Chapter 1

INTRODUCTION

1.1 Background

The World Health Organisation (WHO) reports that 25% of all preventable diseases are due to a poor physical environment.[1] Furthermore, over 40% of the global burden of disease attributed to environmental factors falls on children below five years of age, who account for about 10% of the world's population.[2] The burden of disease is defined as lost healthy life years, which includes those lost to premature death and those lost to illness as weighted by a disability factor (severity).[3] The WHO estimates that the number of people exposed to unsafe indoor air pollution levels exceed those exposed to unacceptable outdoor air pollution levels in all of the world's cities collectively.[4] Air pollution is the largest single environment-related cause of ill health among children in most countries.[1,5] In other countries it is the second, after the scarcity of safe water. Globally, 2.6% of all ill-health is attributable to indoor smoke from dirty fuels (such as wood, animal dung, crop residues, coal, paraffin), nearly all in poor regions.[1,4] Dirty fuels are also referred to in the literature as 'solid' fuels. Distinction is also made between biomass fuels or biofuels and fossil fuels. Biomass fuels comprised any material derived from plants or animals, which is deliberately burnt by humans. Wood is the most common example, but the use of animal dung and crop residues is also widespread.[5] Fossil fuels refer to any carbon containing fuel e.g. coal, peat, petroleum and natural gas derived from the decomposed remains of prehistoric plants and animals.[6] Indoor air pollution is a serious global public health risk demanding significantly improved research and policy-making contributions. No case in support of environmental action is deeper than that of the need to eradicate health risks.

Despite all the shortcomings of epidemiological studies, they are important in linking exposure to human health *directly*.[7-22] The ultimate endeavor of epidemiology is to identify modifiable determinants of disease occurrence and progression and to contribute in testing the efficacy and effectiveness of interventions on these determinants including the health services. Environmental epidemiology is specifically focused at linking environmental exposure to human health. It is the study of the distribution of health-related states or events in specified populations in relation to determinants/hazards in the living environment of these populations and the application of this study to the control of such hazards.[23,24] The term "environment" comprises everything that is not genetic, such as diet, smoking and even exercise. However, environmental epidemiology has a more restricted connotation, referring to those environmental factors that are outside the immediate control of the individual, such as active smoking. A comprehensive introduction to the science of environmental epidemiology and environmental health is beyond the scope of this article. The reader may consult Yassi et al., Baker et al. and Beaglehole et al. in this regard.[23-25]

The reader is referred to Chapter 2 for an introduction on the chemical properties of air pollutants and their environmental fate and transport, exposure assessment, adverse health effects from mainly outdoor low levels of air pollution, health evidence and research needs for indoor air pollution and the relevance of air pollution epidemiological studies in South Africa.

1.2 Impetus for this thesis

Much of what must be done to prevent various morbidity and mortality outcomes lies outside of the sphere of health care. Therefore interventions should be targeted at risk factors and determinants (primary prevention), rather than only diagnosing and providing medical treatment for those already affected (secondary and tertiary prevention). This is parallel with the ultimate endeavour of epidemiology research: to identify modifiable determinants of disease occurrence and progression and to contribute in testing the efficacy and effectiveness of interventions on these determinants including the health services.[25] Given the tremendous health impact of air pollution exposure, as identified in the previous section, the focus of this thesis is on primary prevention, that is the identification of outdoor air pollution and the use of highly polluting fuels for cooking and space heating as risk factors, whilst controlling for confounding. Motivation for the use of the selected health and exposure data along with the focus on the selected health outcomes in the data analyses will be deliberated in this section.

Unfortunately, despite the large and expanding literature (especially in developed countries), relatively few people have reaped the potential health benefits identified in environmental epidemiology. This situation is worse in many developing countries, including South Africa, where indoor and outdoor environmental and/or occupational exposures exceed national and international standards or guidelines by a considerable amount. Regrettably very little is done to rectify these trends in the country. Possible reasons are the lack of risk management strategies (such as interventions), failure to extrapolate results from developed to developing countries with complete confidence, weak design and/or implementation of local studies leading to presence of systematic and random errors or even the complete lack of studies conducted in developing country settings.

In an ideal world with unlimited funds it will be possible to conduct the perfect air pollution epidemiological study, which will be able to follow a vast number of people up from the day they were conceived to the day they die with detailed quantitative exposure, health and confounder measurements, whilst implementing interventions derived from the study results during the follow-up period. However, we are living in a world with limited funds for research and more so in the case of a developing country like South Africa, where approximately 5% of the research budget is spent on health related research, compared to 30% in developed countries.[26] In this regard, developing countries face a double hurdle: they often do not have easy access to routinely collected data and they face considerable difficulties in disseminating the information they themselves generate. Thus it is the lack of funding that drives the lack of detailed, accurate and valid information to minimise measurement error and bias in epidemiological studies along with the lack of research capacity to disseminate information to the research community and policy makers.

Local researchers emphasised in 1990 the necessity for policies to be enlightened by research that highlight the connection between environment and health.[27] Other local researchers stressed the fact that most health research concentrates on the identification and description of the problem, whilst action orientated research is neglected.[28] A study conducted in 1991 by the South African Medical Research Council (MRC) highlighted the deficiencies in public health research, particularly with regard to policy-directed health systems research.[26,29,30]

Recognising the importance of health research, the White Paper for Transformation of the National Health Systems in South Africa formally adopted the Essential

National Health Research (ENHR) strategy in 1997 as a mechanism to drive the health research agenda setting.[28,31] The 1996 ENHR Priority Setting workshop was the first attempt in South Africa to develop criteria for priority setting for the country's health research. Recommendations for implementing the ENHR action included promotion and advocacy, a mechanism, priority setting, capacity building, networking, funding and evaluation.

In order for the public to benefit from epidemiological results, these must be translated from theory into public health practice more efficiently. This process requires the epidemiologist to be involved in the process of addressing the solutions to the problems they study. Given the finite resources available to protect health, there is a need to weight different risks and to allocate preventive resources to get the maximum benefit. Population attributable fractions (PAFs), also known as population attributable risks, are useful for estimating the proportion of disease cases that could be prevented if one or more risk factors for that disease were reduced or eliminated.[32-39]

Furthermore, the new National Health Act (Act 61 of 2003) may offer relief to the lack of political commitment to environmental health and improve the dilapidated function – along with air quality measurements - in South Africa.[40] The Act has been developed from the 1996 Draft National Environmental Policy.[41] This policy stipulated the paradigm shift of the old 'health inspector' model to a community development approach in addressing environmental health issues by transferring accountability for most environmental health services from provincial level to metro and district municipalities. Regrettably environmental health is not presently a main concern in municipality budgets.

The science of environmental epidemiology is essential to implement Clause 70 of the new National Health Act (Act 61 of 2003).[40] It stipulates that health research priorities should be identified in the country on the basis of burden of disease, cost-effectiveness of interventions aimed at reducing the basis of burden, the availability of human and institutional resources for the implementation of an intervention at the level closest to the affected communities, the health needs of vulnerable groups such as women, older persons, children and people with disabilities and the health needs of communities.

In order to prioritise on health research needs a country should ideally use risk estimates projected from local epidemiological studies in the calculation of the attributable risk due to a specific risk factor and consequently the computation of the disease burden indicators. Disease burden indicators are expressed as daily adjusted life-years lost due to ill health (DALYs) or years of life lost (YLLs).[3] South Africa, a middle income country, is faced by health risk factors from a First World situation (such as industry, traffic, aging population) along those from a Third World situation (such as domestic burning dirty fuels, poor sanitation, overcrowding). Results deduced from epidemiological studies conducted in developed countries and even other developing countries are not merely applicable in this country. In the South African context economical, social and cultural factors may render the population more vulnerable to increased air pollution exposure, due to factors such as poor hygiene, overcrowding, dusty environments, poor nutrition, open dwellings, outdoor lifestyles and the escalating HIV/AIDS epidemic. It is estimated that 10.5 million lives might be lost to AIDS by 2015 in the country.[42] The reader is referred to Chapter 2 for more information on the vulnerability of the South African society as well as published indoor air pollution concentrations due to dirty fuel use.

However, although locally derived risk estimates is desired for application in local policy decisions, Yach et al addressed the methodological difficulties in undertaking epidemiological studies in developing countries.[43] They pointed out the use of ecological and cross-sectional studies in determining the relationship between risk factors and disease and consequently applying detailed analytical studies to determine the reasons for these relationships. In South Africa, detailed analytic epidemiology studies will have to compete with the demands on limited public and research funds for work on common diseases of pressing current importance, such as HIV/AIDS, malaria, TB. Therefore analytical studies should not merely redocument the impact of known risk factors, but should provide a basis for designing interventions, albeit technical or socio-behavioural. Innovative research options, should therefore be explored to enhance air pollution epidemiology in the country, which in turn may improve public health and inform policy.

Considering the immense health impact of air pollution exposure, the need for local risk estimates to apply in burden of disease calculations and the lack of funding for air pollution epidemiology studies in the country, it is important to prioritise on which health outcomes to focus. On the one hand there are indoor air pollution research gaps identified by a WHO report, Smith, Ezzati et al and Bruce et al and on the other hand the local prevalent health outcomes as identified by the ENHR.[44-47] South Africa, as a developing country, also has an obligation to enhance understanding of health issues related to other developing countries.[48-50] Twenty health priority areas were identified by the ENHR, of which 5 correspond with indoor air pollution research gaps, namely injuries, TB, cancer, respiratory infections and perinatal conditions.[28]

The new National Health Act (Act 61 of 2003)[40] transfers accountability for most environmental health services from provincial level to metropolitan councils and district municipalities. It was therefore logical to approach a local metropolitan council for in depth statistical analysis of its air quality data. The main air pollution hotspots in the country are Durban, Johannesburg, Cape Town, Pretoria, Richards Bay, Witbank and the Vaal Triangle. Cape Town was selected as the city adheres to stringent quality assurance guidelines from the US-EPA when monitoring outdoor air pollution.[51]

Air quality monitoring in the cities of South Africa has been in place for decades, for example in Cape Town it commenced during 1958 with the introduction of the first monitoring station collecting SO_2 and smoke concentration data.[51] Bailie et al pointed out the deficiencies in the Cape Town monitoring equipment and lack of information on trends in photochemical smog levels.[52] They called for an upgrading of monitoring of air pollution in the city and for appropriate steps to prevent its further increase. Progress was made in the mean time.

Various environmental challenges confront the Cape Town area. These are primarily the consequence of the growing population of over 3.15 million people and their concurrent need for infrastructure, housing, employment and education.[51] Outdoor air quality remains a key issue in Cape Town, largely because of the visible air pollution, particularly during March to August - known as the 'brown haze'. The brown haze is associated with calm atmospheric conditions and low level temperature inversions. It occurs over most of the City and is typically most severe in the morning.

A few years ago the National Association for Clean Air (NACA) commenced a pilot study executed by the Energy Research Institute (ERI) of the University of Cape Town.[53] The key objective of the study was the source apportionment of the brown haze. Conclusions were that small particles are the single largest cause of the visible brown haze; vehicular emissions are accountable for 65% of visible degradation, of which 49% is caused by diesel driven vehicle emissions; industry is a notable source, in particular low level emitting industries, the industrial contribution estimated to be 22%; wood burning and natural sources, such as wind-blown dust and sea salt, contribute very little towards the brown haze and assuming a laissez faire approach, air pollution is projected to escalate by 48% from 1997 to 2007.

Due to the lack of a computerised health data management system in the country, it was not feasible to conduct a time-series study using the high quality outdoor air pollution data from Cape Town. However, as will be addressed in Chapter 2, indoor and personal air pollution concentrations often correlate poorly with outdoor air levels.[54-65] Indoor, personal and outdoor correlations are dependent on the pollutant under investigation. Nevertheless, time-series studies are at least steppingstones to address air pollution epidemiology in the country.

The local MRC was contacted to provide the 1998 South African Demographic and Health Survey (SADHS) data free of charge. The data were analysed in more detail than reported in the SADHS report.[66] It was the first national adult and child health survey conducted across the entire country. Data from this survey provided the opportunity to examine the prevalence and determinants of various diseases in a representative national population rather than a selected high risk population, as has been the case in most previous studies in developed countries.

Studies addressing cardiovascular diseases were identified as one of the indoor air pollution research gaps.[44-47] The 1998 SADHS collected information on the prevalence of heart attacks and various risk factors on demographics, diet, lifestyle and the environment. A preliminary analysis was conducted on the 1998 SADHS data as a pilot study during June 2004. The preliminary results indicated that too few cases of lung cancer, still births and perinatal deaths were reported. Birth weight data were also missing for the vast majority of participants. However, respiratory ill health is the main reason for use of the health services in the country and is also one of the research priorities identified by the ENHR.[67]

A recent report by Statistics South Africa, listed the ten leading underlying natural causes of death for different age groups during 1997, 1999 and 2001.[68] Infant deaths were mostly due to causes related to the perinatal stage, as also reported in the literature.[69-82] However, between 22.6% and 18.7% of infant deaths were due to unexplained causes. It is likely that some of these premature deaths may be attributed to high indoor air pollution exposure. A local study conducted 15 years ago reported that acute respiratory infections (ARI)(such as pneumonia) were then the principal cause of death amongst young children in large parts of country.[83] This is supported by international findings that ARI are a leading cause of childhood illness and death worldwide, accounting for an estimated 6.5% of the entire global burden of disease[4]. In addition there is no simple and rapid treatment for ARI as is the case with diarrhoeal disease and oral rehydration therapy.

A series of 5 papers on child survival appeared in *The Lancet* during 2003 and described a major public health challenge: more than 10 million children dying each year because they have not been reached by known and effective interventions.[84-88] One of the most challenging Millennium Development Goals (MDGs) is addressing this global public health dilemma, to achieve a 66% reduction in child mortality by 2015 (Goal 4, Target 5).[89] The MDGs adopted by the United Nations in 2000 provide an opportunity for concerted action to improve global health. They place health at the heart of development and establish a novel global compact, linking developed and developing countries through clear, reciprocal obligations. Over the past 20 years, the hazards of indoor air pollution has been documented by a growing body of literature[44-47] but very few studies focused on its impact on infant and child mortality. Another MDG is addressing the proportion of dirty fuel use in countries (Goal 7, Target 9, Indicator 29).[89]

Additionally, asthma and other chronic diseases were the main cause of death of South Africans in 2000.[90] Recent publications highlighted that prevalence rates of chronic respiratory diseases are escalating in developing countries.[91-97] Most environmental epidemiological studies in South Africa focused on children health.[98-112] TB is also one of the diseases targeted by the MDGs (Goal 6, Target 8): start to reverse the incidence of TB and eradicate the disease by 2015.[89] This thesis therefore placed priority on determining risk factors of adult and childhood respiratory health and 1-59 month mortality.

Demographic and health surveys (DHS) are usually of cross-sectional design. As there is no follow-up, these surveys are less time-consuming and costly than more rigorous prospective cohort studies. Due to the inherent characteristics of health surveys, they do not adhere to some of Hill's causation guidelines (Table I): temporal relation, reversibility and strong study design.

Table I Hill's causation guidelines[25]

Temporal relation	Does the cause precede the effect (essential)
Plausibility	Is the association consistent with other knowledge (e.g. regarding mechanism of action, evidence from experimental animals)
Consistency	Have other studies had similar results?
Strength	What is the strength of the association between the cause and the effect?
Dose-response	Is increased exposure to the possible cause associated with increased effect?
Reversibility	Does the removal of a possible cause lead to reduction of disease risk?
Study design	Is the evidence based on a strong study design?
Judging the evidence	How many lines of evidence lead to the conclusion?

However, the function of a DHS is not to prove causation, but to answer specific questions about the population related to measurements taken at a point in time, to provide information on intercorrelations among variables in the population at that current point in time, to detect high-risk groups, to give hints about causal relations, to generate hypotheses, to provide a baseline for comparisons with future measurements and to measure changes in health and risk factor prevalence rates through a sequence of surveys.[113,114] The results from these surveys are also important descriptively in health administration, planning and policy analysis as information on disease prevalence is often required to assess the need and demand for health services and to evaluate intervention programs in specific target populations. Thus DHS data are mainly applied in secondary or tertiary prevention.

Although the weaknesses of DHS are known, this thesis will investigate the association between indoor air pollution indicators and various health outcomes nevertheless. During the statistical analyses, various limitations regarding confounding and exposure assessment will be identified and the usefulness of secondary exposure and health data will be assessed. Recommendations will be made how to address these limitations in future SADHS in order to improve the link between indoor air pollution indicators and various health outcomes.

1.3 Research question

Does air pollution (using secondary exposure and health data) pose a significant potential risk on human health (specifically respiratory health of people >15 years and <5 years as well as 1-59 month mortality) in South Africa?

The following hypothesis will be tested:

Air pollution (using secondary exposure and health data) poses a significant potential risk on human health (specifically respiratory health of people >15 years and <5 years as well as 1-59 month mortality) in South Africa.

1.4 Aims

This thesis will attempt to investigate the usefulness of analysing secondary South African air pollution exposure and health data to project preliminary risk estimates for adult respiratory health, under five ARI and 1-59 month mortality due to exposure to indoor air pollution from using dirty fuels for cooking and heating purposes and ultimately improve public health in the country. These preliminary risk estimates will be used to determine preliminary attributable fractions and finally approximate estimates of the number of cases of disease or premature mortality that could be avoided if indoor air pollution due to combustion of dirty fuels for cooking and heating purposes could be completely eliminated in South Africa.

Furthermore, it will contribute to the current body of knowledge of strong evidence (ARI, chronic bronchitis) and moderate evidence (TB) on dirty fuel use. The findings of these analyses will be compared to the status quo of air pollution epidemiology in the country. The use of outdoor air pollution data from Cape Town in future time-series studies will be evaluated. Lastly, the study will investigated the current and future health implications due to outdoor PM_{10} mass exposure in the Khayelitsha sub-district in the City of Cape Town.

The specific aims are:

1. To determine the number of air pollution epidemiological studies conducted in South Africa and critically review them for study design and the strength of their results in linking air pollution exposure to human health.
2. To determine the temporal inter-site correlations of 24-hour averaged outdoor PM_{10} mass, NO_2, NO, SO_2, O_3 and CO concentrations in Cape Town whilst controlling for seasonal effects.
3. To investigate the current and future potential health implications due to outdoor PM_{10} mass exposure in the Khayelitsha sub-district in the City of Cape Town.
4. To determine the potential risk factors for adult respiratory diseases and symptoms in South Africa, whilst controlling for a number of confounders and effect modifiers.
5. To determine the whether the use of wood, animal dung, coal and paraffin for cooking and heating poses a potential risk for acute respiratory infections (ARI) in preschool children (0-59 months) living in South Africa, whilst controlling for a number of confounders and effect modifiers.
6. To determine whether the use of wood, animal dung, coal and paraffin for cooking and heating poses a potential risk for childhood mortality (1-59 months) in South Africa, whilst controlling for a number of confounders and effect modifiers.

1.5 Study design and structure of thesis

Chapter 2 will address the status quo of air pollution epidemiology in the country through a narrative review. In light of the lack of unique South African exposure-response curves, the next chapter will address the question whether outdoor air pollution is homogenously distributed in Cape Town, South Africa (Chapter 3). This is useful to know when conducting relatively easy and inexpensive time-series studies, which outputs can be used to derive exposure-response curves. If outdoor concentrations of a particular air pollutant are homogenously distributed within a city area there will be inadequate exposure variation. Consequently health data cannot be linked to these outdoor air pollutant concentrations during time-series analyses. Chapter 4 reports on the current and future health implications due to outdoor PM_{10} mass exposure in the Khayelitsha sub-district in the City of Cape Town. Next the 1998 South African Demographic and Health Survey (SADHS) data were analysed in more detail than reported in the SADHS report. This endeavour resulted in the calculation of unique South African risk estimates for adult (15 years and older) respiratory health (Chapter 5), under five respiratory health (Chapter 6) and 1-59 month mortality (Chapter 7) due to exposure to indoor air pollution from using fossil and biomass fuels for cooking and heating purposes. Chapter 8 presents a general discussion on the main results of Chapters 2-7 and their bias and limitations. The final chapter will concentrate on research recommendations and will also look at the application of the results in policy and interventions.

1.6 References

1. WHO World Health Report, 1997 World Health Organisation. World Health Report: Reducing Risks, Promoting Healthy Life. Geneva (Switzerland): World Health Organisation; 2002. Available from: http://www.who.int/whr/2002/en/index.html. Last accessed 10 May 2005.
2. Tamburlini G, von Ehrenstein OS, Bertollini R, editors. Children's environmental health: review of the evidence. Copenhagen (Denmark): European Environment Agency and World Health Organisation, Regional Office for Europe; 2002. Available from: http://www.who.it/childrenhealth. Last accessed 10 May 2005.
3. Murray CJL, Lopez AD. Global Health Statistics: A compendium of incidence, prevalence and mortality estimates for over 200 conditions. In: Murray CJL, Lopez AD, editors. The global burden of disease: a comprehensive assessment of mortality and disability from diseases, injuries and risk factors in 1990 and projected to 2020. Cambridge: Harvard University Press; 1996.
4. Desai MA, Mehta S, Smith KR. Indoor smoke from solid fuels: Assessing the environmental burden of disease. Environmental burden of disease series No. 4. World Health Organisation; 2004. Available from: http://www.who.int/quantifying_ehimpacts/publications/en/Indoorsmoke.pdf. Last accessed 10 May 2005.

5. United Nations Statistics Division - Millennium Indicators. Available from: http://unstats.un.org/unsd/mi/mi_def_list.asp. Last accessed 12 July 2005.
6. Environmental Dictionary. Available from: http://www.uk-environment.co.uk/environmental-dictionary.html. Last accessed 12 July 2005.
7. Künzli N, Tager I. Long-term health effects of particulate and other ambient air pollution: research can progress faster if we want it to? Environ Health Perspect. 2000;108:915-8.
8. Kjellström T. What is environmental epidemiology. In: Baker D, Kjellström T, Calderon R, Pastides H, editors. Environmental Epidemiology: A textbook on study methods and public health applications. Malta: Interprint Ltd, 1999; 1-15.
9. Graham NMH. The epidemiology of acute respiratory infections in children and adults: A global perspective. Epidemiol Rev. 1990;12:149-78.
10. McKee DJ, Rodriguez RM. Health effects associated with ozone and nitrogen dioxide exposure. Water Air Soil Pollut. 1993;67:11-35.
11. Rothman KJ. Methodological frontiers in environmental epidemiology. Environ. Health Perspect. 1993;101(Suppl 4):S113-9.
12. Thomas D, Stram D, Dwyer J. Exposure measurement error: Influence on exposure-disease relationships and methods of correction. Annu Rev Publ Health. 1993;14:69-93.
13. Grandjean P. Epidemiology of environmental hazards. Public Health Rev. 1993-1994;21:255-62.
14. Navidi W, Thomas D, Stram D, Peters J. Design and analysis of multilevel analytic studies with applications to a study of air pollution. Environ Health Perspect. 1994;102(Suppl 8):25-32.
15. Brunekreef B, Dockery DW, Krzyzanowski M. Epidemiologic studies on short-term effects of low levels of major ambient air pollution components. Environ Health Perspect. 1995;103(Suppl 2):S3-13.
16. Dunn C, Kingham S. Establishing links between air quality and health: Searching for the impossible? Soc Sci Med. 1996;42(6):831-41.
17. Katsouyanni K, Schwartz J, Spix C, Touloumi G, Zmirou D, Zanobetti A, et al. Short term effects of air pollution on health: a European approach using epidemiologic time series data: the APHEA protocol. J Epidemiol Community Health. 1996;50(Suppl):S12-8.
18. Schwartz J, Spix C, Touloumi G, Bachárová L, Barumamdzadeh T, le Tertre A, et al. Methodological issues in studies of air pollution and daily counts of deaths or hospital admissions. J Epidemiol Community Health. 1996;50(Suppl):S3-S11.
19. Lipfert FW. Air pollution and human health: Perspectives for the '90s and beyond. Risk Anal. 1997;17(2):137-46.
20. Hertel O, de Leeuw FAAM, Raaschou-Nielsen O, Solvang Jensen S, Gee D, Herbarth O, et al. Human exposure to outdoor air pollution. Pure Appl Chem. 2000;173(6):933-58.
21. Monn C. Exposure assessment of air pollutants: a review on spatial heterogeneity and indoor/outdoor/personal exposure to suspended particulate matter, nitrogen dioxide and ozone. Atmos Environ. 2000;35:1-32.
22. Mage DT. A particles is not a particle is not a particle. J Expos Anal Environ Epidemiol. 2002;12:93-5.

23. Yassi A, Kjellstrom T, de Kok T and Guidotti T, eds. Basic Environmental Health: Preliminary Edition. World Health Organisation, United Nations Environmental Programme, United Nations Education, Science and Cultural Organisation 1998.
24. Baker D, Kjellström T, Calderon R and Pastides H, eds. Environmental Epidemiology: A textbook on study methods and public health applications. Preliminary Edition. Malta: Interprint Ltd 1999.
25. Beaglehole R, Bonita R, Kjellstrom T. Basic Epidemiology. Geneva, World Health Organisation 1993.
26. Chimere-Dan G, Makubalo LE, Ntuli NH, Netshidzivhani P, Mahlasela L, Johnson C. Essential National Health Research in South Africa, The Council on Health Research for Development May 2001. Available from: http://www.doh.gov.za/docs/reports/2001/enhr/index.html; Last accessed 17 May 2005.
27. Thomas EP, Seager JR, Mathee A. Environmental health challenges in South Africa: policy lessons from case studies. Health Place. 2002;8(4):251-61.
28. Dick J, Yach D, Vurgarellis P. Implementation of public health research in the south-western Cape. Nursing RSA. 1990;5(2):8.
29. Parry CD, Yach D, Tollman SM. Towards an essential national health research strategy for South Africa. S Afr Med J. 1992;82(5):299-300.
30. Parry CD, Yach D, Tollman SM. The setting of health research priorities in a new South Africa. S Afr Med J. 1992;82(5):306-8.
31. White Paper for transforming NHS in SA
32. Rowe AK, Powell KE, Flanders WD. Why Population Attributable Fractions Can Sum to More Than One. Am J Prev Med. 2004;26(3):243-9.
33. McElduff P, Attia J, Ewald B, Cockburn J, Heller R. Estimating the contribution of individual risk factors to disease in a person with more than one risk factor. Journal of Clinical Epidemiology. 2002;55:588-92.
34. Gefeller O, Land M, Eide GE. Averaging attributable fractions in the multifactorial situation: assumptions and interpretation. J Clin Epidemiol. 1998;51(5):437-41.
35. Eide GE, Gefeller O. Sequential and average attributable fractions as aids in the selection of preventive strategies. J Clin lhidemiol. 1995;48(5):645-55.
36. Rowe AK, Kleinbaum DG, Koplan JP. Practical Methods for Public Health Practitioners. Am J Prev Med. 2004;26(3):252-3.
37. Künzli N, Kaiser R, Medina S, Studnicka M, Chanel O, Filliger P, Herry M, Horak Jr F, Puybonnieux-Texier V, Quénel P, Schneider J, Seethaler R, Vergnaud J-C, Sommer H. Public-health impact of outdoor and traffic-related air pollution: a European assessment Lancet. 2000;356:795-801.
38. Valent F, Little D, Bertollini R, Nemer LE, Barbone F, Tamburlini G. Burden of disease attributable to selected environmental factors and injury among children and adolescents in Europe. Lancet. 2004; 363: 2032-39.
39. Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJL, the Comparative Risk Assessment Collaborating Group. Selected major risk factors and global and regional burden of disease Lancet. 2002; 360: 1347-60.

40. National Health Act (Act 61 of 2003). Government Gazette Vol. 469 Cape Town 23 July 2004 No. 26595. Available from: http://www.info.gov.za/gazette/acts/2003/a61-03.pdf. Last accessed 14 July 2005.
41. National Environmental Policy of 1996. Available from: http://www.info.gov.za/greenpapers/1996/environmental.htm. Last accessed 14 July 2005.
42. South African Institute for Race Relations. South African Survey 2000/2001. Millenium Edition. Johannesburg; 2000.
43. Yach D, Mathews C, Buch E. Urbanisation and health: methodological difficulties in undertaking epidemiological research in developing countries. Soc Sci Med. 1990;31(4):507-44.
44. Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. Bull World Health Organ. 2000;78(9):1078-92.
45. Von Schirnding YER. Addressing the Links between Indoor Air Pollution, Household Energy and Human Health, WHO/HDE/HID/02.10, Washington, DC, 3-4 May 2000. Available from: http://www.who.int/mediacentre/events/HSD_Plaq_10.pdf. Last accessed 12 July 2005.
46. Smith KR. Indoor air pollution in developing countries: recommendations for research. Indoor Air. 2002;12:1-7.
47. Ezzati M, Kammen DM. The Health Impacts of Exposure to Indoor Air Pollution from Solid Fuels in Developing Countries: Knowledge, Gaps, and Data Needs. Environ Health Perspect. 2002;110:1057-68.
48. Yach D. Addressing Africa's health needs--time for strong South African involvement. S Afr Med J 1998;88(2):127-9.
49. Nchinda TC. Research capacity development for CVD prevention: the role of partnerships. Ethn Dis. 2003;13(2 Suppl 2):S40-4.
50. Nchinda TC. Research capacity strengthening in the South. Soc Sci Med. 2002;54(11):1699-711.
51. City of Cape Town. State of Environment Report for Year 5; 2002. Available from: Available from: http://www.capetown.gov.za/soe; Last accessed 22 April 2005.
52. Bailie RS, Ehrlich RI, Truluck TF. Trends in photochemical smog in the Cape Peninsula and the implications for health. S Afr Med J. 1994;84(11):738-42.
53. Wicking-Baird MC, De Villiers MG, Dutkiewicz RK. Cape Town Brown Haze Study Report No. Gen. 182; 1997.
54. Ott WR. Total human exposure F an emerging science focuses on humans as receptors of environmental pollution. Environ Sci Technol. 1985;19(10):880-6.
55. Letz R, Ryan PB, Spengler JD. Estimating personal exposures to respirable particles. Environ Monit Assess. 1984;4:351-59.
56. Sexton K, Spengler JD, Treitman RD. Personal exposure to respirable particles: a case study in Waterbury, Vermont. Atmos Environ. 1984;18(4):1385-98.
57. Dockery DW, Spengler JD. Indoor–outdoor relationships of respirable sulfates and particles. Atmos Environ. 1981;15:335-43.

58. Ryan PB, Spengler JD, Letz R. Estimating personal exposures to NO_2. Environ Int. 1986;12:395-400.
59. Spengler JD, Treitman RD, Tosteson TD, Mage DT, Soczek ML. Personal exposures to respirable particulates and implications for air pollution epidemiology. Environ Sci Technol. 1985;19:700-7.
60. Lioy PJ. Assessing total human exposure to contaminants: A multidisciplinary approach. Environ Sci Technol. 1990;7:938-45.
61. Lioy PJ. Measurement methods for human exposure analysis. Environ Health Perspect. 1995;103(3):35-44.
62. Law PL, Lioy PJ, Zelenka MP, Huber AH, McCurdy TR. Evaluation of a probabilistic exposure model applied to carbon monoxide (pNEM/CO) using Denver personal exposure monitoring data. J Air Waste Manage Assoc. 1997;47:491-500.
63. Law MR, Morris JK, Wald NJ. Environmental tobacco smoke exposure and ischaemic heart disease: an evaluation of the evidence. BMJ. 1997;315:973-80.
64. Pellizzari ED, Clayton CA, Rodes CE, Mason RE, Piper LL, Fort B, et al. Particulate matter and manganese exposures in Toronto, Canada. Atmos Environ. 1999;33(5):721-34.
65. Kousa A, Oglesby L, Koistinen K, Künzli N, Jantunen M. Exposure chain of urban air PM2.5 – association between ambient fixed site, residential outdoor, indoor, workplace and personal exposures in four European cities in the EXPOLIS-study. Atmos Environ. 2000;36:3031-9.
66. Department of Health, Medical Research Council and Measure DHS+. South Africa Demographic and Health Survey. Full Report. Pretoria: Department of Health; 2002. Available from: http://www.doh.gov.za/facts/1998/sadhs98; Last accessed 12 July 2005.
67. Mathee A. Indoor Air Pollution and Health: Commentary. Agenda for Research on Health and the Environment, Workshop 3, Health and Urbanisation, India, 4 - 6 October, 1999. Available from: http://geog.queensu.ca/h_and_e/healthandenvir/India%20Papers/AngelaMathee.doc; Last accessed 4 May 2005.
68. Mortality and causes of death in South Africa, 1997–2003: Findings from death notification). Statistics South Africa. 2004. http://www.statssa.gov.za. Accessed 29 March 2005.
69. Ashworth A, Waterlow JC. Infant mortality in developing countries. Arch Dis Child. 1982;57:882-4.
70. Mavalankar DV, Trivedi CR, Gray RH. Levels and risk factors for perinatal mortality in Ahmedabad, India. Bull World Health Organ. 1991;69:435-42.
71. Van den Broeck J, Eeckels R, Massa G. Maternal determinants of child survival in a rural African community. Int J Epidemiol. 1996;25:998-1004.
72. Binka FN, Maude GH, Gyapong M, Ross DA, Smith PG. Risk factors for child mortality in Northern Ghana: a case-control study. Int J Epidemiol. 1995;24:127-35.
73. Hull TH, Gubhaju B. Multivariate analysis of infant and child mortality in Java and Bali. J Biosoc Sci. 1986;18:109-18.
74. Vajpayee A, Govila AK. Effect of family structure, family size, and crowding on neonatal mortality in Indian villages. J Trop Pediatr. 1987;33:261-2.

75. Ceesay SM, Prentice AM, Cole TJ, et al. Effects on birth weight and perinatal mortality of maternal dietary supplements in rural Gambia: 5 year randomised controlled trial. BMJ. 1997;315:786-90.
76. Comstock GW, Shah FK, Meyer MB, Abbey H. Low birth weight and neonatal mortality rate related to maternal smoking and socioeconomic status. Am J Obstet Gynecol. 1971;111:53-9.
77. Greenwood AM, Greenwood BM, Bradley AK, Williams K, Shenton FC, Tulloch S, et al. A prospective survey of the outcome of pregnancy in a rural area of the Gambia. Bull World Health Organ. 1987;65:635-43.
78. Edouard L. The epidemiology of perinatal mortality. World Health Stat Q. 1985;38:289-301.
79. Malloy MH. Risk of previous very low birth weight and very preterm infants among women delivering a very low birth weight and very preterm infant. J Perinatol. 1999;19:97-102.
80. McCormick MC. The contribution of low birth weight to infant mortality and childhood morbidity. N Engl J Med. 1985;312:82-90.
81. Weiner CP, Sabbagha RE, Vaisrub N, Depp R. A hypothetical model suggesting suboptimal intrauterine growth in infants delivered preterm. Obstet Gynecol. 1985;65:323-6.
82. Siega-Riz AM, Adair LS, Hobel CJ. Maternal underweight status and inadequate rate of weight gain during the third trimester of pregnancy increases the risk of preterm delivery. J Nutr. 1996;126:146-53.
83. Von Schirnding YER, Yach D, Klein M. Acute respiratory infections as an important cause of childhood deaths in South Africa. S Afr Med J. 1991;80:79-82.
84. Black RE, Morris SS, Bryce J. Where and why are 10 million children dying every year? Lancet. 2003;361:2226-34.
85. The Bellagio Study Group on Child Survival. Knowledge into action for child survival. Lancet. 2003;362:323-7.
86. Jones G, Steketee RW, Black RE, Bhutta ZA, Morris SS, and the Bellagio Child Survival Study Group*. How many child deaths can we prevent this year? Lancet. 2003;362:65-71.
87. Victora CG, Wagstaff A, Armstrong Schellenberg J, Gwatkin D, Claeson M, Habicht J-P. Applying an equity lens to child health and mortality: more of the same is not enough. Lancet. 2003;362:233-41.
88. Bryce J, el Arifeen S, Pariyo G, Lanata CF, Gwatkin D, Habicht J-P, and the Multi-Country Evaluation of IMCI Study Group*. Reducing child mortality: can public health deliver? Lancet. 2003;362:159-64.
89. United Nations. United Nations Millennium Declaration. United Nations General Assembly resolution 55/2. New York, NY: United Nations; 2000. Available from: http://www.un.org/millennium/declaration/ares552e.pdf. Last accessed 10 May 2005.
90. Reddy, P. Chronic Diseases. In: South African Health Review 2003/2004. Durban : Health Systems Trust; 2004. p. 175-87. Available from: http://www.hst.org.za/uploads/files/chap13_03.pdf; Last accessed 17 May 2005.
91. Aït-Khaled N, Enarson D, Bousquet J. Chronic respiratory diseases in developingcountries: the burden and strategies for prevention and management. Bull World Health Organ. 2001;79:971-9.

92. Yach D, Kellogg M, Voute J. Chronic diseases: an increasing challenge in developing countries. Trans R Soc Trop Med Hyg. 2005;99(5):321-4.

93. Yach D, Leeder SR, Bell J, Kistnasamy B. Global chronic diseases. Science. 2005;307(5708):317.

94. Yach D, Hawkes C, Gould CL, Hofman KJ. The global burden of chronic diseases: overcoming impediments to prevention and control. JAMA. 2004;291(21):2616-22.

95. Epping-Jordan JE, Bengoa R, Yach D. Chronic conditions--the new health challenge. S Afr Med J. 2003;93(8):585-90.

96. Beaglehole R, Yach D. Globalisation and the prevention and control of non-communicable disease: the neglected chronic diseases of adults. Lancet. 2003;362(9387):903-8.

97. Mendis S, Yach D, Bengoa R, Narvaez D, Zhang X. Research gap in cardiovascular disease in developing countries. Lancet. 2003;361(9376):2246-7.

98. Zwi S, Davies JC, Becklake MR, Goldman HI, Reinach SG, Kallenbach JM. Respiratory health status of children in the eastern Transvaal highveld. S Afr Med J. 1990; 78(11): 647-53.

99. Ehrlich RI, Du Toit D, Jordaan E, Zwarenstein M, Potter P, Volmink JA, et al. Risk factors for childhood asthma and wheezing. Importance of maternal and household smoking. Am J Respir Crit Care Med. 1996;154(3 Pt 1):681-8.

100. Ehrlich RI, White N, Norman R, Laubscher R, Steyn K, Lombard C, et al. Predictors of chronic bronchitis in South African adults. Int J Tuberc Lung Dis 2004;8(3):369-76.

101. Von Schirnding YER, Yach D, Blignault 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(8):457-61.

102. Von Schirnding YER, Mokoetle KE. Johannesburg-Soweto Child Health Respiratory Study: Methodology and Preliminary Results at 6 months. Urbanisation and Health Newsletter. 1993;17(1):58-61.

103. Wesley AG, Loening WE. Assessment and 2-year follow-up of some factors associated with severity of respiratory infections in early childhood. S Afr Med J. 1996;86(4):365-8.

104. Dudley L, Hussey G, Huskissen J, Kessow G. Vitamin A status, other risk factors and acute respiratory infection morbidity in children. S Afr Med J 1997;87(1):65-70.

105. Kossove D. Smoke-filled rooms and lower respiratory disease in infants. S Afr Med J. 1982;6l:622-4.

106. Coetzee AM, Smith FC, van der Merwe CA, Dreyer RJ. The influence of air pollution on health in the Sasolburg area. S Afr Med J. 1986;70(6):339-43.

107. Terblanche AP, Opperman L, Nel CM, Reinach SG, Tosen G, Cadman A. Preliminary results of exposure measurements and health effects of the Vaal Triangle Air Pollution Health Study. S Afr Med J. 1992;81(11):550-6.

108. Terblanche AP, Nel CM, Opperman L, Nyikos H. Exposure to air pollution from transitional household fuels in a South African population. J Expos Anal Environ Epidemiol. 1993;3(Suppl 1):15-22.

109. Terblanche P, Nel R, Golding T. Household energy sources in South Africa - an overview of the impact of air pollution on human health. Pretoria: CSIR Environmental Services, Department of Mineral and Energy Affairs and EMSA (Pty) Ltd 1994.

110. Terblanche P. Vaal Triangle Air Pollution Health Study – bibliography, summary of key findings and recommendations. Prepared for the South African Medical Research Council, ISBN 10874826-89-7 1998.

111. Richards GA, Terblanche AP, Theron AJ, Opperman L, Crowther G, Myer MS, et al. Health effects of passive smoking in adolescent children. S Afr Med J. 1996;86(2):143-7.

112. Sanyal DK, Maduna ME. Possible relationship between indoor pollution and respiratory illness in an Eastern Cape community. S Afr J Sci. 2000;96:94-6.

113. Fienberg SE, Loftus EF, Tanur JM. Cognitive aspects of health surveys for public information and policy. Milbank Memorial Fund Quarterly - Health & Society. 1985;63(3):598-614.

114. Fienberg SE, Loftus EF, Tanur JM. Cognitive aspects of health survey methodology: an overview. Milbank Memorial Fund Quarterly - Health & Society. 1985;63(3):547-64.