modifying drinking-water disinfection processes (Craun *et al*. 1994a,b). The use

of DALYs as a tool to quantify all effects in one single metric has simultaneously been suggested in the Netherlands (Havelaar *et al*. 2000b) and by the United States Environmental Protection Agency (US EPA). Havelaar *et al*. (2000b), using a hypothetical case study, examined the reduction of the risk of infection with *Cryptosporidium parvum* following ozonation of drinking water in comparison to the concomitant increase in the risk of renal cell cancer arising from the formation of bromate. It was found that the health benefits of preventing gastroenteritis in the general population and premature death in AIDS patients outweighed health losses by premature death from renal cell cancer by a factor of more than ten.

3.5.1.4 Defining a level of acceptable risk

The approach used above can be extended to derive a target value for acceptable risk from pathogens in water that offers a similar level of protection as current standards for genotoxic carcinogenic compounds.

The definition of acceptable risk used in the guidelines for drinking water quality (WHO 1993) for genotoxic carcinogens is: '*less than one excess cancer case per* 10^{-5} *consumers after lifetime exposure*'. If a cohort of one million people experienced this risk, there would be ten excess cancer cases in this cohort. Renal cell cancer (RCC) caused as a result of exposure to bromate (as discussed above) will be used as an example. RCC occurs at a median age of 65 years (standardised life expectancy 19 years) and has a case-fatality ratio of 60%. If the relatively minor effects of morbidity are ignored, the health burden of one case of RCC is equal to the number of Life Years Lost, which is $1 \times 60\% \times 19 = 11.4$ years (Havelaar *et al*. 2000b). Averaged over the total life expectancy of this population at birth (80 years), the annual (acceptable) loss of healthy life years is a fraction of $10 \times 11.4/80 \times 10^6 = 1.4 \times 10^{-6}$. Compare this fraction with the annual health burden of *Campylobacter*-associated infections in the Netherlands of almost 1500 DALYs per year per 15 million inhabitants. This is a fraction of 10^{-4}, or more than 70 times higher than deemed acceptable for genotoxic carcinogens. Note that in the Netherlands, as in many other industrialised countries, the acceptable level of risk is set at 10^{-6}, making the current health burden of campylobacteriosis 700 times higher than the equivalent risk limit for carcinogens. It should be noted, however, that cancer types other than RCC may occur at different ages and may have a different prognosis. Therefore, the level of protection of one standard for acceptable risk from all types of cancer does not lead to a common level of protection.

3.6 PROBLEMS IN ASSESSING DISEASE BURDEN IN RELATION TO WATER QUALITY

As for many environmental exposures, the links between disease burden and specific water-related exposures have been difficult to identify. In recent years, with the development of more sophisticated epidemiological methods, increased evidence has been compiled for the health impacts related to water. This is the case for exposure to recreational water (Prüss 1998), and also the impacts of microbiological aspects of drinking water (Payment 1997).

The main difficulties in assessing the water-related disease burden lie in the following points:

- Exposure often occurs at household or small community level and can only be measured with major expenditure and, therefore, cannot be determined on a routine basis. This means that exposures such as drinking-water quality cannot realistically be measured on a large scale, because contamination may vary between adjacent households. Although drinking-water quality is routinely assessed at the point of distribution, it has been shown that the quality at point of consumption may differ significantly.
- The diseases transmitted by water are mostly non-specific, such as the large cluster of 'diarrhoeal diseases'. The problem associated with this relates to the difficulty in attributing a disease to a specific exposure, especially when it is difficult to assess this exposure.
- In settings where the water-related disease burden is greatest (in certain developing country situations and in small community supplies), exposures to disease-causing organisms are frequent and occur often through various 'competing' pathways. These pathways can include exposure to drinking-water, contaminated food, person-to-person contact and lack of hygiene, and it is difficult to determine the relative contributions of these various causes.
- For many water-related exposures, the risks have not been clearly established in terms of exposure–risk relationships. Without an established linkage between exposure and disease outcome, and the difficulties, outlined above, in attributing outcome to specific exposures, disease burden cannot be estimated with any degree of confidence.

Given the importance of the disease burden related to water supply, sanitation and hygiene (two to three million deaths per year), it is imperative that further investigations be made to improve our knowledge about the relative importance of pathways of transmission and the relation between population exposure and disease burden. This information is necessary to construct the picture that will allow efficient and equitable allocation of resources and efforts in order to achieve the greatest improvement of population health status.

3.7 IMPLICATION FOR INTERNATIONAL GUIDELINES AND NATIONAL REGULATIONS

Developments in the global burden of disease and the use of DALYs will play an important role in prioritising risk factors, determining levels of acceptable risk, setting health targets and appraising effectiveness through examining public health outcome. Their use is, therefore, key to the development of future guidelines driven by the harmonised framework. Because international guidelines should be tailored to the public health needs and conditions of individual countries, DALYs are also likely to play an important role in that process of adaptation.

3.8 REFERENCES

Anand, S. and Hanson, K. (1997) Disability-adjusted life years: a critical review. *Journal of Health Economics* **16**, 695–702.

Barendregt, J.J., Banneux, L. and Van de Maas, P.J. (1996) DALYs: the age weights on balance. *Bulletin of the World Health Organization* **74**, 439–443.

Brooks, R. with the EuroQol Group (1996) EuroQol: the current state of play. *Health Policy* **37**, 53–73.

Craun, G.F., Bull, R.J., Clark, R.M., Doull, J., Grabow, W., Marsh, G.M. *et al*. (1994a) Balancing chemical and microbiological risks of drinking water disinfection, part I. Benefits and potential risks. *J. Water SRT-Aqua* **43**, 192–199.

Craun, G.F., Regli, S., Clark, R.M., Bull, R.J., Doull, J., Grabow, W. *et al*. (1994b) Balancing chemical and microbiological risks of drinking water disinfection, part II. Managing the risks. *J. Water SRT-Aqua* **43**, 207–218.

Essink-Bot, M-L. (1995) Health status as a measure of outcome of disease and treatment. Rotterdam: Erasmus Universiteit.

Havelaar, A.H. and Teunis, P.F.M. (1998) Effect modelling in quantitative microbiological risk assessment. In *Proceedings of the 11th Annual Meeting of the Dutch Society for Veterinary Epidemiology* (eds A.M. Henken and E.G. Evers), Bilthoven, the Netherlands.

Havelaar, A.H., De Wit, M.A.S. and Van Koningsveld, R. (2000a) Health burden of infection with thermophilic Campylobacter species in the Netherlands. Report no. 284550004, Bilthoven: National Institute of Public Health and the Environment.

Havelaar, A.H., De Hollander, A.E.M., Teunis, P.F.M., Evers, E.G., Van Kranen, H.J., Versteegh, J.F.M., Van Koten, J.E.M. and Slob, W. (2000b) Balancing the risks and benefits of drinking water disinfection: DALYs on the scale. *Environmental Health Perspectives* **108**, 315–321.

Jamieson, D.T. (1996) Forward to the global burden of disease and injury series. In *The Global Burden of Disease and Injury Series. Volume I. The Global Burden of Disease* (eds C.J.L. Murray and A.D. Lopez), pp. xv–xxiii, Boston: Harvard School of Public Health, World Health Organization, World Bank.

Murray, C.J.L. (1994) Quantifying the burden of disease: the technical basis for disability-adjusted life years. *Bulletin of the World Health Organization* **72**(3), 429–445.

Murray, C.J.L. (1996) Rethinking DALYs. In *The Global Burden of Disease and Injury Series. Volume I. The Global Burden of Disease* (eds C.J.L. Murray and A.D. Lopez), pp. 1–98, Boston: Harvard School of Public Health, World Health Organization, World Bank.

Murray, C.J.L. and Lopez, A.D. (1996a) *The Global Burden of Disease and Injury Series. Volume I. The Global Burden of Disease. A comprehensive assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projected to 2020*. Harvard School of Public Health, World Bank, World Health Organization.

Murray, C.J.L. and Lopez, A.D. (1996b) *The Global Burden of Disease and Injury Series. Volume II. Global Health Statistics. A compendium of incidence, prevalence and mortality estimates for over 200 conditions*. Harvard School of Public Health, World Bank, World Health Organization.

Murray, C.J.L. and Lopez, A.D. (1999) Progress and directions in refining the global burden of disease approach. World Health Organization, GPE Discussion Paper No. 1.

Nord, E. (1995) The person-trade-off approach to valuing health care programs. *Medical Decision Making* **15**, 201–208.

Payment, P. (1997) Epidemiology of endemic gastrointestinal and respiratory diseases: Incidence, fraction attributable to tap water and costs to society. *Water Science and Technology* **35**(11–12), 7–10.

Prüss, A. (1998) Review of epidemiological studies on health effects from exposure to recreational water. *International Journal of Epidemiology* **27**(1), 1–14.

Teunis, P.F.M., Van der Heijden, O.G., Van der Giessen, J.W.B. and Havelaar, A.H. (1996) The dose–response relation in human volunteers for gastro-intestinal pathogens. Report no. 284550002, Bilthoven: National Institute of Public Health and the Environment.

Teunis, P.F.M., Medema, G.J., Kruidenier, L. and Havelaar, A.H. (1997) Assessment of the risk of infection by *Cryptosporidium* or *Giardia* in drinking water from a surface water source. *Water Research* **31**, 1333–1346.

Torrance, G.W. (1986) Measurement of health utilities for economic appraisal. *Journal of Health Economics* **5**, 1–30.

Van der Maas, P.J. and Kramers, P.G.N. (eds) (1997) Gezondheid en levensverwachting gewogen Volksgezondheid Toekomst Verkenning 1997, deel III. Bilthoven; Maarssen: Rijksinstituut voor Volksgezondheid en Milieu; Elsevier/De Tijdstroom.

WHO (1993) Drinking Water Quality Guidelines – Volume 1, Recommendations. World Health Organization, Geneva.

WHO (1998) Guidelines for Safe Recreational-water Environments: Coastal and Freshwaters. Draft for consultation, World Health Organization, Geneva.

WHO (1999) The World Health Report. Making a Difference. World Health Organization, Geneva.

Williams, A. (1999) Calculating the global burden of disease: time for a strategic reappraisal? *Health Economics* **8**, 1–8.