



Estimating the burden of disease attributable to unsafe water and lack of sanitation and hygiene in South Africa in 2000

Simon Lewin, Rosana Norman, Nadine Nannan, Elizabeth Thomas, Debbie Bradshaw and the South African Comparative Risk Assessment Collaborating Group

Objectives. To estimate the burden of disease attributable to unsafe water, sanitation and hygiene (WSH) by age group for South Africa in 2000.

Design. World Health Organization comparative risk assessment methodology was used to estimate the disease burden attributable to an exposure by comparing the observed risk factor distribution with a theoretical lowest possible population distribution. A scenario-based approach was applied for estimating diarrhoeal disease burden from unsafe WSH. Six exposure scenarios were defined based on the type of water and sanitation infrastructure and environmental faecal-oral pathogen load. For 'intestinal parasites' and schistosomiasis, the burden was assumed to be 100% attributable to exposure to unsafe WSH.

Setting. South Africa.

Outcome measures. Disease burden from diarrhoeal diseases,

intestinal parasites and schistosomiasis, measured by deaths and disability-adjusted life years (DALYs).

Results. 13 434 deaths were attributable to unsafe WSH accounting for 2.6% (95% uncertainty interval 2.4 - 2.7%) of all deaths in South Africa in 2000. The burden was especially high in children under 5 years, accounting for 9.3% of total deaths in this age group and 7.4% of burden of disease. Overall, the burden due to unsafe WSH was equivalent to 2.6% (95% uncertainty interval 2.5 - 2.7%) of the total disease burden for South Africa, ranking this risk factor seventh for the country.

Conclusions. Unsafe WSH remains an important risk factor for disease in South Africa, especially in children under 5. High priority needs to be given to the provision of safe and sustainable sanitation and water facilities and to promoting safe hygiene behaviours, particularly among children.

S Afr Med J 2007; 97: 755-762.

Diarrhoeal diseases are an important cause of morbidity and mortality in low- and middle-income countries, annually resulting in the death of 4.9 out of every 1 000 children aged less than 5 years in these regions.^{1,2} In South Africa diarrhoeal diseases account for 3.1% of total deaths – the eighth largest cause of death nationally.^{3,4} Among children under 5, diarrhoeal diseases are the third largest cause of death (11.0% of all deaths), and the third greatest contributor to the burden of disease, constituting 8.8% of all disability-adjusted life years (DALYs) in this age group.⁴ Survey data show that 13% of under-5s in South Africa were reported to have had a bout of diarrhoea in the previous 2 weeks.⁵ While the proportion of

deaths attributable to diarrhoeal diseases in under-5s in 2000 was substantially lower than the 27.7% reported for 1984,⁶ these figures are still cause for concern.

The World Health Organization (WHO) estimates that there are 0.75 cases of diarrhoea per person worldwide every year. This rate varies between regions, sub-Saharan Africa having the highest rate of 1.29 cases per person annually. In contrast, rates in Europe and the USA are 0.18 and 0.07 cases per person per year respectively.⁷ In South Africa the estimated incidence of diarrhoeal disease in under-5s in 2004, based on cases presenting to primary health facilities (and therefore likely to be an underestimate of true incidence), was 128.7/1 000, with wide variations between provinces, from 8.1/1 000 in Gauteng to 244.2/1 000 in KwaZulu-Natal.⁸ These differentials indicate potential for reducing the disease burden through improvements in provision of water and sanitation services and changes in hygiene behaviour.

Unsafe water and lack of sanitation and hygiene (WSH) is a key risk factor for diarrhoeal and other diseases. Worldwide, unsafe WSH has been estimated to account for 3.1% of all deaths and 3.7% of all DALYs.⁹ These figures conceal enormous regional variation – the disease burden related to this risk factor is up to 240 times higher in developing regions such as Africa than in industrialised regions.² Unsafe WSH remains a concern in South Africa. Census 2001 data indicate that 13.6% of households have no toilet facility.¹⁰ A further 4.1%

Health Systems Research Unit, Medical Research Council of South Africa and Department of Public Health and Policy, London School of Hygiene and Tropical Medicine

Simon Lewin, MB ChB, PhD

Burden of Disease Research Unit, Medical Research Council of South Africa, Tygerberg, Cape Town

Rosana Norman, PhD

Nadine Nannan, MSc

Debbie Bradshaw, DPhil (Oxon)

Health and Development Research Group, Medical Research Council of South Africa, Johannesburg

Elizabeth Thomas, PhD

Corresponding author: S Lewin (simon.lewin@mrc.ac.za)



and 22.8% respectively use bucket and pit latrines with no ventilation – both inadequate forms of sanitation that increase risk of diarrhoeal and parasitic diseases.¹¹⁻¹⁴ The proportion of households with inadequate facilities is much higher in the Eastern Cape, KwaZulu-Natal and Limpopo provinces.

While most households have access to piped water (84.5%), this is more than 200 m away for 12.4% of households, while 7.5% still utilise rivers, streams or dams, placing residents at risk for diseases such as schistosomiasis.¹⁵ Again there is wide variation, with 23.0% and 12.9% of households in the Eastern Cape and KwaZulu-Natal respectively using rivers or streams as their main water source.¹⁰ Risk of exposure to infections as a result of inadequate water and sanitation is not limited to the home environment. In 2002 it was estimated that 15% of clinics and nearly 12% of schools in South Africa were without sanitation.¹⁶

Unsafe WSH as a risk factor is particularly important from a policy perspective, because knowledge of how to reduce exposure through improving water and sanitation facilities and hygiene, and the effects on diarrhoeal and other illnesses of doing so, are fairly well developed.^{14,17,18} There are also significant synergistic effects of improving WSH in terms of improving nutritional status,¹³ reducing poverty and promoting development.^{19,20}

Access to adequate basic facilities is also a rights issue, and clearly interpreted as such within the South African Constitution. Internationally the Millennium Development Goals (MDGs) aim to halve the proportion of people without sustainable access to basic sanitation and safe drinking water by 2015, and South Africa has committed itself to contributing to this.²¹ It is therefore of concern that in 2015, 1 in 5 and 1 in 4 South African households, respectively, are projected to have inadequate access to water and sanitation facilities.²² Many are likely to be rural households, further contributing to rural-urban inequalities (Table I).

In this article we attempt to estimate the burden attributable to unsafe WSH by age group for South Africa in 2000.

Methods

Comparative risk assessment (CRA) methodology was used, as developed by the WHO^{23,24} and applied specifically to unsafe WSH by Prüss *et al.*²⁹ The composite risk factor, unsafe

WSH, was defined as including 'multiple factors, namely the ingestion of unsafe water, lack of water linked to inadequate hygiene, poor personal and domestic hygiene and agricultural practices, contact with unsafe water, and inadequate development and management of water resources or water systems'.⁹

Two approaches for estimating disease burden attributable to unsafe WSH were used, according to disease outcome. For selected related diseases other than infectious diarrhoea (combined in the category 'intestinal parasites') and for schistosomiasis, the burden was assumed to be 100% attributable to exposure to unsafe WSH.⁹ The South African National Burden of Disease study⁴ provided revised estimates for some of these diseases. Although largely attributable to unsafe WSH, trachoma is not common in South Africa and is therefore not listed separately in the South African burden of disease list and could not be included in this analysis. A number of other diseases related to unsafe WSH, such as hepatitis A and scabies, could not be included as their risk factor-disease relationships remain unclear.²

For diarrhoeal disease burden from unsafe WSH, estimates were based on calculation of a population-attributable fraction derived from exposure information. A scenario-based approach was applied.⁹ Here risk of diarrhoeal disease is conditioned by a typical exposure or representative combination of risk factors at commonly encountered levels. Scenarios were defined on the basis of, firstly, type of water and sanitation infrastructure, and secondly, load of faecal-oral pathogens in the environment.

The resulting six exposure scenarios capture combinations of the risk factors related to unsafe WSH:

- Scenario I: ideal situation or theoretical minimum, conferring lowest possible population risk for transmission, corresponding to the absence of transmission of diarrhoeal disease through WSH. Environmental faecal-oral pathogen load is very low in this scenario. It is assumed that the prevalence for this scenario is zero in all WHO regions because even in the most developed regions cases of food poisoning, etc. occur.
- Scenario II: typically encountered in developed or high-income countries. This scenario has low to medium load of faecal-oral pathogens in the environment, characterised by more than 98% coverage in improved water supply and

Table I. South African Millennium Development Goals: Indicators of past and present access to water and sanitation and future access targets

Indicators	Proportion of total population with access (%)		
	1994	2004	2015 target
Improved water source within 100 m of household	60.1	78.7	80.1
Basic sanitation	48.7	63.7	74.4

Source: South Africa. Millennium Development Goals Country Report, 2005: 49.²²



sanitation and regional incidence of diarrhoea of less than 0.3/person/year.^{25,26}

- Scenario III: various improved forms of provision that reduce risk of exposure compared with scenario IV; a transitional scenario between high (scenario IV) and low (scenario II) environmental pathogen loads² (Table II).
- Scenarios IV - VI: high faecal-oral pathogen environments typical in developing countries and characterised by poor access to water and sanitation.

Risk estimates assigned to each exposure scenario were based on those of Prüss *et al.*,⁹ who used large surveys and reviews of multi-country studies to derive risk averages – the average risk related to the described scenarios across the world and in an array of situations (Table III).⁹ The ideal situation (scenario I) was assigned a relative risk (RR) of 1.0. Because of the uncertainties associated with these risk estimates, upper and lower uncertainty boundaries were constructed, drawing on those used for the global study (Table III).⁹ The lower

estimate was based on the diarrhoeal disease risk reduction achieved through personal hygiene interventions only; the best estimate on the reduction from improvements in both water quality and personal hygiene; and the upper estimate on the additional improvements from provision of a continuous piped water supply. No differences in RRs across age groups or between sexes was assumed.

Data on prevalence and population distribution of exposure were obtained from the South African Census 2001,¹⁰ which reported the main source of water supply and toilet facilities available to households. Based on these data, households were allocated to 1 of 3 categories: poor, intermediate, or good access to water supply and sanitation facilities (Table IV). These 3 groups were then matched as closely as possible to the exposure scenarios (Table II).

The situation for certain population subgroups in South Africa was sufficiently different from that of other African countries such that it could not be captured entirely by scenario

Table II. Scenarios for estimating exposure for diarrhoeal diseases

Scenario	Description	Environmental faecal-oral pathogen load
VI	No improved water supply and no basic sanitation in a country not extensively covered by those services, and where water supply is not routinely controlled	Very high
Vb	Improved water supply and no basic sanitation in a country not extensively covered by those services, and where water supply is not routinely controlled	Very high
Va	Basic sanitation but no improved water supply in a country not extensively covered by those services, and where water supply is not routinely controlled	High
IV	Improved water supply and basic sanitation in a country not extensively covered by those services, and where water supply is not routinely controlled	High
IIIc	IV and improved access to drinking water (generally piped to household)	High
IIIb	IV and improved personal hygiene	High
IIIa	IV and drinking water disinfected at point of use	High
II	Regulated water supply and full sanitation coverage, with partial treatment for sewage, corresponding to a situation typically occurring in developed countries	Medium to low
I	Ideal situation, corresponding to the absence of transmission of diarrhoeal disease through WSH	Very low

Source: Prüss *et al.*, 2002: 539.²

Table III. Relative risk estimates associated with exposure scenarios and distribution of the population between exposure scenarios, South Africa, 2000

	Exposure scenario						
	I	II	III	IV	Va	Vb	VI
Lower estimate	1	2.5		3.8	3.8	4.9	6.1
Best estimate	1	2.5		6.9	6.9	8.7	11.0
Upper estimate	1	2.5		10.0	10.0	12.6	16.0
% of households assigned to each scenario in SA	0	27.8	0	51.4	4.0	12.7	4.0

Source: Prüss-Üstün *et al.*, 2004: 1343.⁹



IV. Urban households with full sanitation coverage and good access to improved water supplies were considered at low risk of diarrhoeal disease. Using Census 2001 data we assigned households in urban areas and with access to improved water supply and full sanitation coverage (27.8% of all) to scenario II. The 22.9% of households with piped water and full sanitation coverage but in rural or urban informal settlements were assigned to scenario IV, together with households with intermediate water and sanitation facilities. The remaining 20.7% were placed in scenarios Va, Vb and VI (Table III).

Population-attributable fractions (PAFs) were calculated in Excel using the formula:

$$PAF = \frac{\sum_{i=1}^k p_i (RR_i - 1)}{\sum_{i=0}^k p_i (RR_i - 1) + 1}$$

where p_i is the prevalence of exposure in level i , RR_i is the RR of disease in exposure level i and k is the total number of exposure levels. The PAFs were then applied to the revised South African burden of disease estimates for 2000 (deaths, years of life lost (YLLs), years lived with disability (YLDs), and DALYs) for the single outcome of diarrhoeal disease.⁴

We used Monte Carlo simulation-modelling techniques to present uncertainty ranges around point estimates so as to reflect all the main sources of uncertainty in the calculations. We used the @RISK software version 4.5 for Excel,²⁷ which

allows multiple recalculations of a spreadsheet, each time choosing a value from distributions defined for input variables. For the RR estimates, we specified a triangular probability distribution with 3 points: the published best RR estimate as the most likely point and the published upper and lower risk estimates for different exposure scenarios² as the maximum and minimum entered values of the distribution (Table III). We calculated 95% uncertainty ranges for our output variables (attributable burden as a percentage of total burden in South Africa, 2000) bounded by the 2.5th and 97.5th percentiles of the 2000 iteration values generated.

Results

For South Africa for 2000 it was estimated that 84% (95% uncertainty interval 79 - 86%) of all deaths due to diarrhoeal diseases, or about 13 368 deaths, were attributable to unsafe WSH. Of these diarrhoeal deaths, 66.4% ($N = 8 871$) were in children under 5, constituting 9.2% of all deaths in this age group. Schistosomiasis and intestinal parasites contributed a further 20 and 46 deaths, respectively, to unsafe WSH, giving an estimated total of 13 434 attributable deaths (Table V).

The total burden of disease due to this risk factor in 2000 was 418 790 DALYs, 92.2% of which was caused by diarrhoeal diseases and 5.3% and 2.5% by schistosomiasis and intestinal parasites, respectively. The DALYs attributable to WSH were equivalent to 2.6% (95% uncertainty interval 2.5 - 2.7%) (Table VI) of the total disease burden for South Africa, ranking this risk factor seventh out of 17 risk factors analysed in the country.

Table IV. Proportion of households with different standards of water and sanitation access, South Africa, 2000

Standard of water supply	No. of households	Standard of sanitation facilities			Total
		Poor	Intermediate	Good	
Poor	923 360	1 926 641	4 448 707	5 136 206	11 511 555
Intermediate	7 329 232	4.0%	4.0%	0.02%	8.0%
Good	3 258 963	12.4%	34.4%	16.8%	63.7%
Total	11 511 555	0.32%	0.17%	27.8%	28.3%
		16.7%	38.7%	44.6%	100.0%

Source: Stats SA Census 2001.¹⁰

Poor = water from a dam, pool, or stagnant water source from a river, stream or rainwater tank, no sanitation or a bucket system; Intermediate = water from a spring or borehole or piped water collected from up to 200 m away (outside dwelling or yard) or from a water vendor and basic sanitation (pit latrine with or without ventilation); Good = piped water into the residence and flush toilet and living in urban areas.

Note: Households with piped water into the residence or yard and a flush toilet in rural areas or informal urban settlements were assigned to the intermediate category.

Table V. Burden of disease attributable to unsafe water, sanitation and hygiene, by disease, South Africa, 2000

Disease	ICD-9 codes included in assessment	Deaths	YLLs	YLDs	DALYs
Diarrhoeal diseases	001, 002, 004, 006-009	13 368	375 476	10 685	386 160
Schistosomiasis	120	20	445	21 617	22 062
Intestinal parasites, including ascariasis, trichuriasis, hookworm	126-129	46	1 612	8 956	10 568
Total attributable burden		13 434	377 533	41 258	418 790

YLLs = years of life lost; YLDs = years lived with disability; DALYs = disability-adjusted life years; ICD-9 = International Classification of Diseases, 9th revision.



The largest proportion of the disease burden attributable to unsafe WSH is experienced by children under 5 (Table VI), with 7.4% (95% uncertainty interval 7.1 - 7.7%) of disease burden from all causes attributable to unsafe WSH. This ranks WSH as the third largest risk factor for disease among under-5s, behind vertical transmission of HIV due to unsafe sex and undernutrition. Unsafe WSH is therefore a considerably more important risk in this age group than in the South African population as a whole. The burden attributable to unsafe WSH was similar for males and females across all age groups.

Upper and lower limits around estimates of disease burden attributable to unsafe WSH, based on the range of RRs assigned to each exposure scenario, were relatively narrow (Table VI), indicating that they were not very sensitive to the range of RRs assigned (Table III).

Discussion

These findings highlight the substantial disease burden attributable to unsafe WSH in South Africa, particularly for children under 5 years of age. Estimates are comparable with those reported in the global unsafe WSH risk factor assessment, although in South Africa the proportion of all attributable deaths and DALYs in the age group 0 - 4 years is less than global estimates for this age group.⁹ This results from the approach used to allocate the South African population to different exposure scenarios for determining risk of diarrhoeal diseases from unsafe WSH. Based on data from the 2001 Census,¹⁰ 27.8% and 51.4% of the South African population were allocated to scenarios II and IV respectively. This is very different from the distribution for the WHO African subregion (AFR-E, which includes South Africa) - where 0% was allocated to scenario II, 42% to scenario IV, and 9% and 38% to scenarios Vb and VI respectively.⁹ However, we believe that the allocation described here reasonably reflects access to improved water and sanitation facilities for certain urban populations in South Africa compared with other developing countries in the WHO African subregion.

A substantial proportion of disease burden due to unsafe WSH in South Africa could be prevented if water supplies,

sanitation services and hygiene behaviours were further improved. Significant headway has already been made in improving water supplies. Since 1994 an additional 18.6% of the population has gained access to improved water, within 100 m of their home (Table I). This is largely the result of the Department of Water Affairs and Forestry's capital works programme, which provided new water services for approximately 7 million people between 1994 and 2002.^{28,29} Access to safe sanitation also improved, from 48.7% to 63.7% between 1994 and 2004 (Table I).²² This suggests that exposure to unsafe WSH in South Africa decreased over the last decade.³⁰

However, rural-urban and intra-urban differentials in access to safe WSH remain a concern. Residents of inner-city, low-income, high-density areas and urban informal settlements struggle to gain access to basic services or share these with many households. Variation in access between urban and rural areas is also stark - while only 5% of urban households did not have access to purified water and any toilet in 2001, 37% and 28% of rural households did not have access to purified piped water or any form of toilet, respectively.²²

Reducing the risks to which children are exposed through unsafe WSH is particularly important given the large disease burden attributable to this in children under 5 years of age. This includes reducing diarrhoea risks in the household and local environments. A study in Port Elizabeth³¹ showed that diarrhoea levels were significantly higher in children under 6 who shared a tap with more than 6 other households, and also in those who shared a toilet with more than 5 households. Informal preschool and child care facilities have also been shown to be an important environment for transmission of diarrhoeal diseases.³²

While improving access to adequate water and sanitation facilities is key, the impact of both personal and domestic hygiene behaviours should not be neglected. In the same Port Elizabeth study,³¹ diarrhoea levels were 4.8 times higher in caregivers who stored water in their kitchens, a risk that could be mitigated by improved domestic hygiene behaviours.

Reviews have suggested that good hygiene may result in a 33% reduction in diarrhoeal mortality,¹⁴ and that hygiene

Table VI. Burden of disease attributable to unsafe water, sanitation and hygiene (WSH) in persons and children under 5 years, South Africa, 2000

	Total burden attributable to unsafe WSH	Burden attributable to unsafe WSH as % of total burden for South Africa	Burden attributable to unsafe WSH, children < 5 yrs	Burden attributable to unsafe WSH in children < 5 yrs as % of total burden for South Africa for children < 5 yrs
Deaths	13 434	2.6	8 910	9.3
95% uncertainty interval	12 718 - 13 905	2.4 - 2.7	8 435 - 9 222	8.8 - 9.6
DALYs	418 790	2.6	305 738	7.4
95% uncertainty interval	398 100 - 432 379	2.5 - 2.7	289 464 - 316 426	7.1 - 7.7

DALYs = disability-adjusted life years.



education is a highly cost-effective intervention for reducing childhood diarrhoeal diseases.³³ A systematic review of the impact of hand-washing with soap showed that this cheap intervention could reduce diarrhoea risk in the community by 42 - 44%.¹⁸ Improvements in hygiene behaviour should also reduce intestinal parasite infections. However, the best way to change hygiene behaviours in different settings remains unclear.^{18,34}

Secondary prevention of diarrhoeal diseases is also important. Impacts can be mitigated by prompt and appropriate treatment at household and health facility level. Providing hygiene information to caregivers of children with diarrhoeal disease may also contribute to reducing disease spread within households and the likelihood of further episodes.

Improving WSH is also likely to have positive impacts on household economies due to the time saved in water collection.³⁵ This would free time for other tasks including education, domestic hygiene and commercial activities,^{36,37} particularly for female children and women.^{31,38} All of these activities are likely to contribute to improved health. Improving WSH is therefore key to breaking the cycle of poverty and disease and to promoting development.

This analysis considered only the disease burden attributable to unsafe WSH. However, this risk factor may work jointly or synergistically with others, such as underweight/malnutrition (including iron-deficiency anaemia and vitamin A and zinc deficiency), to increase incidence and effects of diseases such as diarrhoea and intestinal parasites. Some risks related to unsafe WSH may be mediated through underweight, while equally, some risks for underweight may be mediated through WSH-related diseases such as diarrhoea.^{13,39} In South Africa, HIV/AIDS may also be an important moderator of the risk of diarrhoeal disease from unsafe WSH, particularly in children living in informal settlements.⁴⁰

These synergistic effects are not within the scope of this analysis. However, policies to reduce disease burden due to diarrhoeal diseases need to be cross-sectoral to reduce exposure to multiple risks. Increased demand for water in providing care for a household member living with AIDS also highlights the importance of improved access and multisectoral developmental approaches.⁴¹ Government programmes such as those focusing on informal settlement eradication and integrated rural development, as well as the Extended Public Works Programme, provide opportunities for this.

This study has a number of limitations. Firstly, while the Census provides information on water and sanitation facilities, it does not indicate whether these are operating. The termination of household water supplies for non-payment is also pertinent.⁴² While legislation establishing the right to a basic minimum free household water supply may have partly mitigated this problem, residents of rented 'backyard'

shacks may not have access to this supply as they are often not registered with the local authority. Such uncertainty regarding the functioning of basic facilities would result in an overestimate of the number of households meeting criteria for exposure scenario II and underestimation of the fraction of the burden of diarrhoeal disease attributable to unsafe WSH. The true attributable fraction may therefore be higher than reported.

Secondly, assignment of households to exposure scenarios was not always straightforward. For example, should households using pit latrines without ventilation be assessed as having 'poor' or 'intermediate' sanitation?

Thirdly, it is not within the scope of this framework to look at the synergistic effects of risk factors such as unsafe WSH and malnutrition, including micronutrient deficiencies and underweight, and childhood mortality in poor households in this setting. The burden of diarrhoeal diseases reported as attributable to these risk factors may therefore be an underestimate of the true attributable fraction. A recent evaluation⁴³ suggests that approximately 50% of the disease burden of malnutrition can be attributed largely to unsafe WSH, highlighting the complexity of these effects.

Fourthly, it is not possible within this assessment to examine how the burden is distributed between rural and urban settings and poorer and wealthier households. However, RRs associated with different exposure scenarios clearly indicate that households with poorer access to water and sanitation facilities are at substantially greater risk of developing diarrhoeal and other diseases. Since most of these households are likely to be located in poor rural or peri-urban settlements, it can fairly safely be assumed that the burden attributable to unsafe WSH is borne largely by poorer households and, more specifically, by children within them. Research on water access in relation to the recent cholera epidemic supports this assumption.⁴⁴

Finally, we did not assess the attributable burden from all intestinal parasite infestations, but rather focused on the major ones. We were also unable to include in our estimates other WSH-related diseases, such as hepatitis A, for which current knowledge does not allow an attributable fraction to be estimated. In addition, estimates for morbidity were based on the AFR-E ratio of morbidity to mortality for diseases attributable to unsafe WSH.⁴ However, it is unclear whether this ratio adequately represents the South African situation and it is therefore possible that the morbidity component of the burden has been underestimated. Other uncertainties, related to the methodological approach, are discussed elsewhere.⁹

Recommendations

High priority needs to be given to improving access to safe and sustainable sanitation and water facilities, particularly in poorly served urban and rural communities in South Africa.



The high burden attributable to unsafe WSH, especially in children, provides a strong public health justification for this. However, there are also clear development, equity and human rights reasons for improving access, as part of our commitment to achieving the MDGs.²¹ Although debate continues regarding relative effectiveness of different approaches to provision of water and sanitation interventions,^{17,45} integrated approaches are likely to be the most appropriate.

More attention needs to be paid to the promotion of hand-washing with soap and other hygiene behaviours. Since it is not yet clear how best to change hygiene behaviours in South African settings,⁴⁶ further rigorous research is needed. Particular attention needs to be paid to children's hygiene behaviours within the home and in childcare facilities. Water and sanitation infrastructure programmes need to include a strong hygiene behaviour component to ensure that maximum health benefits are realised. Prompt and appropriate treatment of diarrhoeal disease also needs to be promoted.

More research is also required on effectiveness of programmes for mass deworming of children. School-based programmes may improve individual and community health and have benefits for educational attendance and performance, but studies are not conclusive.⁴⁷ There is some evidence of improving maternal and child health by treating intestinal parasites and schistosomiasis in pregnant women,⁴⁸ but again further research is needed.

In the drive to address the disease burden related to lifestyle, injuries and HIV/AIDS, diseases of poverty related to unsafe WSH should not be forgotten.

The other members of the Burden of Disease Research Unit of the South African Medical Research Council: Pam Groenewald, Michelle Schneider, Jané Joubert, Desireé Pieterse, and Beatrice Nojilana are thanked for their valuable contribution to the South African Comparative Risk Assessment Project. Ms Ria Laubscher and Dr Lize van der Merwe of the MRC Biostatistics Unit made contributions via their statistical expertise and assistance. Our sincere gratitude is expressed for the valuable contribution of Associate Professor Theo Vos, University of Queensland, School of Population Health, for providing technical expertise and assistance, and for his enthusiasm and support from the initial planning stages of this project. We also gratefully acknowledge the contribution of Annette Prüss-Üstün, WHO, for sending us information and spreadsheets as well as for critically reviewing the manuscript. John Fincham, Medical Research Council of South Africa, is acknowledged for sending data on intestinal parasite infestation prevalence in South Africa. Sibongile Twala, research intern with the MRC, assisted in checking sources and obtaining references. Elize de Kock, Sylvia Louw and Karin Barnard, MRC, provided administrative support.

References

- Kosek M, Bern C, Guerrant RL. The global burden of diarrhoeal disease, as estimated from studies published between 1992 and 2000. *Bull World Health Organ* 2003; 81: 197-204.
- Prüss A, Kay D, Fewtrell L, Bartram J. Estimating the burden of disease from water, sanitation, and hygiene at a global level. *Environ Health Perspect* 2002; 110: 537-542.
- Bradshaw D, Groenewald P, Laubscher R, et al. *Initial Burden of Disease Estimates for South Africa, 2000*. Cape Town: Medical Research Council of South Africa, 2003.
- Norman R, Bradshaw D, Schneider M, Pieterse D, Groenewald P. *Revised Burden of Disease Estimates for the Comparative Risk Factor Assessment, South Africa 2000*. Cape Town: Medical Research Council of South Africa, 2006. <http://www.mrc.ac.za/bod/bod.htm> (last accessed 31 May 2007).
- Department of Health. *South African Demographic and Health Survey 1998*. Full Report. Pretoria: DOH, 2002.
- Yach D, Strebel PM, Joubert G. The impact of diarrhoeal disease on childhood deaths in the RSA, 1968 - 1985. *S Afr Med J* 1989; 76: 472-475.
- Hutton G, Haller L. *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level*. Geneva: Water Sanitation and Health Protection of the Human Environment, World Health Organization, 2004.
- Day C, Gray A. Health and related indicators. In: Jumba P, Barron P, eds. *South African Health Review 2005*. Durban: Health Systems Trust, 2005.
- Prüss-Üstün A, Kay D, Fewtrell L, Bartram J. Unsafe water, sanitation and hygiene. In: Ezzati M, Lopez A, Rodgers A, Murray CJL, eds. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors*. Geneva: World Health Organization, 2004: 1321-1353.
- Statistics South Africa. *Census 2001: Census in Brief*. Pretoria: Statistics South Africa, 2003.
- Boadi K, Kuitunen M. Childhood diarrhoeal morbidity in the Accra Metropolitan Area, Ghana: socio-economic, environmental and behavioral risk determinants. *Journal of World Health and Population* 2005; 2-13.
- von Schirnding YE, Yach D, Bignon R, Mathews C. Environmental determinants of acute respiratory symptoms and diarrhoea in young coloured children living in urban and peri-urban areas of South Africa. *S Afr Med J* 1991; 79: 457-461.
- Esrey SA. Water, waste, and well-being: a multicountry study. *Am J Epidemiol* 1996; 143: 608-623.
- Esrey SA, Potash JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bull World Health Organ* 1991; 69: 609-621.
- Wolmarans C, Bremond P, de Kock K. The occurrence and distribution of schistosome intermediate hosts in relation to the prevalence of schistosome infections in humans in a highly endemic area in the Limpopo Province, South Africa. *Southern African Journal of Epidemiology and Infection* 2005; 20(1): 18-22.
- Department of Water Affairs and Forestry. *Sanitation for a Healthy Nation: The Policy on Basic Household Sanitation Made Easy*. Pretoria: National Sanitation Task Team, Department of Water Affairs and Forestry, 2002.
- Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, Colford JJM. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect Dis* 2005; 5(1): 42.
- Curtis V, Cairncross S. Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. *Lancet Infect Dis* 2003; 3: 275.
- Whittington D, Yeongae C. *Economic Benefits Available From the Provision of Improved Potable Water Supplies. A Review and Assessment of the Existing Evidence*. WASH Technical Report No. 77. Washington, DC: Office of the Health Bureau for Research and Development, USAID, 1992.
- World Health Organization Commission on Macroeconomics and Health. *Macroeconomics And Health: Investing in Health for Economic Development*. Geneva: WHO, 2001.
- United Nations. *United Nations Millennium Declaration*. United Nations General Assembly resolution 55/2. New York: UN, 2000. <http://www.un.org/millennium/declaration/ares552e.pdf> (last accessed 31 May 2007).
- Government of South Africa. *South Africa. Millennium Development Goals Country Report*. Pretoria: Government of South Africa, 2005.
- Ezzati M, Lopez A, Rodgers A, van der Hoorn S, Murray CJL. Selected major risk factors and global and regional burden of disease. *Lancet* 2002; 360: 1347-1360.
- World Health Organization. *The World Health Report 2002. Reducing Risks, Promoting Healthy Life*. Geneva: WHO, 2002.
- Food Standards Agency. *A Report of the Study of Infectious Intestinal Disease in England*. London: HMSO, 2000.
- Murray CJL, Lopez A, eds. *Global Health Statistics: A Compendium of Incidence, Prevalence and Mortality Estimates For Over 200 Conditions*. *Global Burden of Disease and Injury*. Vol. 2. Cambridge, Mass.: Harvard School of Public Health on behalf of the World Health Organization, 1996.
- Palisade Corporation. @Risk software version 4.5 for Excel. New York: Palisade Corporation, 2002.
- Muller M. *The National Water and Sanitation Programme in South Africa: Turning the 'Right to Water' into Reality*. Kenya: The World Bank Water and Sanitation Programme - Africa Region, 2002.
- Department of Water Affairs and Forestry. *Department of Water Affairs and Forestry Annual Report 2004-5*. Pretoria: Department of Water Affairs and Forestry, South Africa, 2005.
- Department of Water Affairs and Forestry. *Multi-year Strategic Plan 2005/6 - 2007/8*. Pretoria: Department of Water Affairs and Forestry, South Africa, 2005.
- Thomas E, Seager J, Vijoen E, et al. *Household Environment and Health in Port Elizabeth, South Africa*. Urban Environment Series Report no. 6. Stockholm: Stockholm Environment



- Institute in collaboration with the South African Medical Research Council and the Swedish International Development Cooperation Agency (Sida), 1999.
32. Genthe B, Strauss N, Vundule C, Maforah F, Seager J. The effect of water supply, handling and usage on water quality in relation to health indices in a developing community in South Africa. *Urban Health Newsletter* 1995; 26: 32-36.
 33. Varley RC, Tarvid J, Chao DN. A reassessment of the cost-effectiveness of water and sanitation interventions in programmes for controlling childhood diarrhoea. *Bull World Health Organ* 1998; 76: 617-631.
 34. Loevinsohn B. Health education interventions in developing countries: a methodological review of published articles. *Int J Epidemiol* 1990; 19: 788-794.
 35. Churchill A, de Ferranti D, Roche R, Tager C, Walters A, Yazzer A. *Rural Water Supply and Sanitation: Time for a Change*. World Bank Discussion Papers No. 18. Washington, DC: World Bank, 1987.
 36. Aiga H, Umenai T. Impact of improvement of water supply on household economy in a squatter area of Manila. *Soc Sci Med* 2002; 55: 627-641.
 37. Okun DA. The value of water supply and sanitation in development: an assessment. *Am J Public Health* 1988; 78: 1463-1467.
 38. Sims J. *Women, Health and Environment*. Geneva: World Health Organization, 1994.
 39. Ezzati M, van der Hoorn S, Rodgers A, Lopez A, Mathers C, Murray CJL. Potential health gains from reducing multiple risk factors. In: Ezzati M, Lopez A, Rogers A, Murray CJL, eds. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors*. Geneva: World Health Organization, 2004: 2167-2190.
 40. Guarino A, Bruzzese E, De Marco G, Buccigrossi V. Management of gastrointestinal disorders in children with HIV infection. *Paediatr Drugs* 2004; 6: 347-362.
 41. Kamminga E, Wegelin-Schuringa M. *HIV/AIDS and Water, Sanitation and Hygiene. Thematic Overview Paper*. Netherlands: IRC International Water and Sanitation Centre, 2003.
 42. McDonald D. No money, no service: South Africa's poorest citizens lose out under attempts to recover service costs for water and power. *Alternatives Journal* 2002; 28: 16-20.
 43. Prüss-Üstün A, Corvalan C. *Preventing Disease Through Healthy Environments. Towards an Estimate of the Environmental Burden of Disease*. Geneva: World Health Organization, 2006.
 44. Hemson D, Dube B, Mbele T, Nnadozie R, Ngcobo D. Still paying the price: Revisiting the cholera epidemic of 2000-01 in South Africa. In: McDonald D, Ruiters G, eds. *Municipal Services Project Occasional Papers Series Number 8*. Pretoria: Human Sciences Research Council, 2006. <http://www.hsre.ac.za/Document-1318.phtml> (last accessed 31 May 2007).
 45. World Health Organization/ UNICEF Joint Monitoring Programme for Water Supply and Sanitation. *Global Water Supply and Sanitation Assessment 2000 Report*. Geneva: WHO, 2000.
 46. Jagals P, Nala NP, Tsubane TJ, Moabi M, Motaung KC. Measuring changes in water-related health and hygiene practices by developing-community households. *Water Sci Technol* 2004; 50(1): 91-97.
 47. Dickson R, Awasthi S, Demellweck C, Williamson P. Anthelmintic drugs for treating worms in children: effects on growth and cognitive performance. *The Cochrane Database of Systematic Reviews* 2000 (Issue 2): Art. No.: CD000371. DOI: 10.1002/14651858.CD000371.
 48. Haider B, Bhutta Z. Effects of interventions for helminthic infections in pregnancy. (Protocol). *The Cochrane Database of Systematic Reviews* 2005 (Issue 4): Art. No.: CD005547. DOI: 10.1002/14651858.CD005547.