"The whole is greater than the sum of its parts": Cumulative risk of indoor air pollution and urban vulnerability in Cato Manor

by

MICHELLE LOUISE BINEDELL

In partial fulfilment of the requirements for the degree of
Master of Environmental Management in the
School of Life and Environmental Sciences,
University of Natal
Durban

September 2003

PREFACE

The work described in this dissertation represents the thesis component of a course-work Masters in Environmental Management and was carried out in the School of Life and Environmental Sciences, University of Natal, Durban, under the supervision of Ms Catherine Oelofse.

This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

This dissertation was made possible through funding from the CSIR.

ACKNOWLEDGEMENTS

I would like to sincerely thank the communities of Cato Manor and specifically the households in Cato Crest who so willingly allowed us to conduct both the air quality monitoring exercise and household survey in their homes.

I would like to thank my supervisor, Ms Catherine Oelofse for her guidance and encouragement. I am truly grateful for her understanding and wisdom in both the academic and personal challenges which the study offered.

I am grateful for the financial support I have received from the CSIR's Division of Water, Environment and Forestry Technology. I would like to thank Ms Maria Berry for her help with formatting and Arjoon Singh for the maps. To all my Environmentek colleagues, thank you for your un-ending moral support and encouragement.

To my moms Marilyn and Jenny - your practical support and encouragement has made this all possible!

Finally, to my husband Steve and my little angels Justine and Greg, your support was all that I needed to press on! I dedicate my love and this thesis to you.

ABSTRACT

Low-income communities are potentially more vulnerable to physical, social and environmental hazards than wealthier communities. The lack of services associated with these communities (such as water supply, sanitation facilities and electrification) has increased the exposure of households to health hazards. These households also lack the coping mechanisms and resources to deal with the stress that these hazards impose on them.

This study is concerned with the potential health hazards imposed from indoor air pollution. Traditional health risk assessments are used to determine the level of risk to human health from a variety of chemical or biological hazards. What these assessments do not include however, is a measure of the vulnerability of the household. The aim of this study therefore, was to develop a methodology for generating a vulnerability index for the inclusion of factors underlying urban poverty and vulnerability into a risk assessment of indoor air pollution.

The approach adopted in this study followed an iterative and inductive pathway. Theories on risk assessment and urban vulnerability were explored in order to understand the manner in which risk to human health is assessed and compounded by vulnerability. Secondary data sources as well as a household survey provided information that aided the selection of a number of vulnerability indicators. These indicators were chosen as measures of vulnerability specifically for low-income households in South African settlements.

The findings of the research show that there are a number of factors or issues which underlie vulnerability. The issues are related to demographics, livelihoods, physical exposures, externalities, services and general health. This study used a four-tiered selection approach to sift through the issues of vulnerability and to transform the key issues into a set of vulnerability indicators which make up the vulnerability index.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF BOXES

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

CHAPTER 1: INTRODUCTION

1.1 RATIONALE FOR THE STUDY

Traditional health risk assessments aim to determine the probability and magnitude of risks to human health from exposure to a particular hazard. These assessments consider some of the characteristics of an exposed population and include these into the assessment of risks. However, there are a number of other physical, social, economic and built environment factors which may influence the magnitude of adverse health effects in these low-income households, and which are not accounted for in traditional risk assessments.

According to the United Nations Environmental Programme, poor communities are considered more vulnerable to environmental disasters and threats (UNEP, 2002). These communities often live in marginalised areas in informal settlements that are located in spaces that offer opportunities for survival. The resultant informal settlements are characterised by the lack of formality in their structure, level of services and poor living conditions. Besides being exposed to a variety of environmental hazards, these communities lack the mechanisms and resources to cope with and recover from environmental threats and risks. Poor health is exacerbated by low immunity and inadequate nutrition. These factors all contribute to heightening an individual's susceptibility to environmental hazards such as air pollution. The socio-economic status of individuals living in these areas is often low and they lack the financial resources to pay for housing, services and basic human needs. There are, therefore, a number of environmental, social and economic characteristics which typify informal settlements in South Africa.

The degradation of the natural environment in poor urban areas is often viewed as a consequence of the lack of services and infrastructure. However, the impact that the degraded environment has on the health and quality of life of residents in poor communities is often unobserved, overlooked or understated. Informal communities are exposed to biological, chemical and social risks which cumulatively affect human health. Cumulative effects arising from development in or around the poor urban community are not adequately identified in

impact assessments. There are also a variety of hazards which these poor individuals are exposed to. These include unhygienic water supplies, exposure to contaminated water from pit latrines, overcrowded living conditions, exposure to damp, indoor air pollution, fire, discarded organic waste and exposure to vectors such as rats. Furthermore, there are a number of social characteristics which characterise informal settlement communities. These include high levels of unemployment, low household income, and often a high number of dependents per household head.

Indoor air pollution is a common problem in informal settlements where the use of paraffin and coal are widespread (Thomas, *et al.*, 1999). These fuels emit a number of pollutants which may adversely affect the health of those exposed to them (Muller, 2001). The concentration of the pollutant indoors may also increase due to the lack of ventilation or air flow. Measurements of air pollution can be taken using passive and continuous samplers and aim to determine the concentration levels of a selection of toxic pollutants in the indoor air environment. Kerosene combustion products can have severe health effects on exposed individuals, especially the young, the elderly and those with pre-existing disease (Muller, 2001). There are also a number of factors which affect both the level of exposure to a toxic pollutant and the manner in which an individual will cope with this exposure. These compounding factors underlie urban vulnerability and should be considered when determining risks to indoor air pollution.

In order to measure the extent of this vulnerability, and its compounding influence on raising the risk to human health, it is necessary to develop a vulnerability index which can consider and provide measurements for a number of factors which underlie urban vulnerability. In order to achieve this, it is necessary to establish which factors underlie urban poverty and vulnerability in South African low-income communities, and secondly to be able to measure each factor and include it in the determination of risk to human health.

1.2 AIMS AND OBJECTIVES

The aim of this study is to develop a methodology for generating a vulnerability index for the inclusion of factors underlying urban poverty and vulnerability into a risk assessment of indoor air pollution. In order for this to be achieved, the following objectives need to be realised:

Objective 1: To describe the risks to human health from indoor air pollution using traditional Health Risk Assessment (HRA) approaches

Objective 2: To determine the factors underlying vulnerability that are associated with health within low-income communities of Cato Manor

Objective 3: To develop a methodology for generating a vulnerability index for poor urban households in Cato Crest

Objective 4: Explore how vulnerability factors compound air pollution health effects to increase risk in households in Cato Crest.

1.3 CATO CREST: A CASE STUDY FOR INTEGRATING HEALTH RISK ASSESSMENT AND VULNERABILITY

Cato Manor is a rapidly developing low-income settlement situated 7km to the west of Durban's city centre within the eThekwini Municipality (Figure 1.1). It is divided into a number of geographical units called precincts which are made up of a number of residential communities.

Cato Crest is an informal settlement located within the Greater Cato Manor area. It is one of the most densely populated informal settlements in Cato Manor and has been affected and shaped by a number of racially inspired land disputes and invasions (Hindson and Pupuma, 1996). It consists of an informal network of dirt roads and pathways amongst a number of self-

constructed dwellings. Service provision is lacking and houses are poorly constructed (Vermaak, *et al.*, 2001). Most residents share pit latrines and access water from shared water pipes (Vermaak, *et al.*, 2001). Overcrowding, high crime rates, unemployment and a high prevalence of HIV/AIDS are some of the key problems facing the community (Thomas, 2001). The lack of electricity in the area necessitates the use of kerosene (paraffin) which has been shown to produce a number of health effects in exposed individuals (Thomas, *et al.*, 1999).

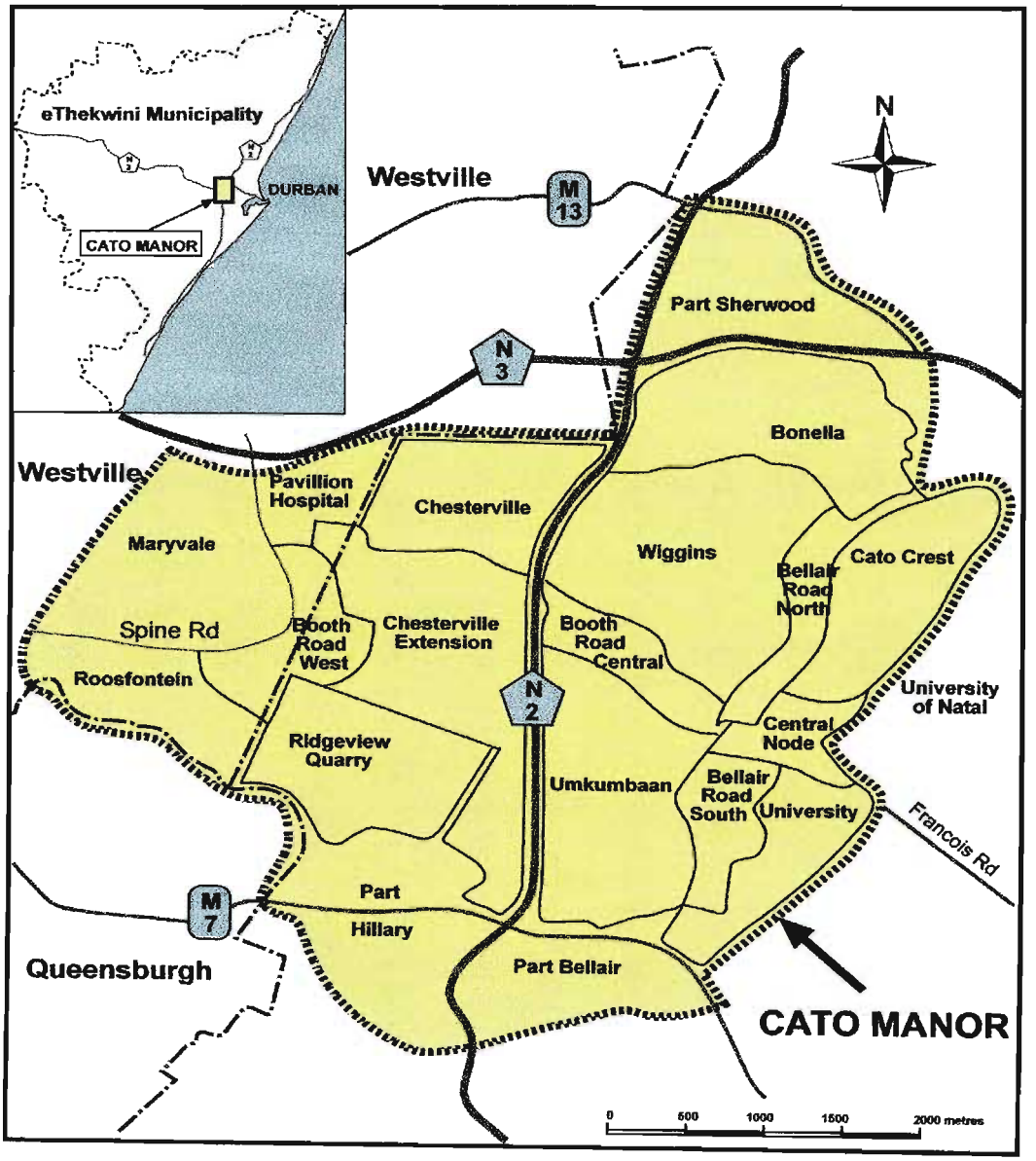


Figure 1.1: Location of Cato Manor within the eThekwini municipal boundary (Source: CMDA, 1995)

Cato Crest is considered an appropriate case study for the identification of vulnerability factors as it displays some of the typical socio-economic and biophysical characteristics of informal settlements in South Africa.

1.4 OUTLINE OF THESIS

Chapter 1: Introduction

This chapter provides a brief rationale for the study; explains the aims and objectives of the research and provides an outline of the study area and thesis content.

Chapter 2: A conceptual framework for health risk assessment and vulnerability

This chapter provides the theoretical content for a number of subjects. Firstly, it provides a broad introduction to risk assessment. Secondly, the health risk assessment process is explained and an introduction to air pollution and health risk is given. The third component of this chapter introduces the concept of cumulative risk assessment. It highlights the theory around cumulative effects and describes the approaches taken to determine cumulative risk assessment of mixtures of air pollutants. This leads on to another large component of this chapter, which is to provide the theoretical framework around poverty and vulnerability. International and local literature sources are cited and characteristics of urban vulnerability are highlighted. The last portion of this chapter provides a discussion around risk assessment and presents an argument for the inclusion of social, biophysical and political factors into determining risk.

Chapter 3: The living environment of Cato Manor

This chapter provides a geographical description of the case study area of Cato Manor and one of its suburbs, Cato Crest. The social, biophysical and institutional characteristics are discussed to provide a description of informal settlements in Durban, South Africa.

Chapter 4: Methods and approaches

This chapter provides an introduction to the research methods used. It provides a description of the secondary and primary information sources that were used and provides a detailed

description of the approach taken in developing a method for generating and populating a vulnerability index.

Chapter 5: Developing a vulnerability index

This chapter provides the results of the approach taken in developing a set of vulnerability indicators which may be used to measure vulnerability in low-income households. The chapter includes a discussion of the possible compounding risk to selected households in Cato Crest when hazard quotients (representing the physical risk of indoor air pollution) are combined with a suite of vulnerability factors in each household.

Chapter 6: Conclusion

The final chapter of this thesis provides a discussion around the methodology developed for generating a vulnerability index for informal settlement risk assessment and for the inclusion of vulnerability into the risk equation. It highlights some of the limitations in the index development process and provides some ideas on the application of the vulnerability index.

CHAPTER 2: A CONCEPTUAL FRAMEWORK FOR HEALTH RISK ASSESSMENT AND VULNERABILITY

This chapter provides some background into the assessments of risk and particularly the process of health risk assessment. Traditional health risk assessments are described in order to understand their rigorous process and deductive structure and the absence of cumulative factors which may heighten risk. Thereafter, studies involving the determination of risk to physical hazards such as floods, landslides and other acts of nature have been explored in order to understand how social aspects of marginalized communities contribute to their vulnerability to these hazards. A number of studies on poverty and vulnerability have been researched in order to determine the underlying factors of vulnerability which may contribute to increasing the risk of low-income communities. Finally, this chapter explores the manner in which vulnerability factors may be included into the assessment of risk so that the cumulative risk of hazards to marginalised communities may be identified.

2.1 RISK ASSESSMENT

Risk assessment processes have been used in a variety of disciplines to determine the risk to human health, buildings and infrastructure and to natural habitats and ecosystems (Blaikie, *et al.*, 1994; Law, 1999; Matooane, 2000 and ISDR, 2002). Risk assessment can be defined as the process of estimating the probability of occurrence of an event and the probable magnitude of adverse effects (safety, health, ecological, or financial) over a specific time period (NRC, 1994). There are numerous risk assessment processes available. The major types are detailed in Figure 2.1.

Many people confuse risk with hazards. A hazard is a chemical, physical, or biological agent or a set of conditions that has the potential to cause harm; it is a *source* of risk but not a risk *per se.* Risk is a function of the nature of the hazard, accessibility or avenue of contact (exposure potential), characteristics of the exposed populations (receptors), the likelihood of occurrence, the magnitude of exposures and consequences, and the vulnerability to the hazard or set of conditions that has the potential to cause harm (NRC, 1994).

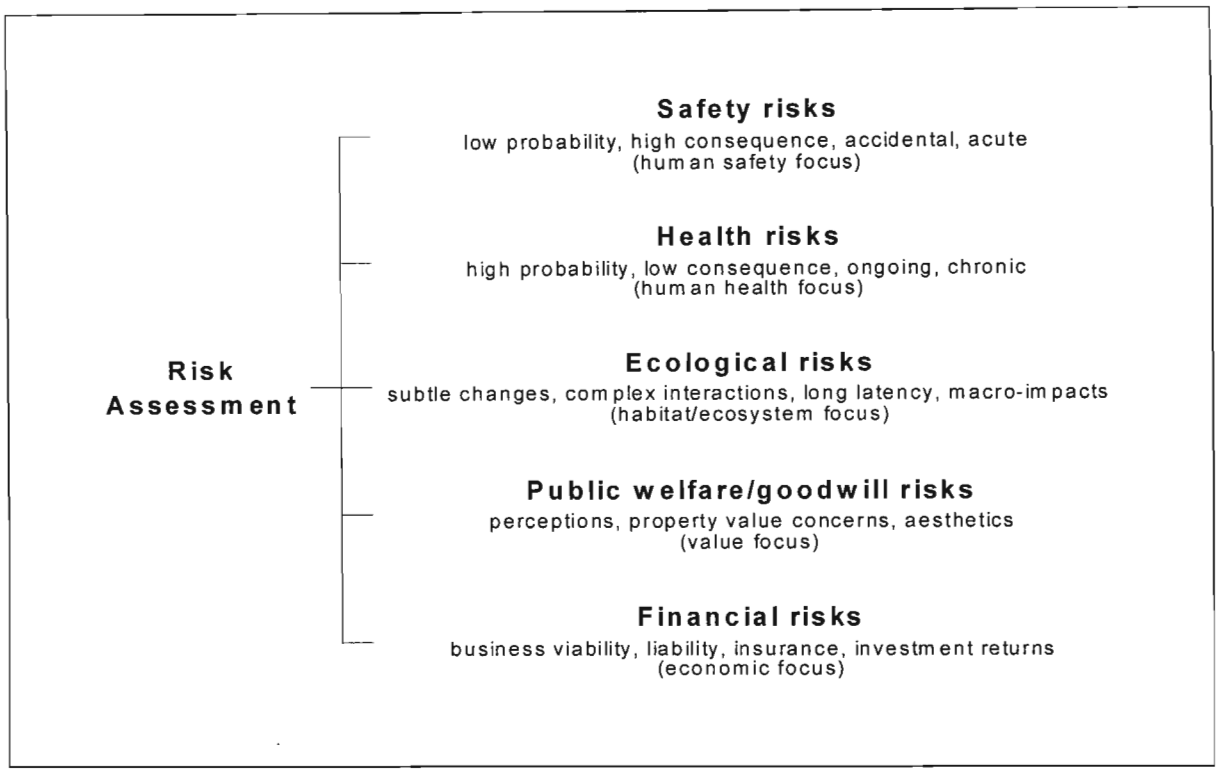


Figure 2.1: Major types of risk assessment and their focus (Source: Claasen, 1999).

In order to determine the probability of occurrence and the magnitude of adverse effects, a risk assessment should seek to understand the nature of hazards or set of conditions that have the potential to harm while examining the way in which a receptor may be exposed to a hazard, be influenced by it, or respond to this agent or set of conditions. A risk assessment should also examine the characteristics of the exposed population so that the likelihood of exposure as well as the likelihood of detrimental effects can be determined. It is necessary to stress the importance of each component in the risk assessment as these components all contribute to determining the probability and magnitude of adverse effects (NRC, 1994).

This study is concerned with the manner in which health risks are assessed. It is therefore necessary to provide some background and detail as to the various components of a health risk assessment in order to show what characteristics, variables or factors are considered when characterising health risks.

2.2 HEALTH RISK ASSESSMENT

Health risk assessments are one of three categories of environmental health linkage methods used for determining the health effects of different pollutants (Briggs *et al.*, 1996). The other two categories are analytical epidemiology and observational studies. Health risk assessments (HRAs) are used to determine the level of risk to human health from a variety of chemical or biological hazards. The United States Environmental Protection Agency (USEPA) method for determining risk to human health is internationally recognized and is based on rigorous and in-depth research, toxicological data and epidemiological studies (NRC, 1994).

The HRA process consists of four key components which are used to characterize the risk of potential pollutants or hazards to human health (NRC, 1994). Coupled with this are the processes for managing risks and communicating potential risks to affected groups and decision-makers. The interrelation of these phases is depicted in Figure 2.2.

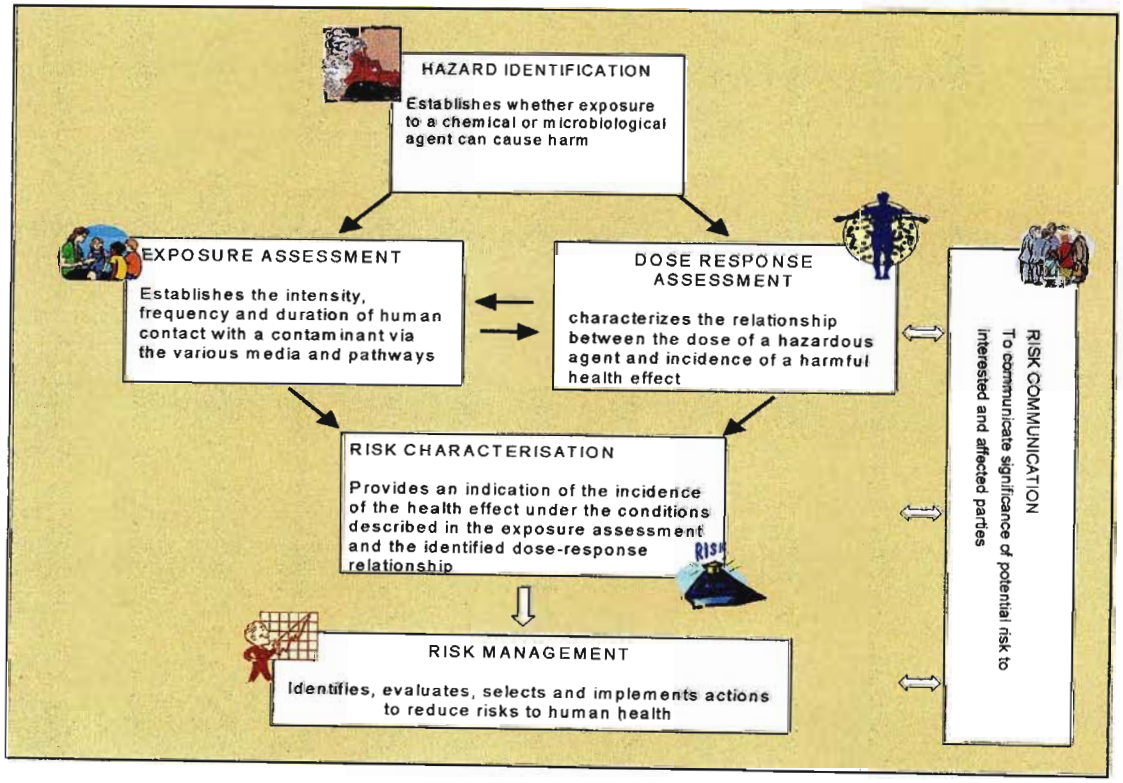


Figure 2.2: The Health Risk Assessment process (Source: Adapted from NRC, 1994).

Hazard Identification establishes whether exposure to a chemical or microbiological agent can cause harm. Once a health hazard has been identified, the remainder of the process encompasses the description of the properties of the hazardous agent, and the identification of both acute and chronic health effects.

Exposure Assessment establishes the intensity, frequency and duration of human contact with a contaminant. To determine exposure, it is necessary to combine an estimation of environmental concentrations of the hazards with demographic or behavioral descriptions of the exposed population. These can be measured or modeled to determine environmental concentrations.

Geographic distributions, activity patterns and population estimates influence exposure and may vary significantly among countries or regions according to culture, education and climate. When conducting an exposure assessment it is therefore necessary to determine time-activity patterns.

Dose-response Assessment characterizes the relationship between the dose of a hazardous agent (i.e. the amount of pollutant taken into the body through inhalation, ingestion and dermal contact) and incidence of an adverse effect in the exposed pollution. This assessment relies on toxicological information supplied from human epidemiological studies, human exposure studies, animal exposure studies and short-term *in vivo* and *in vitro* tests. Numeric benchmark values are used to describe the dose-response relationship. These are called reference doses or reference concentrations.

Risk Characterisation provides an indication of the incidence of the health effect under the conditions of exposure described in the exposure assessment and the identified dose-response relationship. The product of a quantitative risk characterization is a numeric estimate of the public health consequence of exposure to the pollutant. Two types of risk estimates are calculated:

- The probability of an individual developing cancer (carcinogenic effects); and
- The potential of developing toxic effects (non-carcinogenic effects) (NRC, 1994).

Non-cancer health effects are expressed as a hazard quotient (HQ) which indicates the presence or absence of adverse health effects due to exposure to non-carcinogenic pollutants. The average daily dose (ADD) of the chemical (obtained in the exposure assessment) is divided by the relevant dose-response value (DRV), obtained from the dose-response assessment, to determine the hazard quotient. A HQ that is less than 1 indicates a negligible risk, even to a sensitive individual, whereas a HQ greater than 1 indicates that there will be some risk as a result of exposure (NRC, 1994). Risk is therefore expressed as follows:

RISK to HAZARD = HQ

The formulae used in the determination of acute and chronic hazard quotients are given in Appendix 1.

The HRA process has been used in a number of studies to determine the risk of human populations to chemical and biological pollutants such as treated waste water (Genthe, 1998), emissions from oil storage facilities (Binedell and van der Voort, 1999) and carcinogenic and toxic compounds emitted during kerosene combustion (Matooane, 2000; Muller, 2001). These risk assessments assess the risk of a single hazard in isolation of a number of other physical and social factors which may affect an exposed population. The reality is that there are a number of biological and chemical hazards that particularly low-income communities are exposed to, at any one time. In addition to this, factors of vulnerability and urban poverty are additional pressures which may either compound the risks to human health or prevent communities from accessing the resources needed to cope with these pressures.

This study focuses on the health risk assessment of low-income communities who are exposed to the pollutants of kerosene combustion. Traditional health risk assessments are being used to characterize the risks to community and household members who are exposed to these pollutants (Muller, 2001). However, there are also a number of other chemical and biological pollutants which arise from living conditions in these low-income communities which affect human health and well-being. The following section details some of these biological and chemical hazards and the effects that they have on the health of exposed individuals.

This research is concerned with understanding the spectrum of health hazards and factors which influence susceptibility to these hazards so that they be included into an enhanced health risk assessment tool which will provide a more accurate and inclusive prediction of the severity of health impacts and risks of low-income communities.

2.2.1 Hazards that affect human health in informal settlements

Levels of service provision in informal communities are low. The majority of the population may use public water supplies or make use of non-flush toilets. Houses may be constructed of mud, wood or corrugated iron, with minimal windows and doors leading to poor ventilation (Oelofse, 1999). Just as the lack of a clean energy supply can induce indoor air pollution, the lack of a suitable water supply, sanitation facilities and waste services may impact negatively on the health of informal communities. All these conditions can give rise to a number of biological and chemical hazards that threaten the health of exposed individuals.

Biological pollutants and their health effects

Biological pollutants are or were living organisms. They impact on indoor air quality and may be a major cause of doctor or hospital visits. Biological pollutants that may persist in informal dwellings include animal dander (minute scales from hair, feathers or skin), dust mite and cockroach parts, fungi (or mould), infectious agents (bacteria or viruses) and pollen (USEPA, 2002a). Two conditions that are essential to support biological growth are nutrients and moisture. Rising damp from unsealed walls and poorly constructed roofs are significant causes of damp in informal dwellings and encourage the growth of moulds and fungi. This is depicted in Plate 1.

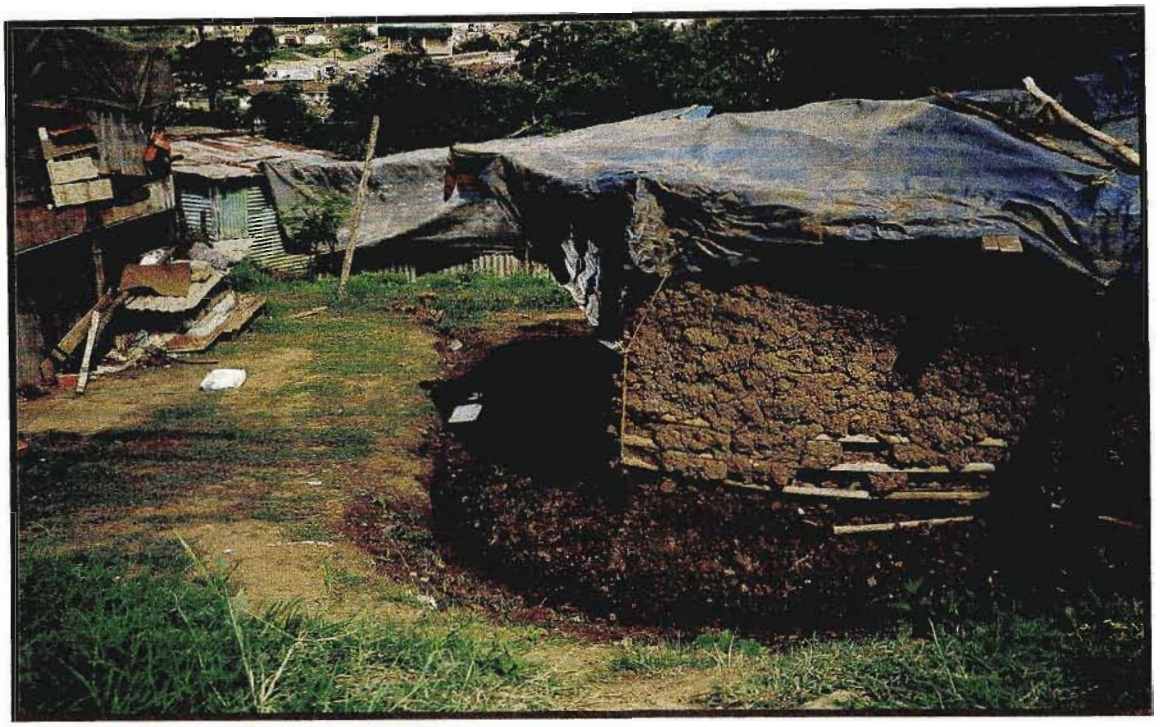


Plate 1: An informal dwelling in Cato Crest showing water damage and an attempt to prevent further damage by constructing a ditch around the house. (Source: Thomas, 2001)

The effects on health depend on the type and the amount of biological pollution and on the individual person. According to the United States EPA, some reactions of biological pollutants can include allergic responses, infectious responses or toxicity (USEPA, 2002a). Allergic responses may be the most common health problem and may be life-threatening with common signs and symptoms being watery eyes, runny nose, sneezing, nasal congestion, itching, coughing, wheezing, headache and fatigue. People with asthma are particularly sensitive to biological irritants and can experience a difficulty in breathing when exposed. Moulds, that grow in moist areas of the home, produce allergens (substances that can cause allergic reactions), irritants and in some cases toxic substances (mycotoxins) (USEPA, 2002b). Allergic reactions to moulds can be delayed or immediate and can cause asthma attacks in people who are asthmatic and allergic to mould. Other allergic responses are often connected with dust mites, animal dander, and pollen.

Infectious diseases such as influenza, measles, chicken pox and tuberculosis, may be spread indoors. Most infectious diseases pass from person to person through physical contact and crowded conditions with poor air circulation promoting this spread.

Chemical pollutants and their health effects

In addition to dense living conditions, rising damp and leaking dwellings, households in informal settlements are exposed to chemical pollutants that threaten their health. Studies have shown that indoor air may be more polluted than outdoor air (USEPA, 2002a). Both chemical and biological pollutants may be released and spread in the home and are causes of poor health in infants, children, the elderly and those with chronic illnesses.

Studies in South Africa have shown that more than 70% of households in low income metropolitan areas rely on kerosene for domestic purposes, leading to widespread problems of poor indoor air quality (Jones, *et al.,* 1996). Kerosene combustion products include carbon monoxide, carbon dioxide, nitrogen dioxide, sulphur dioxide, formaldehyde, particulate matter and hydrocarbons such as benzene and toluene. These products have been widely associated with various health effects due to the harmful nature of many of the pollutants.

The main health effects associated with exposure to these combustion products include mucous membrane irritation, respiratory irritation and immunological effects. Some of the combustion products have more severe health effects, for instance benzene is known to cause cancer. Health effects due to exposure to kerosene combustion products are likely to be more severe in sensitive individuals such as young children, the elderly and those with pre-existing diseases.

2.2.2 Health risk assessment of indoor air pollution

Indoor air pollution studies are numerous and focus mainly on those pollutants which can adversely affect human health (Mølhave, 1979; Leaderer, 1982; Dong, *et al.,* 1988; Shah and Singh, 1988; Brown, *et al.,* 1994; Brown and Crump, 1996 and Ezzati and Kammen, 2001, cited in Jones, 1999). These studies have focused on measuring concentrations of selected

indoor air pollutants and have compared measured values against health guidelines and standards such as the World Heath Organisation (WHO) Guidelines for Ambient Air Quality (WHO, 2000). Concentrations which exceed the standard or guideline are described as "detrimental to the health of humans" and the results of these studies serve to inform decision-makers on the potential health impacts imposed on individuals from pollution sources.

Health Risk Assessments of indoor air pollution take the assessment one step further. They take measurements of indoor air pollutants and characterise the risks to human health by evaluating and including activities of potentially exposed populations. A HRA also includes knowledge on dose-response relationships between the pollutants and the human receptors and characterises the risks to selected individuals (adults, children and infants).

Currently, it is only possible to determine the probability of occurrence and the magnitude of adverse effects of a single pollutant on exposed individuals. Assessments of multiple pollutants on human health, however, have only recently been attempted (Oosthuizen and John, 2002). Advances in this field are underway but recent research suggests that it is a difficult process and one which is fraught with uncertainties and limitations (Oosthuizen and John, 2002). Much research is still needed on understanding the synergistic and antagonistic relationships which may exist between chemicals in mixtures and between chemical pollutants and other air contaminants such as tobacco smoke.

Toxicologists and health risk professionals have recognised the potential for pollutants to interact and combine with one another to potentially increase adverse effects on health. Research into the assessment of chemical mixtures is an attempt by scientists to quantify health risks by recognising the spectrum of chemical and biological pollutants which may cumulatively affect the health of an individual at one time. The assessment of risk from multiple pollutants or multiple stressors can be termed "cumulative risk assessment" and is discussed in the following section.

2.3 CUMULATIVE RISK ASSESSMENT

Cumulative effects of multiple sources of air pollution have been relatively well assessed by simple addition of single chemical pollutants from multiple sources. The result (a cumulative concentration of a particular pollutant) is then modeled to reveal areas of potential impact (Zunckel, *et al.,* 2000). This methodology is limited to multiple sources of pollution in the ambient environment and evaluates the impact of chemical pollutants individually. While the cumulative concentration of multiple sources can be assessed, the methodology does not evaluate the potential risk of these cumulative effects to human health in areas of impact.

Air quality in the indoor environment is affected by a sequence of interactions involving many indoor and outdoor ventilation, microbiological, toxicological and physical systems (Jones, 1999). According to Jones (1999), the assessment of indoor air quality therefore, may require the investigation of a multitude of synergistic processes due to the interdependence of these systems. Assessment techniques and methodologies, therefore, need to consider, "not just individual classes of pollutants, but also a whole range of combinations and mixtures" (Jones, 1999, p 4556).

Just as air quality is affected by a multitude of processes, so individuals are exposed to multiple pollutants. According to Jones (1999, p 4538), "in reality, individuals are often concurrently exposed to a range of different sources of air pollution, leading to patterns and levels of exposure that are rather different from the apparent sum of their parts". Research that is limited to knowledge of a single class of pollutant therefore, is unlikely to explain accurately the human health problems that result from several interacting contaminants (Seltzer, 1995, cited in Jones, 1999).

Apart from the difficulty in quantifying risks to human health from multiple pollutants, health risk assessments (whether they consider single pollutants or multiple pollutants) have not taken into account the social variables which impact or affect the lives of those exposed to the chemical pollutants. In reality there are numerous variables which determine the social or economic context within which communities live. This context may be a state of poverty or a

level of vulnerability and will determine how an individual, household or community will respond to or cope with adverse effects or impacts. In evaluating risk to a particular hazard, it is essential that the social and economic context, within which exposure to the hazard takes place, is "factored" into the evaluation (Marsh and Oelofse, 1999; Kotze, 1999; Oelofse, 2003). In order to achieve this, an understanding of urban poverty is necessary. The characteristics of poverty and vulnerability need to be determined and these variables need to be considered and included in the equation for determining risk.

The following section explores some of the critical factors which underlie urban poverty and vulnerability, particularly in low-income communities. The factors which will be identified in this literature review will be used as criteria upon which indicators of vulnerability will be developed in order to build an assessment index which may be used to "factor in" the vulnerability characteristics of households affected by indoor air pollution. The following section therefore is critical to the study in that it not only serves to identify vulnerability factors but is a critical step in the methodology that has been designed.

2.4 POVERTY AND VULNERABILITY

Although everyone is vulnerable to environmental impacts of one kind or the other, the ability of people to adapt and cope with change is very varied (UNEP, 2002; Oelofse, 2003). People living in poverty are considered more vulnerable as they lack the coping mechanisms to adapt to change and reduce the impacts of hazards. Although poverty and vulnerability are inextricably linked, they are similar, but not the same (Chambers, 1995). This section attempts to understand the nature of poverty and vulnerability and will attempt to determine which characteristics, attributes or factors underlie urban poverty and vulnerability.

2.4.1 Defining poverty and vulnerability

Poverty and vulnerability are not the same. Most definitions associate poverty with a "lack" or "deficiency" of the necessities required for human survival and welfare. However, "there is no consensus about what basic needs are or how they can be identified" (Wratten, 1995, p 12).

This has resulted in both the definition of poverty based on income or consumption indicators and the definition of poverty based on non-material or social variables (Wratten, 1995). This view is accepted by Chambers (1995) who makes a distinction between deprivation and poverty, stating that "the dimensions of deprivation are physical, social, economic, political and psychological/spiritual while poverty refers to the lack of physical necessities, assets or income" (Chambers, 1995, p 174). This type of poverty (also referred to as income-poverty or "low per-capita income") is only one aspect of deprivation, but has been accepted as a measure of poverty because the data on other dimensions of poverty (such as longevity, access to power or access to health and education facilities) are not available. Satterthwaite (1999) confirms this view by stating that there are four sets of deprivation; namely income, asset base (material and non-material), basic services and housing, and rights within political or legal systems. Vulnerability is therefore another form of deprivation which has resulted from numerous inadequacies.

According to Hardoy, *et al* (2001), vulnerability is broad and includes not only vulnerability to environmental hazards but also to other hazards or economic shocks and stresses. While poverty is referred to as lack of physical necessities, vulnerability is defined as "exposure and defencelessness – the exposure to shocks, stress and risks and the lack of means to cope" (Chambers, 1995, p 189). Chambers makes the distinction between poverty and vulnerability by explaining that vulnerability is defencelessness, insecurity and exposure to risk, shocks and stress and not lack or want. It is linked with assets but cannot be measured by income, so is therefore not synonymous with poverty (Chambers, 1995).

The International Society for Disaster Risk (ISDR) defines vulnerability as "a set of conditions and processes resulting from physical, social, economic and environmental factors which increase the susceptibility of a community to the impact of hazards" (ISDR, 2002, p 46). Vulnerability is further described as "a reflection of the state of the individual and collective physical, social, economic and environmental conditions at hand that are shaped continually by attitudinal, behavioural, cultural, socio-economic and political influences at the individual, families, communities and countries" (ISDR, 2002, p 46). The different dimensions of vulnerability are described here and are placed into four broad areas – vulnerability caused by

physical factors, social factors, economic factors or ecological factors. Physical aspects of vulnerability are those aspects often described during the assessment of the built environment in which people live or to location considerations. Social factors refer to aspects of human well-being such as literacy levels, the existence of peace and security, social networks and organisational systems. Social vulnerability is also linked to issues of gender, public health, education, religious affiliation and governance. Economic vulnerability is dependent on the economic status of individuals and is affected by the individual or community's economic reserves, levels of dept and ability to access credit. Finally, ecological vulnerability is linked to levels of environmental degradation as this compounds the actual impact caused by hazards or disasters (ISDR, 2002).

Moser (1996, cited in Coetzee, 2002) describes five classes of assets on which households depend. These are not only financial assets, but also productive, social and human capital, labour and household relations. According to Coetzee (2002), at the household level, individuals become vulnerable when the depletion of these assets prevents them from being able to reverse the damage. In her opinion households can reduce their vulnerability in the short term by transforming these assets into basic necessities, such as income and food, but the ability to cope with shocks requires households to cope with adverse periods while still maintaining their asset base.

For the purpose of this study, one definition of vulnerability has been accepted and is defined by Chambers (1995, p 189) who states that vulnerability is "exposure and defencelessness – the exposure to the shocks, stress and risks and the lack of means to cope". It is a definition which recognises that vulnerability is a coin with two sides. On one side, being vulnerable means that an individual or community is prone to numerous hazards, stressors and risks while on the other side, being vulnerable means that one lacks the ability or means to deal with (or cope with) the stresses imposed upon it.

2.4.2 Poverty and environmental exposure

As mentioned in the previous section, poverty and vulnerability are inextricably linked. It is difficult to separate them as in many instances vulnerability is a cause of poverty and ill-health, but it is also a consequence of being poor and lacking the means to cope with exposure to hazards.

Vulnerability is not only a condition of the poor. While different levels of income groups are more or less vulnerable to certain types of hazards (ISDR, 2002); it is often the poor communities who are considered more vulnerable to environmental disasters and threats (Hardoy, *et al.*, 2001). According to the United Nations Environmental Programme, poor communities are considered more vulnerable to water-borne, respiratory and other infectious diseases as these are associated with high levels of economic insecurity, inadequate water supplies and lower health standards (UNEP, 2002).

Poor communities often live at a close interface with the environment creating a strong dependence on the environment for their survival and quality of life. They are therefore closer to the shocks and stressors imposed by that environment and therefore more affected by them (Oelofse, 2003). Levels of income would therefore be a strong measure of vulnerability and may be used to determine what hazards a community may be affected by.

Hardoy, *et al* (990) estimate that at least 600 million of the urban residents of the Third World live in threatening homes and neighbourhoods. They are exposed to a number of biological, chemical and physical risks which threaten their health and safety. These risks (and their possible causes) are tabled in Table 2.1.

Table 2.1: Risks threatening the health and safety of third world communities

RISK	POSSIBLE CAUSE
Typhoid, diarrhoeal diseases, cholera and intestinal worms	Contaminated water and food
Malaria	Poor drainage and garbage collection
Disease vectors such as lice, fleas, scabies, rats and cockroaches	Overcrowded poor quality housing and insufficient water for domestic hygiene
Tuberculosis, influenza and meningitis	Poor ventilation
High lead blood levels which retard children's mental development	Poor ventilation
Respiratory infections	Poor ventilation and open fires
Landslides, flooding and earthquake damage	Development on marginalized sites
Injury in fire and domestic accidents	No safe play areas
Lack of mobility for disabled people	Overcrowded neighbourhoods with poor accessibility

(Source: Harpham, *et al.,* 1988; Tabibzadeh, 1989 and Surjadi, 1993; cited in Wratten, 1995)

In a later publication, Hardoy, *et al* (2001), confirm their view that certain households are more at risk from environmental hazards. This, they attribute to being less able to avoid hazards and therefore being more affected by them, but also because they are less able to cope with the consequences of them, such as illness.

The urban poor are therefore particularly prone to exposure to environmental hazards, partly due to their close interface with their environment and partly due to their levels of vulnerability or defencelessness. In many at-risk communities, there are underlying processes of economic, environmental and social disadvantage which can increase the severity of an impact of a disaster more than a rare, large-scale disaster event (Holloway, 1999; Oelofse, 2002).

2.4.3 Determinants of poverty and vulnerability

It is very difficult to provide a definitive list of determinants of poverty, as poverty is viewed in different ways (as described above). According to Amis, (1995), employment is the single

most important determinant of urban poverty. He further states that labour markets and wage levels influence poverty. Rakodi, *et al.*, (2000), rank the inability to access adequate income-generating activities as the most important factor pushing people into poverty. They include large family size, divorce or bereavement, landlessness, lack of education, nepotism and insecurity as other significant factors. Amis (1995) also reports that lack of resources such as access to land, employment and employment necessary to provide for basic subsistence, are reasons for poverty. He therefore suggests that access to land and adequate wages are two determinants of poverty.

If vulnerability is to be viewed as defencelessness, the lack of coping strategies, insecurity, and exposure to risks and stresses, then the determinants of vulnerability should be broad and inclusive of all these aspects. In line with her broader view of poverty, Moser (1995) lists the determinants and associated indicators of urban vulnerability and well-being at the individual, household and community levels. These determinants and indicators highlight the important measures of urban vulnerability and well-being. They are listed in Table 2.2 below.

Table 2.2: Determinants and associated indicators of urban vulnerability and well-being at different levels

LEVEL	Determinants and associated indicators of urban vulnerability and well-being
INDIVIDUAL	• Access to adequate nutrition and health care (infant mortality) • Access to adequate education (drop-out rates) • Access to adequate income (per capita income) • Personal safety from domestic violence • Access to credit
HOUSEHOLD	• Household type • Household structure in terms of members in productive, reproductive and community work • Stage in the lifecycle • Access to housing

LEVEL	Determinants and associated indicators of urban vulnerability and well-being
COMMUNITY	• Access to, reliability and quality of basic needs of water, electricity, sanitation, roads, education and health care • Personal safety from robbers and violence • Capability and capacity of community based organisations

(Source: Moser, 1995, p 167)

These determinants and indicators of urban vulnerability and well-being are not only income or financial asset measures, but recognise that there are determinants of urban vulnerability other than monetary or income-based measures, such as "personal safety".

Other factors which are recognised as contributors to vulnerability are: the very young and old; women and children; and refugees and immigrants who lack physical resources and social structures (UNEP, 2002). Winchester (1992) lists family type, household size, age, sex composition of household, skills, education and caste as household characteristics of vulnerability.

Hardoy, *et al* (2001) list income and assets, economic or social roles, healthcare provision, and coping mechanisms as four factors which affect vulnerability. Rakodi, *et al* (2000, p 156) found that "female-headed households were thought to be vulnerable because they have in the past, had poorer access to education and have as a result lower literacy rates. They own limited productive assets, especially land and have limited access to credit in relation to men. Furthermore they tend to be ignorant of their rights and thus are exploited and discriminated against in economic activities.

Young people in low-income groups are also described as "helpless, frustrated and dangerous" in that rates of unemployment are high amongst the young people because they lack practical training, exposure to the world of work and business, and access to credit, information on employment and where to go for assistance (Rakodi, *et al.*, 2000, p156).

According to Wratten (1995) health problems experienced by the urban poor result from a number of factors. These may include "a competition for land; high living densities and overcrowded housing in hazardous areas; the speed of urban growth and the inadequate pace at which clean water supply, sanitation and solid waste disposal services are expanded; risks of traffic congestion and the inability to implement effective controls over pollution and accident prevention" (Wratten, 1995, p 22). While these external factors are significant determinants of ill-health and vulnerability, susceptibility of individuals to environmental stressors can be also be influenced by a number of physiological factors such as weak body defences (low immunity), limited mobility, strength and balance (such as the aged), asthma and genetic factors, age and micro-nutrient deficiencies (Hardoy, *et al.*, 2001). When determining the susceptibility of communities or household members to impaired indoor air quality, certain members of the population are more susceptible than others. These include, the elderly, those with impaired health, children (due to greater physical activity and developing lungs) and asthmatics (who have lower thresholds to pollutant gases) (Zummo and Karol, 1996).

2.4.4 Coping strategies, mechanisms and capacity

It is generally accepted that poverty and coping capacities determine levels and patterns of vulnerability. According to UNEP (2002), poverty is generally recognised as one of the most important causes of vulnerability to environmental threats, based on the fact that the poor seem to have much lower coping capacities.

The ISDR define coping capabilities as "the manner in which people and organisations use existing resources to achieve various beneficial ends during unusual, abnormal and adverse conditions of a disaster event or process" (ISDR, 2002, p 46). Coping capacity is a combination of all the natural and social characteristics and resources available in a particular location that are used to reduce the impacts of hazards (IATFDR 2001, cited in UNEP, 2002). These include factors of wealth, technology, education, information, skills, infrastructure, access to resources and management capabilities (UNEP, 2002).

In Mombasa, coping strategies of the poor included income-generating activities; expenditure-saving activities; credit; and asking for assistance when very poor or suddenly impoverished (Rakodi, *et al.,* 2000). These coping strategies were purely economic and highlight the importance of income in sustaining livelihoods and reducing vulnerability to environmental threats. However, contributors to well-being such as adequate space, minimum noise, close proximity to friends and family, access to social networks, easy access to desired services and safe play areas for children are other means through which communities are able to cope with environmental threats.

The concept of ***resilience*** is also understood to be the capacity of a community to resist or to change in order that it may obtain an acceptable level in functioning and structure (ISDR, 2002). The ISDR recognise that resilience is a form of coping capability and that it provides the community with the ability to withstand disasters and threats to their livelihood by lowering vulnerability.

2.5 BRINGING POVERTY AND VULNERABILITY INTO THE RISK EQUATION

Within the field of disaster management, work has been done to develop, test and validate tools, methodologies and other instruments for factoring in issues related to social equity, including gender analysis, into risk management at the local level (Kotze, 1999; ISDR, 2002). One such instrument examines people's strengths and abilities, their susceptibilities, socio-economic status and gender (ISDR, 2002). It is important to consider the social contexts in which risks occur, although it should be noted that people do not necessarily share the same perceptions of risk and their underlying causes (Kotze, 1999; ISDR, 2002; Oelofse, 2002).

The global review of disaster reduction initiatives prepared by the ISDR recognises that some phases in risk assessment are weak. They suggest that people's risk perceptions and the socio-economic and environmental contexts where they live, should be incorporated and are essential in the identification of risk scenarios (ISDR, 2002). In the ISDR's disaster management assessments, two elements are essential in the formulation of risk: *the probability of occurrence for a given threat* – the HAZARD and *the degree of susceptibility of the element*

(community) exposed to that source – VULNERABILITY. Coupled with this is the growing interest in the positive capacities of people to cope, withstand and recover from the impact of a hazard.

A formula for risk (ISDR, 2002) is given as:

RISK = HAZARD x VULNERABILITY/CAPACITY

The development of comprehensive risk assessments thus far mainly focuses on more conventional hazardous phenomena namely windstorms, earthquakes and floods. The approach can also be applied to assess the risk and vulnerability to human-induced environmental hazards of indoor air pollution – which is the content of this study.

In previous years, Wisner (1998), in his study of Tokyo's urban poor, called for the assessment of social variables when assessing vulnerability of urban groups. He states: "socio-economic status, occupation and nationality have a marked effect on access to information and services as well as on resources available to people for self-protection and recovery. Certain status, occupation and nationality groups suffer increased vulnerability because their capacity to cope and to recover has been diminished" (Wisner, 1998, p 27). He further states that there is evidence to show that people with certain social characteristics are more likely than others to be affected by lack of resources and the lack of access to these resources. These characteristics may include a low socio-economic status, lack of housing and shelter, no citizenship and lack of access to social and health services.

It is therefore imperative that risk assessments should incorporate dimensions of physical, social, economic and ecological vulnerability. Although the complexity of the environmental change process makes assessing and measuring human vulnerability highly speculative (UNEP, 2002), an attempt to "factor in" vulnerability into the risk assessment equation provides an assessment which may be more socially acceptable. The inclusion of vulnerability and capacity assessments in risk assessments is a move forward to better understanding the full risk to human health and well-being.

2.6 CONCLUSION

This chapter has reviewed the technical and scientific views of health risk assessment (HRA) and has described the various components of the process as well as the exposed population's characteristics which are considered in the assessment. It has also explored the notions of poverty and urban vulnerability and recognises that they are inextricably linked and that vulnerability is about both "exposure" and "defencelessness". Developing world communities and especially low-income communities are exposed to a variety of potentially harmful environmental conditions due to their socio-economic status. This chapter provides a conceptual framework and argument for the development of a more rigorous HRA method that includes both risks to chemical and biological hazards and measures of vulnerability.

The theory used in this literature search was explicitly drawn into this study in that it was used as one of the sieves in the selection procedure for deriving vulnerability indicators. It therefore forms part of the methodology which was developed in this study. This process is described further in Chapters 4 and 5.

CHAPTER 3: THE LIVING ENVIRONMENT OF CATO MANOR

3.1 INTRODUCTION

In order to develop a vulnerability index as well as to demonstrate the applicability of the index in assessing the risk to human health from environmental hazards, a case-study approach was adopted. The informal community of Cato Crest within the Greater Cato Manor area in Durban was chosen as the study area. This community has a number of characteristics which are indicative and representative of informal settlements in South Africa and was considered an appropriate community for the identification and assessment of factors underlying vulnerability.

3.2 LOCATION OF CATO MANOR

Cato Manor is a diverse, rapidly growing low-income development situated 7 km to the west of the central business district of Durban. It is bordered in the north by the Pavilion Shopping Centre and the N3 freeway, in the South by Sarnia Road, in the east by Manor Gardens and the University of Natal and Westville Prison in the West. The national N2 freeway bisects the area (CMDA, 2001). The area is divided into 19 geographical units called precincts, all of which are in some stage of development. It is made up of a number of residential communities that are starkly differentiated in terms of race, income levels, housing, municipal services and levels of education and health (Rich, 2000). These communities range from the dense informal settlement of Cato Crest to the established, fully serviced formal community of Chesterville (See Figure 3.1 for a map of Cato Manor).

There are five main informal settlements in Cato Manor which fall within three precincts. They are:

- Cato Crest Informal settlement (which forms the Cato Crest precinct);
- Old Dunbar, New Dunbar, Emathendeni (forming Wiggins precinct); and
- Jamaica (in Chesterville Extension Precinct).

These informal areas consist of informal networks of dirt roads and paths indicative of unplanned informal community development and are still in the stages of upgrading.

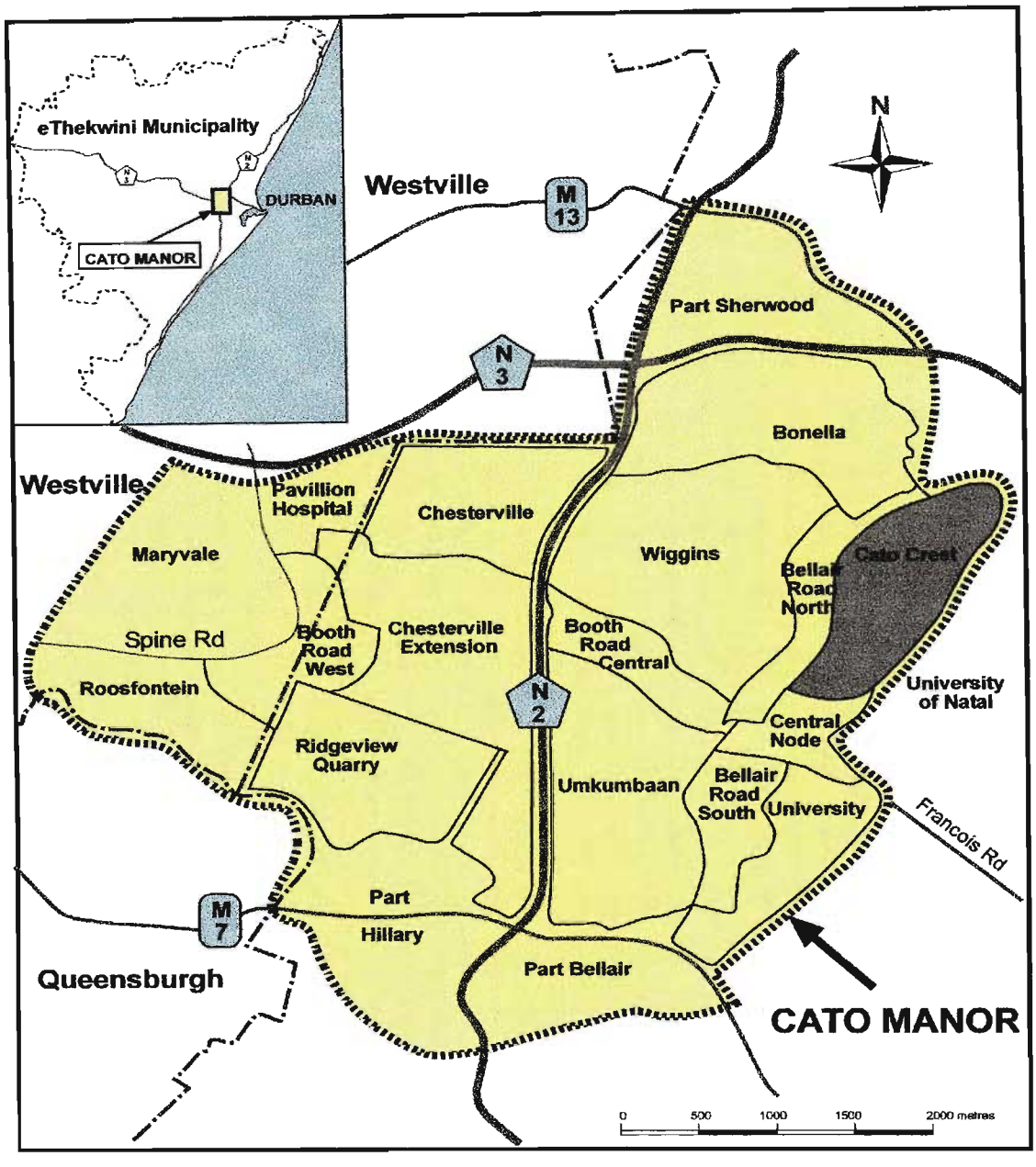


Figure 3.1: Location of Cato Crest (shown in dark grey) within Greater Cato Manor (Source, CMDA, 1995)

The close proximity to Durban's central business district means that many of the inhabitants of Cato Manor are either working in town or seeking employment in and around Durban. In the household surveys conducted in the area, many of the residents mentioned the close proximity to employment activities and good transport facilities as being positive attributes for living in the area (Vermaak, *et al.*, 2001).

3.3 HISTORICAL BACKGROUND

In the 1650s the area was inhabited by numerous small-scale chiefdoms. In 1843 George Cato, the first mayor of Durban, was given the land which became Cato Manor farm. After numerous subdivisions people began settling into the area which grew to 150 000 during the 1950s. After the promulgation of the Group Areas Act in 1955, the entire population was forcibly removed to the racially exclusive townships of KwaMashu, Umlazi and Chatsworth. The area remained largely unoccupied between 1970 and 1990. Between 1989 and 1993, interest in the redevelopment and resettlement of Cato Manor increased. In early 1987, small-scale land invasions resulted in incremental informal settlement within Cato Crest. The Cato Manor Development Association (CMDA), a section 21 company, was established in 1993 to act as a vehicle for the delivery of a redevelopment project as part of the National Government's Reconstruction and Development Programme (CMDA, 2000). The CMDA continues to act as a facilitator of sustainable development in the area.

By 2001, a population of between 18 000 and 23 000 existed in Cato Crest, many of whom were disadvantaged and poor due to forced removals and racial segregation (Gielink, pers comm., March 2001). The area has been associated with powerful interests which dominate community organisation as well as access to resources and has also been the receptor of numerous surveys.

3.4 GEOGRAPHICAL PROFILE OF CATO MANOR

3.4.1 Biophysical environment

Cato Manor is situated in a high rainfall area with steep topography, and is transversed by the Umkumbane River and the Blinkbonnie River. This area is well watered, with numerous springs and streams leading into the Umbilo and Umkumbane rivers. However, both of these river systems have been substantially altered by canalization. This water is heavily polluted by industrial and residential effluent and dumping, mainly by construction companies getting rid of rubble at sites along Bellair and Wiggins Road (Madonsela and Binedell, 2001).

The Umkumbane River, together with the Mayville stream, the Bellair stream and the Chesterville stream, all of which pass through the area, supply Cato Manor with natural river water. In the past, informal settlements such as Jamaica and Cato Crest used to have to rely on river water as their water supply, but currently very few residents still rely on this source due to contamination of the water and its risk to health if ingested (Madonsela and Binedell, 2001). Currently, the informal settlements rely on community standpipes or water tankers while the rest of Cato Manor relies on Durban Water and Waste, which purchases raw purified water from Umgeni Water, and then supplies Wiggins Waterworks for treatment (Madonsela and Binedell, 2001). The water is then stored in three reservoirs, namely Chesterville, Cato Manor and Sherwood Reservoir. From here it is distributed to the households through standard reticulation systems.

The loss of agricultural land in Cato Manor has been mainly due to overgrazing, droughts, toxification through pollution and agricultural chemicals, and urbanization. Development in Cato Manor has also resulted in the destruction of indigenous forest tree species in the area, which has inadvertently led to alien invasion (Pillay and Webster, 1997). Settlements in Cato Manor have impacted negatively on the biophysical environment by removing vegetation and soil cover to prepare stands on which dwellings are built. The result has been the erosion of steep slopes, roads and even the washing away of houses in flood conditions.

There are areas in Cato Manor that are proposed for regeneration of indigenous flora, and these areas fall under the Durban Metropolitan Open Spaces System (D'MOSS). In the shack areas of Cato Crest, Ematendeni and Dunbar Road, open space is important for larger yards around houses for social interaction and gardening (vegetable and flower gardens), but little gardening is evident (Oelofse, 1999). Larger open spaces are important for community recreational use. The increase in domestic space in the form of larger yards is generally perceived to be of greater immediate urgency than the provision of public open spaces (Hindson and Pupuma, 1996).

The main concerns of ambient air pollution in informal settlements are generally dust, smoke from burning refuse, vehicular emissions and industrial activity (which may emit particulates

or toxic gases to the atmosphere) (Matooane, 2000). These concerns may be either exacerbated or diminished depending on the location of the settlement, (including the proximity of heavy industry or mine tailing impoundments), the nature of the fuels being used for cooking, lighting and heating, and the local meteorological conditions. According to Matooane (2000), ambient air quality in Cato Manor is generally good. This is based on the knowledge that there are a small number of polluting sources in the area.

The situation of indoor air quality however, is somewhat different. In 2001, several precincts in this area had not yet been electrified (Thomas, 2001). Since part of Cato Manor can be described as a typical developing world township, the main sources of indoor air pollutants (as normally found in developing world townships) are attributed to domestic activities. Studies that have been conducted in Cato Manor indicate that the most common fuel used is kerosene (paraffin). Some households use wood only, and some a combination of wood and kerosene depending on the season. Gas users in the area are a minority (Muller, 2001). The use of kerosene, wood and coal, especially during winter, adds to the amount of particulate matter in the air and is a serious health concern (Mathee, *et al.,* 1999).

3.4.2 Socio-Economic Environment

Cato Manor represents a diverse community with stark differences in quality of life between the formal and informal areas (Rich, 2000). Some of the socio-economic factors which contribute to quality of life in Cato Manor are population, age and gender profiles, level of education, employment and levels of income. A brief overview of the socio-economic status of Cato Manor is provided.

At the time of the 1996 census, 62% of the South African population resided in informal housing. Of the total population in Cato Manor, 44 % resided in the informal community of Cato Crest, making it one of the most densely populated informal settlements in South Africa. In 2001, Cato Crest housed roughly 4 500 households, and with an estimated 4 to 5 people per household, making a total population of between 18 and 23 000 (Gielink, pers. comm., March 2001).

A relatively high proportion of female-headed households exist in Cato Manor with six out of ten household heads in Cato Manor being male, whilst four out of ten are female (Vermaak, *et al.,* 2001). Many of these female-headed households contain a number of dependants creating an even greater economic and social burden on female earners.

The age profile of the Cato Manor community is relatively young with an average age of all household members being 27 years. More than one-quarter of the household members are aged 15 years or younger, suggesting a constant if not increasing demand for employment and services in the next decade while less than seven percent of the members are over the age of 55 years, indicating a limited population earning private or state pensions (Vermaak, *et al.,* 2001).

Education levels differ between the formal and informal areas of Cato Manor. Nearly a third of the economically active age group in the formal areas have completed grade 12, in comparison to less than a fifth of those in informal areas (Vermaak, *et al.,* 2001), which highlights the large burden on education and social upliftment in the area.

Economically, the Greater Cato Manor community is very dichotomous with upper income professionals living alongside poor informal shack dwellers (Crookes, 2000). Less than half of its population live below the per capita poverty line which is set at R476.30 per capita per month, making it an economically poor area (Vermaak, *et al.*, 2001).

Unemployment rates are also highly variable with higher unemployment rates in informal areas. Within those who are employed, 20% are involved in the informal sector with street vending being the most common informal activity. More females (62%) than males (38%) are involved in the informal sector (Van Schalkwyk & Naidoo, 1999, cited in Crookes, 2000).

In Cato Manor, HIV/AIDS statistics show that HIV prevalence has increased from 41.4% in 1999 to 45.3% in 2000 with the highest prevalence in the 20 to 29 year age group (Smith, 2001).

3.4.3 Institutional Environment

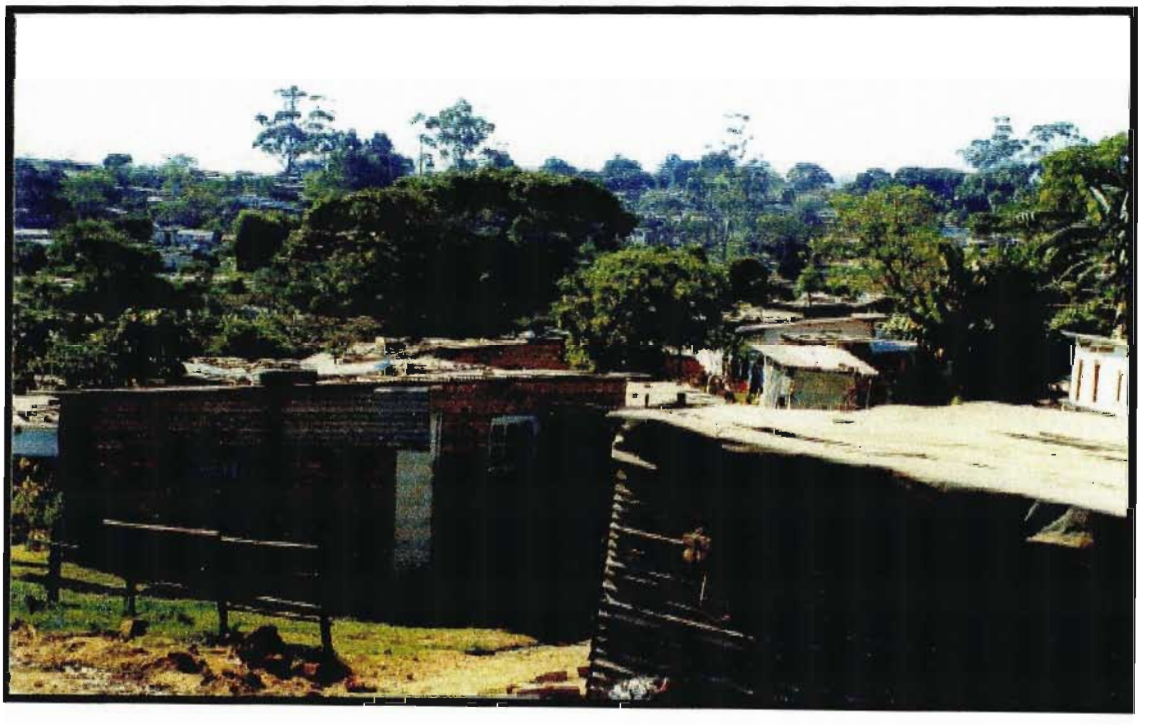
The focus of leadership activities in Cato Crest has shifted from a struggle in the 1980s to prevent removals, to a struggle for service provision in the 1990s and to participation in the planning and development of the area with the CMDA (Rich, 2000).

The Cato Manor Development Association (CMDA) is the dominant institution operating in the area, acting as the agent for provincial and local government to facilitate implementation of the development project (Williamson, 2000). The CMDA also acts as facilitator in committees dealing with important issues, providing short-term employment opportunities, work experience, skills training and adult education. An assessment of the performance of institutional arrangements in Cato Manor shows that the CMDA is recognised as a dedicated development vehicle for facilitating a large-scale, complex development – a role which may not have been as successfully undertaken by local government (Williamson, 2000). NGOs have also provided skills and contributed to the development process and have represented a significant resource in the area. Local government involvement in the area is however lacking and it is said that there is still room for improvement (Williamson, 2000). Community-based organisations (CBOs) are the least successful stakeholders and lack the necessary organisational skills and experience to interact with established development organisations. According to Williamson (2000) there is still widespread ignorance in informal settlements about the operation of institutional structures and systems, including a limited understanding of demographic processes and basic citizen rights and responsibilities. These may be some of the reasons why there have been some conflict-ridden interactions between developers and the community (Williamson, 2000).

3.4.4 Infrastructure

Infrastructural development in Cato Manor is, like most other aspects of the community, diverse. The formal areas such as Chesterville receive piped water, flush sanitation, electricity and other services such as telecommunication lines and waste removal. The informal areas are in the process of upgrading and the appropriate infrastructure is currently being installed.

The location and types of building structures differ between the formal and informal areas within Cato Manor. Formal housing is more widely spaced than informal housing and consists of block houses with solid roofing. Housing in the informal areas consists of shacks constructed from various materials such as planks, plastic sheets, iron sheets, mud and daub or cardboard boxes (Plate 2). These structures utilize any form of insulation or waste material and are spaced close to one another. They are poorly insulated, creating unstable indoor temperatures, and prevent the adequate dispersion of indoor air pollution generated through the use of kerosene, wood or coal.



(Photo: Mark Napier)

Plate 2: Typical informal dwellings in Cato Crest

Reticulated water is supplied to all areas of Cato Manor by Durban Water and Waste (a service unit of eThekwini Municipality). Formal areas such as Chesterville receive piped water into their homes for which they pay a monthly fee. Households in other areas, such as Cato Crest, are supplied with either 200 litre water tanks or with communal standpipes for which there is no cost (Napier and Mulenga, 2000, cited in Madonsela and Binedell, 2001). A number of problems arise from such facilities. This service requires that a number of

households share facilities and sometimes have to wait a long time before they can access their share. Furthermore, the quality of water often deteriorates while in storage and can be contaminated causing water-borne diseases (Madonsela and Binedell, 2001).

Like access to water, there are wide variations in Cato Manor concerning flush sanitation. In 2000, 45% of the total population in Durban did not have flush toilets (Thomas, 2001). This is true too for Cato Manor. Pit latrines and bucket toilets are the most common sanitation method in Old Dunbar, Cato Crest and Wiggins creating a number of unhealthy and unsanitary conditions which increase the likelihood of exposure to harmful disease-causing organisms (Oelofse, 1999).

Most of the formal houses that are electrified in Cato Manor, utilize the pre-paid metering system. The electricity is used for selected purposes such as lighting and entertainment, and depending on the economy of the household, also for refrigeration, cooking and heating. In low-income periods, kerosene or coal may be used for cooking and heating. The informal settlements are, however, not electrified. Here a good number of households use kerosene for most of their energy activities which creates indoor air pollution problems which can cause a number of respiratory related diseases (Madonsela and Binedell, 2001).

The provision of waste removal services in Cato Manor is the responsibility of the eThekwini Municipality. A system is in place to collect and dispose of all the waste that is generated on a weekly basis. Plastic bags are provided to residents. Waste collected from Cato Manor and the surrounding areas is dumped at Bisasar Road dumpsite, which is about 6 km away from Cato Manor (Madonsela and Binedell, 2001). Besides this service, a number of residents dump their bags in illegal areas or place their bags in the street before the collection time where animals forage and spread the rubbish. This creates an unsightly situation and provides a breeding ground for disease-carrying vectors such as flies, rats and cockroaches.

3.5 CONCLUSION

The Cato Crest community within the Greater Cato Manor area was considered an appropriate community for the identification and assessment of factors underlying vulnerability in that it displays some of the generic socio-economic and biophysical characteristics of informal settlements in South Africa.

The economic environment in Cato Crest is dominated by activities in the informal sector which suggests that individuals are struggling to access the vital financial assets required to deal with living costs. While the CMDA is recognized for its role in guiding development in the area, community-based organizations are not adequately facilitating community involvement in development. The social environment is characterized by problems concerning inadequate housing, overcrowding, and high crime rates. It is a relatively young population with a high proportion of female-headed households. High levels of unemployment exist which is exacerbated by the low levels of education found in each household. Exposure to potential health hazards occur as a result of the lack of waste, water and sanitation facilities while the lack of electricity necessitates the use of kerosene for cooking and heating leading to respiratory problems. The high prevalence of HIV/AIDS in the area may be considered an extremely serious implication for development in Cato Manor and will surely contribute to heightening risks to health hazards in the community.

CHAPTER 4: METHODS AND APPROACHES

4.1 INTRODUCTION

According to Eyles, (1988, cited in Robinson, 1998), qualitative methods within human geography are essentially descriptions of people's representations and constructions of a setting. "These descriptions can take several forms ...and may be used in conjunction with statistical surveys and quantitative analysis as complimentary methods for seeking an understanding of society" (Robinson, 1998, p 409). This study uses both quantitative and qualitative methods for determining the cumulative risk of indoor air pollution in poor communities.

Qualitative or interpretative methods have been used throughout the study in order to establish what socio-economic variables underlie urban vulnerability. Qualitative methods were used in the analysis of literature on poverty and vulnerability, in generating primary data on living conditions and factors of vulnerability in Cato Crest, in analysing the data collected in the household survey and in reviewing the health indicators described in South African health studies.

Qualitative methods were used to determine the time-activity patterns of potentially exposed individuals and served to provide vital exposure information for input into the health risk assessment (Muller, 2001). Another qualitative or interpretative method which was used in this study was the household survey. This survey generated data on living conditions and vulnerabilities of low-income communities by using a structured household questionnaire and served to "gain access to the experiences and insights of human subjects" in Cato Crest (Robinson, 1998, p 411).

Quantitative methods have been used in previous studies to generate information on what risks vulnerable households are experiencing when subjected to indoor air pollution (Muller, 2001). The health risk assessment method relies on data of concentrations of air pollutants in the indoor environment which were also derived from quantitative monitoring techniques.

Thereafter, the human health risk assessment method was used as a quantitative tool for predicting the nature and severity of health effects to adults, children and infants (Muller, 2001).

Certain components of this study relied on information from studies conducted within a larger research project funded by the South African Department of Arts, Culture, Science and Technology (DACST) between 1999 and 2002. The research project, termed the Lead Programme in Technologies for Enhanced Environmental Management (Hounsome, *et al.*, 2002), developed a decision-making tool for facilitating the implementation of sustainable services in communities in South Africa. The components of the larger research project which were used in this study include:

- A time-activity pattern survey in Cato Crest (Binedell and Law, 2000);
- An indoor air monitoring exercise conducted in selected Cato Crest households (Binedell, *et al.*, 2001);
- A Health Risk Assessment of households exposed to kerosene combustion in Cato Crest (Muller, 2001); and
- A household survey conducted in Cato Crest (Vermaak, *et al.*, 2001).

The author was fully involved in each component mentioned above, except for the Health Risk Assessment, as this component of the project formed part of Elizabeth Muller's Master's thesis. The author is, however, fully conversant with the methodology followed in the health risk assessment and can verify and/or reproduce the results obtained in the study.

Characteristics of the community have been verified and if possible, quantified through the collection of primary information in the form of household surveys. These surveys are discussed in detail in section 4.3.

4.2 SECONDARY INFORMATION SOURCES

4.2.1 Literature Review

Literature sources have been used to develop the theoretical framework for this study and to determine the set of factors that underlie urban vulnerability. A number of internationally recognized literature sources were consulted to determine the main factors and indicators of urban vulnerability. Secondary sources, such as reports, have been used to develop a baseline socio-economic profile of the Cato Crest community.

4.2.2 Health risk assessment of kerosene combustion pollutants

Muller (2001) conducted a study on health risks to kerosene combustion in Cato Crest. The study involved indoor air monitoring of key pollutants and the characterization of risk to household members (adults, children and infants). The study used the human health risk assessment methodology, defined by the United States Environmental Protection Agency (USEPA), to characterize risk to human health from exposure to kerosene combustion. Although this methodology can be used both quantitatively and qualitatively, only quantitative analysis was used in the risk characterisation in Muller's study.

This health risk assessment relied on two types of information. One set of information was based on the time-activity patterns of residents in Cato Crest. The other type of data collected was levels of air pollution in selected households.

Time-activity pattern survey in Cato Crest

In order to determine exposure patterns of people living in Cato Crest, a time-activity pattern survey was conducted at the household level. The questionnaire, which was compiled by myself and Elizabeth Muller (with inputs from specialists), consisted of a series of close-ended questions designed to determine personal details, type of fuel use, building structure (in order to determine ventilation of the structure) and cooking and time-activity patterns. Field workers from the Universities of Natal (UND) and Durban-Westville (UDW) randomly sampled households within the area. A total of 69 questionnaires were completed during the study,

mainly by women. Data from the questionnaires was entered into an Excel spreadsheet and analysed for use in the health risk assessment process. Details of implementation of the survey can be found in Muller (2001).

Indoor air monitoring in Cato Crest

In order to determine whether indoor air quality was impaired in informal dwellings such as those found in Cato Crest, a small indoor air monitoring exercise was initiated. Twelve households were chosen for the study, based on the use of fuel for cooking and heating, and ventilation of the dwelling. These households were selected from the sample which completed the time-activity survey. Constituents monitored were nitrogen dioxide (NO_2) and volatile organic compounds. NO_2 was measured using ChromAir® Direct Read Passive Monitor badges. Total VOCs were measured using Traceair® Organic Vapour Monitor (OVM-1) badges (K&M Environmental, 1997).

The air quality monitoring took place over a nine day period (Muller, 2001). Both badges were hung from the ceiling in the vicinity of cooking, but not directly over the stove. The NO_2 badges were changed on a daily basis while the VOC badges remained for a period of 9 days. NO_2 concentrations were determined through direct reading off a colourimetric comparator. VOCs were measured using gas chromatography using flame ionization detection. Measures of concentrations of selected pollutants were used in a health risk assessment model to determine risk to NO_2, benzene and toluene (Muller, 2001).

Characterisation of health risks from acute and chronic exposure to non-carcinogenic pollutants

Data acquired from both the time activity pattern survey and the indoor air monitoring exercises were used in the calculation of health risk to Cato Crest residents (Muller, 2001). The USEPA quantitative human health risk assessment (HHRA) process was used. This process is described as a qualitative and/or quantitative process conducted to characterize the nature and the magnitude of risks to public health from exposure to hazardous substances released from specific sites (NRC, 1994). The HHRA process involves the characterization of health risk by identifying hazards of potential concern, establishing the intensity of exposure

to these hazards and by establishing the dose-response relationship between the hazard and human health (NRC, 1994). This process has been described in detail in Chapter 2, section 2.2.

In Muller (2001), this quantitative procedure was used to incorporate local South African conditions (established through the time activity survey) into the exposure assessment in order to characterize the risk of these populations to indoor air pollution. As described in section 2.2 (Chapter 2), non-cancer health effects are expressed as a hazard quotient (HQ) which indicates the presence or absence of adverse health effects due to exposure to non-carcinogenic pollutants. An HQ that is less than 1 indicates a negligible risk, even to a sensitive individual, whereas a HQ greater than 1 indicates that there will be some risk as a result of exposure. Risk which has been characterized through the HRA method is expressed as:
RISK to HAZARD = HQ

Muller (2001) established a hazard quotient for three groups in households (adults, children and infants) in each of the Cato Crest households involved in the study. Hazard quotients were calculated for expressing the potential health risk from exposure to nitrogen dioxide, benzene and toluene as these represent three of the most important pollutants affecting human health.

4.2.3 Use of hazard quotients in this study

The aim of this study is to develop a methodology for generating a vulnerability index for the inclusion of factors underlying urban poverty and vulnerability into a risk assessment of indoor air pollution. The formula that describes the calculation or determination of cumulative risk consists of two main components, namely hazard and vulnerability (ISDR, 2002). This can be expressed in the following equation:

CUMULATIVE RISK = HAZARD X VULNERABILITY

The calculation of the hazard quotients prepared by Muller (2001) represents the data on the hazard. The hazard quotients determined by Muller (2001) were used together with a suite of vulnerability indicators developed in this study, to measure vulnerability at the household

level. By examining both the risk to households from air pollution (the HQ component of the formula) and the risk to households from other stressors (the vulnerability index), it may be possible for a more holistic understanding of risk to be established. This risk would reflect, to a certain extent, how different factors and problems become aggregated. It therefore attempts to quantify the nature of cumulative risk.

4.3 PRIMARY INFORMATION SOURCES

A primary information source that was used in this study was a household survey of selected households in Cato Crest. Details of the survey are given below.

4.3.1 Household survey in Cato Manor

In 2001, a household survey in Cato Manor was initiated through the aforementioned Lead Programme project. The household survey ascertained the demographics of each household including:

- Number of people per household;
- Sex composition of household;
- Mean household age;
- Education levels;
- Vocational status;
- Income per person; and
- Contribution of income to household.

It included a measure of access to water, sanitation, waste management and energy services as well as a measure of environmental pollution (particularly air and soil quality). The questionnaires were administered by Development Research Africa and were completed by 300 households in Greater Cato Manor, with 68 households in Cato Crest completing the questionnaire. The questionnaire is attached as Appendix 2. Only the Cato Crest results were used in this study and were analysed using SPSS and excel software.

4.3.2 Household survey of selected Cato Crest households involved in air monitoring

Once the indoor air monitoring exercise and the household surveys had been completed, a comparison of households involved in both the air monitoring exercise and the randomly sampled household survey revealed that there were no household surveys conducted in the air quality monitored households. The purpose of this study was to develop a methodology for generating a vulnerability index for the inclusion of factors underlying vulnerability into a risk assessment of indoor air pollution. The information on household vulnerability factors (obtained through the household survey) was unfortunately not available for the twelve households for which air pollution risk had been assessed. It was therefore necessary to undertake a survey of these twelve households in order to establish the household characteristics and underlying vulnerability factors present in these households.

This survey was initiated for the purposes of this study. It was completed by a female Zulu-speaking field worker in February 2003. The questionnaire was the same as the questionnaire used in the former household survey with the inclusion of one question on access to health care facilities.

This data and the data from the former household survey in Cato Crest were used to provide information on what factors underlie vulnerability in low-income households in a South African informal settlement. The data collected served to highlight potential physical, environmental, social and economic risks to each household. This data were also used in an attempt to populate the vulnerability index developed in this study in an attempt to show how vulnerability factors may be included in the evaluation of risk. This is explained in more detail in section 5.4.

4.4 DEVELOPMENT OF A VULNERABILITY INDEX

As discussed in the theoretical framework (Chapter 2), there are a number of biological, chemical and physical hazards that particularly low-income communities are exposed to. In addition to this, factors of vulnerability and urban poverty are additional pressures which may either compound the risks to human health or prevent communities from accessing the

resources needed to cope with these pressures. Current health risk assessment methods do not adequately include these factors into the calculation of risk. The HRA method has been used in the South African context and has been adapted to include local exposure characteristics of informal communities (Muller, 2001). However, a methodology for the inclusion of a spectrum of vulnerability characteristics and factors into a risk assessment has not yet been established. Research into the development of this type of method is necessary so that both exposure and vulnerability to hazards may be determined and included in the calculation of risk.

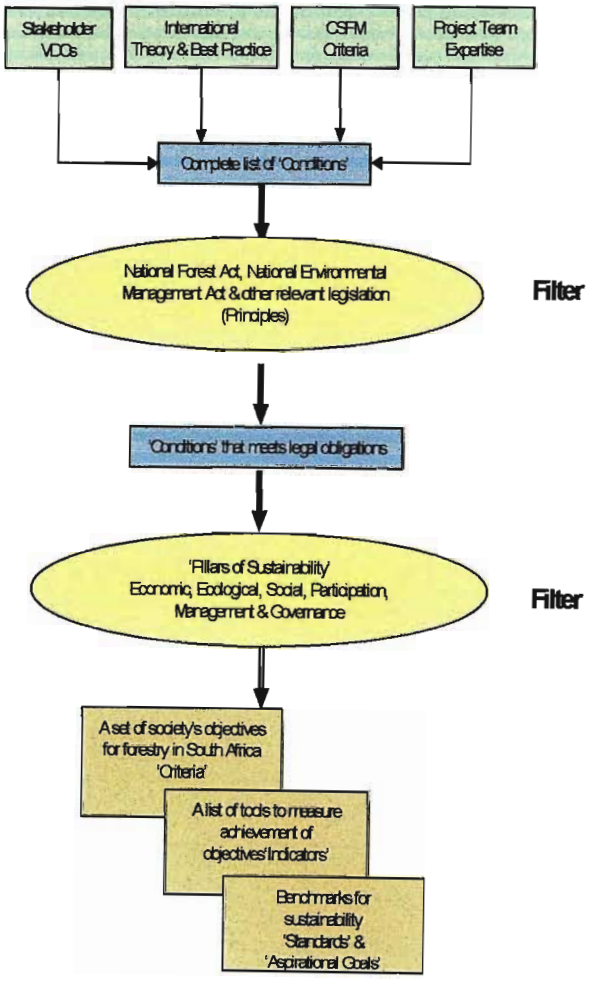
The methodology used in this study was systematic. It was first influenced by the concepts of urban poverty and vulnerability in the literature. These concepts served to broaden an understanding of poverty and vulnerability and highlighted the numerous factors which underlie vulnerability. Thereafter the method was influenced by the primary data collected on households in Cato Crest and by the approach used for developing sustainability indicators for sustainable forest management in South Africa (INR, 2002).

4.4.1 Adaptation of existing model

The INR (2002) was tasked with developing sustainability indicators for sustainable forest management in South Africa. The methodology that was used in the forestry project consisted of both a technical process and stakeholder consultation process in order to produce a set of principles, criteria, indicators and standards (PCI&S). The technical process resulted in the development and refining of the criteria, indicators and standards, while the consultation process facilitated the involvement and participation of stakeholders into the criteria, indicators and standards development as well as in the testing and refining stages (INR, 2002). The two processes are illustrated in Figure 4.1.

The approach that was used was both deductive (top down) and inductive (bottom up) in that it considered inputs from theory and literature, specialist knowledge and experience, stakeholder inputs and the project team's experience and expertise (Oelofse, *et al.*, 2002). It was an

iterative process in that all of the inputs mentioned above were integrated throughout the development of the PCI&S.



Abbreviations: VDCs – Verified Desired Conditions

CSFM – Council for Sustainable Forest Management

(Source: INR, 2002)

Figure 4.1: Methodology for the development of principles, criteria, indicators and standards (PCI&S) for forestry in South Africa

At the start of the process, four selection procedures were used to provide a list of conditions or key issues in forestry in South Africa. These procedures included stakeholder input, literature reviews, a set of criteria developed by the Committee for Sustainable Forest Management and the local experience of the project team. The set of criteria, indicators and standards were filtered through the relevant legislation as well as the principles of sustainability so as to ensure that there were no gaps and that the set was aligned with current policy and legislation. From this verified set of conditions; criteria, indicators, standards and aspirational goals were generated (INR, 2002).

This method provided ideas and the point of departure for developing the methodology used in this study to include vulnerability in air pollution assessment. The filters that were used in the forestry method equated to the sieves that were used in the vulnerability methodology developed for this study. The sieves served to refine the broad list of issues and factors identified from both literature sources and local data into vulnerability indicators which could be used to provide a measurement of a spectrum of vulnerability characteristics. The vulnerability methodology developed in this study is described in the next section.

4.4.2 Vulnerability index methodology

The method that has been developed in this thesis for generating the vulnerability index for low-income households consisted of a 4 tiered approach. This is illustrated in Figure 4.2.

The first tier in the methodology aimed to establish a preliminary list of factors which underlie vulnerability in low-income communities. This step involved the use of a number of literature sources from a variety of case studies around the world. All issues, factors, indicators or variables were identified from each literature source and listed in a matrix (see Table 5.1). A list was then created of the most frequently mentioned vulnerability factors to the least mentioned factors from all studies (Table 5.2).

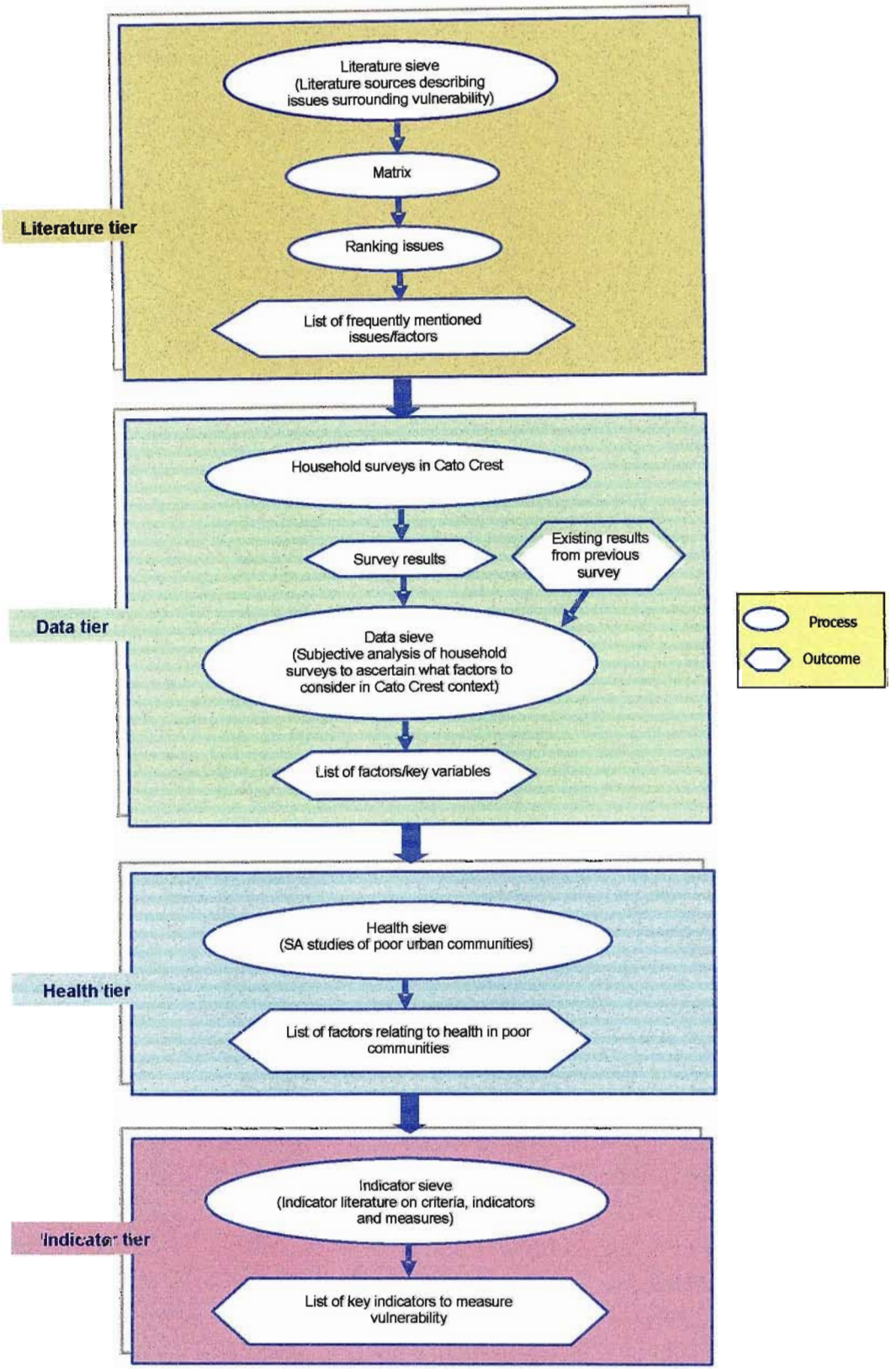


Figure 4.2: Four tiered approach used to establish a list of vulnerability indicators

The second tier in the methodology involved the collection and analysis of primary data collected through a household survey in Cato Crest. The questionnaire has been described in the previous section (section 4.3 of this chapter). Results of the survey were analysed using subjective judgment of the key issues which were thought to make the household vulnerable to physical, environmental and social hazards. These issues were correlated against the list of vulnerability factors identified through the literature survey and a comparison was made between those issues evident in the literature and those issues which were considered important in the Cato Crest community (see Table 5.3). The primary research conducted in these households provided data on living conditions in Cato Crest and was not collected for the purpose of populating the index, but was used to develop and refine the index. The lists generated from the literature sieve (Table 5.2) and the data sieve (Table 5.3) were then compared and listed in Table 5.4

The third tier in the methodology consisted of a "health sieve". This sieve consisted of a number of health studies which had been conducted in informal settlements in South Africa. These studies were used to establish which of the factors identified through the vulnerability sieve (in the first tier) and the data sieve (in the second tier) were applicable to informal settlements in South Africa. More importantly, the link between the factors and their role in contributing to human health were investigated so that the final list of factors derived from this sieve was able to measure the vulnerability of households to human health hazards (see Table 5.6). Both direct and indirect links between the environment and human health were investigated. A composite list of issues and factors that were generated using the three sieves was then produced (see Table 5.7).

The forth and final tier in the methodology consisted on an indicator selection process which involved subjecting the issues and factors collected through the three previous tiers to an indicator methodology which transformed the issues or factors into a list of vulnerability indicators and measures. The indicator methodology consisted of background knowledge of indicator frameworks and criteria against which potential indicators are assessed. The resultant list of indicators and measures formed the vulnerability index.

4.5 QUANTIFICATION OF THE VULNERABILITY INDEX

4.5.1 Scoring vulnerability measures

Once the indicator set and associated measures had been developed, an attempt was made to produce a single vulnerability score from the indicator set. The scoring system was adapted from Klasen (1997) and involved using a 5 point scale of vulnerability - 1 corresponding to the best possible standards or conditions, while a score of 5 indicated severe deprivation or vulnerability, severe health hazards and few physical and human resources (Klasen, 1997). Each of the vulnerability measures were then quantified using this scoring system. Attributes were subjectively assigned based on literature sources, the data collected in Cato Manor and on experience. The table of scores and attributes is presented in Chapter 5, Table 5.10. An example is given in Table 4.1 of these attributes for two of the measures.

Table 4.1: Example of vulnerability scores and attributes for two measures

Measure: *Number of people per household*		**Measure: *Frequency of waste removal***	
Vulnerability Score	**Attribute**	**Vulnerability Score**	**Attribute**
1 (least vulnerable)	1-2	1 (least vulnerable)	Twice a week
2	3-4	2	Once a week
3	5-6	3	Twice a month
4	7-8	4	Once a month
5 (most vulnerable)	>8	5 (most vulnerable)	No removal

4.5.2 Testing the vulnerability index

The development of a single score of vulnerability was attempted to try and show how this could be done. It was not the primary focus of this study and the data for every measure was not available. Where data were available, scores were assigned to each measure for 10 households in Cato Crest. These 10 households were involved in the indoor air monitoring

exercise and were also the subject of Muller's study (Muller, 2001). The scores were then added together to derive a composite vulnerability score for each household (see Table 5.11). In order to show cumulative risk of exposure to indoor air pollution for all individuals in a household, the hazard quotients for adults, children and infants for each of the pollutants were added together. These hazard quotients were taken from Muller (2001) and have been discussed in section 4.2.2. This resulted in a similar composite score which represented the hazard component of the equation RISK = HAZARD x VULNERABILITY (see Table 5.12)

Once a composite score was derived for both the hazard and vulnerability risks, these scores were multiplied together to produce a cumulative risk score for each household. These results are displayed in Table 5.13 in Chapter 5.

4.6 LIMITATIONS

One of the main limitations of this study was the unavailability of household data for each of the measures of vulnerability. As discussed in section 4.3.1, the household survey in Cato Crest was initiated through a broader study funded by the Department of Arts, Culture, Science and Technology and was conducted for another purpose. The data has been used in this study to determine some of the vulnerability characteristics which underlie urban poverty and vulnerability, but not all of the required data were available to be used in populating the vulnerability index which was developed.

The style of questioning used in the household survey was also not conducive to evaluating levels of vulnerability at the household level. Close-ended questions provided some valuable inputs but a more open-ended style would have been more appropriate to probe for conditions of poverty and vulnerability in the household. The style of the questionnaire resulted in a number of data gaps which would have been useful to have.

4.7 CONCLUSION

This study has made use of both quantitative and qualitative techniques in producing a vulnerability index which is to be used to determine cumulative risks to vulnerable communities to the impacts of air pollution. Secondary information sources such as literature on poverty and vulnerability have formed an important resource in this study and have been used to provide both the theoretical framework of the study as well as provide a number of factors which underlie vulnerability in low-income communities. Other secondary sources in the form of reports have provided information on the potential health risks to individuals who are exposed to indoor air pollution. Primary data, in the form of qualitative questionnaires, have been used to verify and "ground-truth" the findings from the literature review.

Due to the lack of an appropriate methodology for the inclusion of vulnerability factors into the assessment of health risks, this study determined to develop a methodology by adapting an existing method which was used for a forestry indicator project (INR, 2002). The four-tiered selection procedure was a logical and systematic process which aimed to "sieve" the selected factors of vulnerability through a number of filters until a six-themed index was derived.

Finally this study attempted to populate this index as far as was possible given the data available, so as to present some ideas about how this work could be tested and taken forward in future research.

CHAPTER 5: DEVELOPING A VULNERABILITY INDEX

This chapter provides the results of each selection procedure used to develop the key vulnerability indicators that could be used to measure the vulnerability of households exposed to the physical hazards of indoor air pollution. It also describes each of the indicators chosen and relates each to its contribution to vulnerability at the household level.

5.1 FACTORS UNDERLYING URBAN VULNERABILITY

The indicator selection process was iterative and included the identification of factors from the literature, the ground-truthing of vulnerability factors with data collected from Cato Crest household surveys, the identification of issues relating to health through a review of selected South African health studies, and the development of state of the environment indicators for the measurement of urban vulnerability in low-income South African communities.

5.1.1 Selection of factors from literature sources: "Literature Sieve"

The first selection process consisted of a literature survey which was conducted in order to identify a number of factors which are being attributed to poverty and vulnerability. Each of these literature sources were used to develop the theoretical framework in Chapter 2. The issues and factors were identified by subjective evaluation of the contribution of each factor to heightening or contributing to poverty and vulnerability.

All of the issues, factors, indicators and key variables which were derived from the literature review were tabulated and then logically grouped into common themes or characteristics. For example, access to health care, incidence of disease and life expectancy were listed under the characteristic of "health". Similarly, per capita income, economic reserves and access to land were listed under the characteristic of "income".

The characteristics which were derived from this exercise included health, employment, income, education, household or family structure, services and housing. There were between

one and eight issues or factors within each characteristic group. The purpose of grouping the issues into characteristics was to check whether a spectrum of vulnerability characteristics was available which spanned the attributes of health, family structure and other social characteristics and not only the income-based characteristics which have in the past been used to describe income-based poverty.

Once all of the issues, factors and variables had been extracted from each individual literature source and grouped into characteristics, a matrix was used as a tool to determine those key vulnerability factors which were common to most of the literature sources. The matrix was used to establish the number of times each variable was mentioned in the literature. The most frequently mentioned issues, factors and variables were then considered as the key factors underlying vulnerability. This matrix is presented in Table 5.1.

The issues or factors were ranked according to the number of times each one was mentioned as a factor underlying urban vulnerability. The issues were ranked from the most frequently mentioned to the least frequently mentioned. Table 5.2 details the first three groups of most frequently mentioned factors which consist of twelve factors.

Table 5.1: Vulnerability matrix developed for determining key indicators of urban vulnerability

CHARAC-TERISTICS	ISSUE/FACTOR/ INDICATOR/ KEY VARIABLE	CITED IN REFERENCES													
		Moser, 1998	ISDR, 2002	Amis, 1995	Rakodi, *et al.*, 2000	Winchester, 1992	Hardoy, *et al.*, 2001	Moser, 1995	UNEP, 2002	Wratten, 1995	Satterthwaite, 1999	Wisner, 1998	Coburn, *et al.*, 1994	Meuller, 1995	Count
HEALTH	Access to healthcare	X					X	X				X			4
	Incidence of disease	X												X	2
	Public health status (e.g. Handicapped)		X			X						X			3
	Infant mortality							X							1
	Levels of pollution													X	1
	Life expectancy													X	1
	Gini coefficient													X	1
EMPLOYMENT	Rate of unemployment	X		X	X					X			X		5
INCOME	Household income	X	X				X		X	X			X	X	7
	Per capita income							X	X	X					3
	Access to finance/credit	X	X					X	X						4
	Productive space	X													1
	Economic reserves		X				X		X	X					4
	Level of debt		X						X						2
	Access to land			X	X								X		3
	Skills					X									1
EDUCATION	Literacy level		X		X	X									3
	Drop-out rates							X							1

CHARAC-TERISTICS	ISSUE/FACTOR/ INDICATOR/ KEY VARIABLE	CITED IN REFERENCES													
		Moser, 1998	ISDR, 2002	Amis, 1995	Rakodi, *et al* 2000	Winchester, 1992	Hardoy, *et al.*, 2001	Moser, 1995	UNEP, 2002	Wratten 1995	Satterthwaite, 1999	Wisner, 1998	DMTP, 1994	Meuller, 1995	Count
HOUSEHOLD	Mean household age	X				X			X			X			4
	Number of children per household					X			X				X		3
	Number of women per household					X			X			X	X		4
	Percentage female headed household	X	X		X	X		X					X		6
	Percentage pension head	X			X	X		X					X		5
	Number of persons per house	X	X		X	X							X	X	6
	Divorce/ Bereavement				X										1
	Length of residency												X		1
SERVICES	Access to services	X	X					X		X				X	5
	Communication		X					X							2
	Water		X					X	X	X				X	5
	Sanitation/sewage		X					X		X				X	4
	Waste		X					X		X				X	4
	Communal child-care facilities	X						X							2
	Access to transport	X	X					X							3
HOUSING	Siting/location		X			X								X	3
	Remoteness		X											X	2
	Design		X											X	2
	Building materials		X											X	2
	Settlement type (formal/informal)	X													1

Table 5.2: Priority list of factors selected from literature review

Factors mentioned in 46% of literature sources
• Household income; • Female headed household; • Number of persons per household.
Factors mentioned in 39% of literature sources
• Pensionable headed household; • Access to services; • Access to safe water; • Rate of unemployment.
Factors mentioned in 31% of literature sources
• Access to healthcare; • Access to finances; • Economic reserves; • Mean household age; • Number of women per household.

Household income was the most frequently mentioned indicator of vulnerability and is being used world-wide in measuring poverty. Female-headed households and crowding issues are also very common issues that are recognised as characteristics or attributes of poverty and vulnerability at the household level. Level of basic services such as water and sanitation are also recognised as factors which may increase an individual's exposure to additional health hazards. These factors and others are described in more detail in a later section (section 5.2.5).

5.1.2 Selection of factors from the household survey in Cato Crest: "Data Sieve"

As explained in Chapter 4 (Methods and Approaches), a second set of vulnerability factors was derived from analysis of primary survey data taken from households in Cato Crest. The survey asked a number of questions related to household demographics (e.g. age, gender, income and employment), access to water, sanitation, waste management and energy services

as well as environmental pollution (particularly air and soil quality). The results of the surveys detailed the living conditions and key problems or issues that the household experiences. An example of living conditions and attributes of a household in Cato Crest have been given in Box 5.1.

Box 5.1: An example of vulnerability data derived from one household in Cato Crest

The household that has been used in this example shall be called Household CC1[1]. It consists of a 40 year old single mother of four children. Their ages are 3, 7, 13 and 17 years of age. The woman has a grade 5 level of education and works in the formal sector for R900 a month. This income equates to a per capita income of R180.00 per household member per month. The household members have been living in the area since 1991 and the family has been living in the same house for 12 years. They collect water from a yard tap and share a pit latrine with another family. They enjoy the services of waste collection once a week and do not pay for either their water or waste removal service. Some of the positive aspects about living in the area which were mentioned were, close proximity to the city, available water and close to transport. Some of the negative aspects included: no development, high crime rate, a lot of disease, sanitation problems and having to share facilities with neighbours. Like all of the households in Cato Crest, they do not have electricity and use kerosene for cooking.

A copy of the completed questionnaire has been given in Appendix 3.

The factors which underlie vulnerability in Cato Crest households were derived by subjectively reviewing and analysing answers to the questions in the survey. The emphasis of the review and analysis was on those conditions which contributed to making a household vulnerable to additional health hazards (i.e. additional exposures) as well as on those conditions which affected a household's mechanisms of coping with those hazards.

For example, the answers to the questions on *type of energy sources used* and *number of household members who sleep in the same room in which the cooking takes place* reveals a

[1] The household name has been changed in order to ensure confidentiality of the data

number of vulnerability factors. Firstly, if the chosen energy source is kerosene, it shows that this household either does not have an option of electrification or it lacks the income to pay for this service. Households who do not have an option of electrification are considered vulnerable in that are restricted to the use of unclean fuels which emit toxic pollutants into the indoor environment. If they lack the income to pay for electrification then this reveals that the household lacks the financial resources to access a desired living standard and exposes the household to air pollution. Furthermore, if all or a number of members sleep in the cooking area and they use kerosene for cooking, those members may be exposed to indoor air pollution for longer periods of time than those members of the household who vacate the room in which meals are cooked. The issues or factors which were then derived from this analysis were air pollution and crowding.

All of the factors derived from the data review are listed in Table 5.3. These are applicable to local living conditions in South African informal settlements and served to ground-truth the list of factors derived from literature sources.

Table 5.3: Factors underlying vulnerability in selected Cato Crest households

ISSUE/FACTOR	ISSUE/FACTOR
Crowding	Access to sanitation
Economic dependency	Access to waste disposal
Dependency on care	Energy
Gender	Air pollution
Education levels	Soil quality
Vocational status	Security
Household income	Building structure
Tenants	Time activities
Length of stay in area	Respiratory health
Attributes of the area lived in	Early motherhood
Access to water	Household responsibility level/ Children-headed household

Comparison of two sets of issues

The two lists of issues derived from both the literature sieve and the data sieve procedures have been displayed in Table 5.4. The list derived from the literature sieve represents a ranked

list of most frequently mentioned factors that were considered in over 30% of literature sources consulted.

Table 5.4: List of factors which underlie vulnerability that were derived from the first two selection sieves

List derived from literature sieve (already ranked)	List derived from data sieve (unranked)
Household income	Household income
Female headed household	Gender
Number of persons per household	Crowding
Pensionable headed household	Household responsibility level
Access to services	Access to water Access to sanitation Access to waste disposal Energy
Access to safe water	Reasonable access to water
Rate of unemployment	Vocational status
Access to healthcare	Respiratory health
Access to finances	Economic dependency
Economic reserves	Economic dependency
Mean household age	Household responsibility level/ Children-headed household
Number of women per household	Gender
	Dependency on care
	Education levels
	Tenants
	Length of stay in area
	Attributes of the area lived in
	Air pollution
	Soil quality
	Security
	Building structure
	Time activities
	Early motherhood

As can be seen from Table 5.4, when the two lists were compared, it was noted that all of the factors which were identified from the household data were also identified through the literature sieve. There were however, a number of important factors which were found to underlie vulnerability in South African settlements which were identified through the analysis of data from the Cato Crest household survey which were not identified as key factors in the majority of literature sources. These factors related to dependency on care, education levels, security, structure of the building and time activities. The inclusion of these factors was considered important as they provided a picture of urban vulnerability in the South African context. For example, some health risk assessments undertaken in South Africa have already recognised the unique time-activity patterns of South African populations and have included these into their assessments of risk (Muller, 2001). The results of these risk assessments show that local conditions and activities can affect the level of exposure of individuals to hazards and can negatively affect their health (Muller, 2001).

The two lists of vulnerability factors were amalgamated and a composite list of issues was derived. This list includes all of the factors listed in the two columns in Table 5.4 above regardless of their apparent contribution or lack of contribution to vulnerability to health impacts. Finding the linkages between factors underlying vulnerability and health was then considered necessary in order to determine their direct or indirect contribution to heightening risk of households to health impacts.

The next step in the selection process therefore involved subjecting the issues or factors (some of which were already indicators) to another selection procedure (sieve) which sifted out those factors which were associated with human health or were linked to human health either directly or indirectly. The question was asked: "How can this factor affect or contribute to human health?" A few South African environmental health studies were reviewed to determine which factors were considered in these assessments in assessing health and quality of life (Terblanche, *et al.,* 1992; Mathee and von Schirnding, 1996; Thomas, *et al.,* 1999 and Mathee, *et al.,* 2001). These studies were used to help judge the applicability of the factors and issues selected from the previous selection processes.

5.1.3 South African Environmental Health Studies and associated vulnerability factors: "Health Sieve"

A number of environmental health studies conducted within South Africa were reviewed. These studies examined the numerous health concerns related to living in low-income communities.

The studies were:

- Household Environment and Health in Port Elizabeth, South Africa (Thomas, *et al.*, 1999)
- Living Conditions and Environmental Health in the Cape Peninsula (Mathee and von Schirnding, 1996)
- Alexandra Environment and Health Study (Mathee, *et al.*, 2001)
- Vaal Triangle Air Pollution and Health Study (Terblanche, *et al.*, 1992)

An analysis of these studies served to inform the development of the vulnerability index by showing which environmental, social and economic factors were considered, recognised or measured in the health studies. The review served to either strengthen the decision to select certain vulnerability factors from the data collected, or it provided guidance on the exclusion of certain factors due to their unsuitability in providing information on heightened exposure to health risk.

*Household Environment and Health in Port Elizabeth, South Africa (*Thomas, *et al.*, 1999*).*

The Port Elizabeth Household Environment and Health study focused on the environment and health problems at the household level across the whole population of the city. The aim of the study was to examine and compare city-wide disparities and identify specific environment and health issues in Port Elizabeth as a representative of a Southern Hemisphere city. The study was conducted between 1997 and 1999 and was supported by funding from the Swedish International Development Cooperation Agency (Sida).

One of the studies commissioned within the project was the Port Elizabeth 1000 household Environment and Health Survey (Potgieter, *et al.,* 1999). The survey examined levels of wealth in relation to a range of environment and health factors. The factors which were selected were:

- Tertiary education;
- Lived in Port Elizabeth for more than 20 years;
- Access to piped water indoors;
- Indoor toilet;
- Rats/mice seen during past 24 hours;
- Electricity used for cooking;
- Zero household members who smoke inside the home;
- Dampness in the home;
- Problem with outdoor air pollution; and
- Land ownership.

The results of the broader Port Elizabeth study revealed that "the poor" appear to consistently suffer the greatest risk of exposure to hazards in the environment, and also bear the greatest burden of ill-health. The study illustrated the relationship between levels of poverty and a number of environmental, health and service factors. The main concerns of the poor were overcrowding, sanitation, littering and dumping which are concerns focusing on factors which directly impact on their living conditions (Thomas, *et al.,* 1999).

Housing issues in the Port Elizabeth study focused on overcrowding and in improving floor size. Thermal efficiency, ventilation and the use of materials for the protection from damp were recognized responses to housing and health-related problems. The health consequences of kerosene usage were also recognized and were perceived to contribute to ill health in the form of respiratory infections, skin and eye problems. Water issues which were examined in the study included reasonable access to water and the problems associated with communal tap use. Sanitation issues were experienced by the lower and low-income communities who did not have access to a sewered (flush) system. These issues included the inadequacy of the

bucket system, health implications associated with cockroaches and flies and overcrowding of toilets. Among the outdoor environmental issues were dumping and littering (Thomas, *et al.*, 1999).

Living Conditions and Environmental Health in the Cape Peninsula (Mathee and von Schirnding, 1996)

The Cape Peninsula study involved a study of living conditions and environmental health status in two informal settlements in Hout Bay and Noordhoek. A number of socio-demographic and environmental health factors were considered in the assessment. These included:

- Socio-demography – Age and gender, home language, employment status and income;
- Living conditions – housing, overcrowding, water storage, sanitation services, fuel usage, household pests and use of tobacco; and
- Health status – the community's perceptions of major household health problems and symptoms of ill-health.

The study concluded that one of the main factors which drove many of the residents to settle in these informal settlements was their need for employment. This is reflected by the predominance of young people in the age distribution. In estimating the crowding density, the study suggested that an alternative measure of crowding density should be used. A measure of overcrowding that has formerly been used is "number of persons per household", but this does not take into consideration the size of the house or dwelling. This has lead to the development of a more accurate measure of overcrowding which is "number of people per square metre" – a suggestion that has been taken into account in developing this vulnerability indicator set.

Respiratory conditions were perceived as the most important household health problem in both communities. Measurements which were used in the study to understand conditions contributing to respiratory problems included type of fuel used for cooking and heating, ventilation of the building and incidence of smoking.

Gastro-intestinal conditions were perceived as the second most important health problem in both communities. These health conditions were measured through determining the level of sanitation and water services, evidence of vectors such as flies and methods of water storage (Mathee and von Schirnding, 1996).

*Alexandra Environment and Health Study (*Mathee, *et al.*, 2001*)*

The Alexandra Environment and Health Study focused on describing the prevailing health concerns of the Alexandra township community in Greater Johannesburg. The study recognized the role of poverty and inequity in determining levels of environmental quality and of human health and well-being. A selection of health concerns were examined. Based on the information obtained, a selection of environment and health indicators for Alexandra was proposed. These indicators are presented in Table 5.5. These indicators have been used to inform the development of the vulnerability index in this study.

Table 5.5: Proposed environment and health indicators for Alexandra (Mathee, *et al.*, 2001)

CATEGORY	PROPOSED INDICATOR/S
AMBIENT AIR QUALITY	Levels of particulate matter (PM_{10}), sulphur dioxide, nitrogen dioxide and ozone in air
ACCESS TO SAFE WATER	Proportion of households with access to sufficient quantities of safe water
DISASTER EPISODES	Number of homes destroyed/number of people left homeless annually by fire Number of homes destroyed/number of people left homeless annually by floods
HOUSING	Proportion of people accommodated in informal or "unhealthy" housing
SAFETY & CRIME	Number of children/people injured in traffic events Number of cases of murder reported Number of cases of rape reported Number of cases of child abuse
SURFACE WATER QUALITY	Levels of coliforms in the Jukskei River at Alexandra
INDOOR AIR QUALITY	Levels of particulate matter in indoor air
SOCIO-ECONOMIC	Proportion of unemployed people Proportion of people without functional education
FOOD QUALITY	Proportion of food samples not meeting guidelines in annual surveys
HEALTH	Number of cases of diarrhoeal disease reported at Alexandra clinics/health centres annually Number of cases of acute respiratory infections reported at Alexandra clinics/health centres annually

CATEGORY	PROPOSED INDICATOR/S
	Proportion of people who smoke Proportion of people with tuberculosis Childhood blood lead levels
PUBLIC PERCEPTIONS	Public perceptions of the state of the environment in Alexandra Public perceptions of the prevalence of threats to health in Alexandra Annual noise complaints Levels of awareness amongst Alexandra residents of the links between the environment and health

The categories of indicators were inclusive of natural environment indicators, socio-economic and health indicators as well as indicators of external risks (disasters).

*Vaal Triangle Air Pollution Health study (*Terblanche, *et al.*, 1992*)*

The Vaal Triangle study consisted of a longitudinal health study of children ages 8-12 years. The study aimed to determine exposure levels and effects of indoor and outdoor air pollution within a number of racial groups within a number of communities in the area. Statistical analysis evaluated the contribution of environmental and socio-economic factors (such as age, gender and period of residence) to both upper and lower respiratory tract infections in the study population. These factors were categorized as:

- Home characteristics – language, socio-economic status (father's education level) and home type;
- Sources of indoor air pollution – heating fuels, cooking fuels, mould and mildew, pets in the home and parental smoking;
- Personal views – concerns about air pollution, sources of air pollution, odour complaints, and air pollution health effects (Terblanche, *et al.*, 1992).

This study contributes to the process of selecting vulnerability factors by highlighting the socio-economic variables which are in some way related to respiratory tract infections. This study revealed much about personal exposures to air pollution and the potential health risks involved with these exposures. For example, the study observed higher levels of personal exposure to suspended particulates in children living in coal-burning townships. The use of coal has been identified as the single most significant risk factor for respiratory tract illnesses

in children living in coal-burning townships. Children living in electrified homes had a 9.3 times lower risk of developing upper respiratory illnesses than those children living in non-electrified homes (Terblanche, *et al.,* 1992). Children living with smokers were also shown to have been exposed to high levels of particulates which are the cause of upper respiratory tract infections.

Vulnerability factors associated with ill-health in South African low-income households

All four of the studies reviewed reflected the conditions of informal settlements and highlighted some of the common environmental factors which are relevant to measuring health. Table 5.6 details a complete list of issues and factors that was derived from all four of the health studies.

These studies have contributed to the vulnerability index development process by indicating a number of health-related factors which should be considered when evaluating the cumulative health risks to low-income communities who are being exposed to air pollution. For example, the presence or absence of damp or mildew can have serious negative effects on a sensitive individual's health. People with asthma are particularly sensitive to biological irritants and can experience a difficulty in breathing when exposed. Moulds that grow in moist areas of the home, produce allergens (substances that can cause allergic reactions), irritants and in some cases toxic substances (mycotoxins) (USEPA, 2002a) which can cause asthma attacks in people who are asthmatic and allergic to mould. If levels of indoor air pollution are high due to the use of kerosene or other polluting fuels, then the compounding influence of moulds and mildew may be a significant contributor to respiratory health effects.

This review has shown that access to safe water, the provision of adequate sanitation facilities, the presence of household pests, overcrowding and indoor air quality are important factors to consider when conducting environmental health assessments in low-income households. The review also suggests that these factors are important inclusions in a vulnerability index which aims to evaluate the compounding influence of factors on health and confirms the choices made in the previous two selection procedures.

Table 5.6: Issues and factors which were considered in each health study

STUDY	FACTORS AND HEALTH CONCERNS	STUDY	FACTORS AND HEALTH CONCERNS
Household Environment and Health in Port Elizabeth	Income Tertiary education Number of years in area Access to piped water indoors Indoor toilet Rats/mice seen during past 24 hours Electricity used for cooking Energy sources (kerosene usage) Household members who smoke indoors Dampness in the home Problem with outdoor air pollution Land ownership Waste disposal Overcrowding Building structure	Living Conditions and Environmental Health in the Cape Peninsula	Age Gender Home language Employment status Income Housing Overcrowding Water storage Sanitation services Fuel usage Household pests Use of tobacco Household health problems (symptoms of ill-health)
Alexandra Environment and Health Study	Ambient air quality Access to safe water Disaster episodes Housing Safety & crime Surface water quality Indoor air quality Socio-economic status Food quality Health Public perceptions	Vaal Triangle Air Pollution and Health Study	Language Socio-economic status (father's education level) Home type Heating and cooking fuels Mould and mildew Pets in the home Parental smoking Perceptions and concerns about air pollution Odour complaints Air pollution health effects

5.1.4 Composite list of issues and factors

Once all of the issues and factors had been identified from the literature, from the ground-truthing exercise with data collected from Cato Crest households, and from the review of selected South African health studies, a composite list of issues and factors that were considered relevant to South African low-income community health risk assessments was created. These issues and factors are tabulated in Table 5.7. This list provided the key issues and factors that were drawn from all three sieves.

When compiling the composite list from the three selection procedures, there were a number of identical factors which were identified. These have been included in the list (e.g. age, income, overcrowding and access to services). There were, however, a number of other factors which had been identified which were excluded from this complete list as they were considered inappropriate as vulnerability factors. These factors are: Home language, length of stay in area, disaster episodes, security, household pests, outdoor air pollution, tenants, soil quality and early motherhood.

Table 5.7: List of vulnerability factors derived from three selection procedures (literature sieve, data sieve and health sieve)

Complete list of issues derived from literature, data and health sieves	
Age (Household responsibility level/ pensionable or children-headed households)	Access to waste disposal
Gender	Energy
Vocational status/employment	Building structure
Household income	Dampness/ mould and mildew
Economic dependency	Smoking indoors
Education levels	Household health problems (symptoms of ill-health)
Crowding	Food quality
Land ownership	Indoor air pollution
Access to water	Respiratory health/access to healthcare
Quality of water	Dependency on care
Access to sanitation	Attributes of the area lived in
	Time activities

The complete list of issues was then subjected to the indicator sieve in the selection methodology which served to translate each of the selected factors into state indicators which could be used to measure vulnerability at the household level.

The next section provides some background on the definition and purpose of indicators and establishes an indicator framework which was used to organise and arrange the indicators within the vulnerability index.

5.2 INDICATORS OF VULNERABILITY

5.2.1 Indicators and Measures

An indicator can be defined as a measurement tool for assessing change in the environment. It acts as an early warning system for potentially destructive changes that may occur in the environment (INR, 2002). Indicators are used to organise and synthesise information about complex systems, allowing us to communicate something meaningful about that system. In the context of this study, indicators are defined as "tools for measuring a particular aspect of a household at a given point in time".

According to literature on urban vulnerability (Coetzee, 2002), a household's vulnerability is not fixed and may change significantly over time due to the influences of a broad range of factors. The vulnerability indicators developed for this vulnerability index are therefore state indicators which, when measured, will provide a "snap-shot" of the level of vulnerability of a household at a particular time.

In order for identified issues/ aspects or factors to be translated into indicators of vulnerability, they were subjected to a number of indicator and measurement criteria so that appropriate measurement tools could be identified which would allow vulnerability to be measured. The purpose of transforming factors of vulnerability into indicators and measures is to allow for the generation of accurate and appropriate information on the physical, social and economic state of low-income households. Particularly, the indicators and measures can be used to

identify and define some of the compounding stressors that have either a direct or indirect bearing on human health.

Measures have been identified for each indicator as they assist in providing a detailed description of the specific aspect to be measured (INR, 2002). It must be noted that there are some indicators which require more than one measure to enable the indicator to provide an accurate picture of the issue to be evaluated. The indicators and measures defined in this study are applicable at the household level.

5.2.2 Indicator frameworks

A framework for organising the selection and development of indicators is essential. Although it can be used to organise the indicators, it was recognised that an indicator framework cannot adequately express the complexities and interrelationships between systems. Indicator frameworks are useful for:

- guiding the data and information collection process;
- suggesting a logical grouping of related information;
- promoting interpretation and integration; and
- helping identify data collection needs and data gaps (DACE, 2002).

Vulnerability is a complex and multi-faceted phenomena which is influenced and moulded by numerous underlying factors and conditions. The development of a vulnerability index is therefore necessary to provide a framework for the presentation and the aggregation of a wide range of information on different vulnerability phenomena.

The indicator framework that was developed in this study was generated by logically and systematically grouping the issues and factors identified through the four-tiered approach described thus far into six broad themes. The issues and factors which were used to generate the themes have been listed in Table 5.7.

The themes are aggregated into a vulnerability index, depicted as:

$$Vi = D + L + P + E + A + H$$

Where:

Vi = represents a composite measure of vulnerability in low-income households

D = Demographic indicators of gender and age

L = Livelihood indicators (measurements of income, employment, dependencies and education)

P = Physical exposures of overcrowding, air pollution and waste

E = Externalities such as building materials

A = Access to services of water and sanitation

H = General health problems associated with food and nutrition and other diseases

The vulnerability index provided a strong framework for the identification of appropriate indicators within each theme. Once a group of indicators had been identified within each theme, possible measures for each indicator were then selected.

5.2.3 Indicator criteria

In order to translate issues and factors into indicators and measures of vulnerability it was necessary to select suitability criteria which were to be used for selecting appropriate indicators. Suitability criteria (or selection criteria) are criteria which should be met in order for the selected indicators to be appropriate, reliable and effective.

Criteria were selected from an environmental health study (Mathee, *et al.,* 1999), the National Environmental Indicators Programme (DEAT, 2002) and a sustainability indicator training manual (Oelofse and James, 2001). Suitability criteria used for selecting appropriate vulnerability indicators and measures for low-income households were chosen from these three sources. These are presented in Table 5.8 below.

Table 5.8: Criteria for the selection of vulnerability indicators and measures identified for this study

An appropriate measure should be relevant in that is must:

- Be based on a known linkage between the environment and health
- Be related to environment and/or health conditions which are amenable to control
- Sensitive to changes in the condition of interest
- Provide information that measures something that is important to the risk assessor or decision maker

The indicator should:

- Be based on good quality data available at an acceptable cost-benefit ratio
- Be simple, easy to interpret and reflect changes over time
- Be measurable
- Be based on data that is easy to collect, accessible, and affordable
- Acceptable to stakeholders
- Available soon after the event or period to which it relates
- Based on data of correct spatial and temporal extent
- Scientifically accurate, credible and unbiased
- Based on data of a known and acceptable quality
- Robust and unaffected by minor changes in methodology/scale used for their construction

(Adapted from Mathee, *et al.,* 1999; Oelofse and James, 2001 and DEAT, 2002)

5.2.4 Selection of appropriate indicators and measures

Each of the issues and factors identified through the selection procedures, and tabulated in Table 5.7, have been grouped into an appropriate theme. Thereafter a number of indicators and measures were chosen to represent the key factors and provide a mechanism for the measurement of these factors within a vulnerability index.

The list of indicators and measures which met the suitability criteria are listed in Table 5.9.

Table 5.9: Key themes, indicators and measures

	THEME	INDICATOR	MEASURES (Environmental, social & economic)
1	Demographics	Gender	Ratio of males to females per household Gender of household head Percentage of males older than 18yrs per household
		Age	Age of household head Average age of household
2	Livelihoods	Unemployment rate	Percentage unemployed of employable age (>18yrs)
		Income distribution and dependency	Monthly household income Per capita income Percentage of household contributing to HH income
		Dependency on care	Ratio of adults to dependents (Ratio of children >15yrs:<15yrs) Number children under 15yrs who do not go to school
		Levels of education	Percentage of household achieving grade 10 (of potential age)
3	Physical exposures	Overcrowding	Number of people per square metre Number people per household
		Air pollution	Percentage of household sleeping in cooking area Percentage windows which open
		Waste	Frequency of removal Cost of service
4	Externalities	Building materials	Presence of damp Type of materials
5	Services	Access to water supply	Number litres accessed per day Proximity to source Reliability Cost of service
		Quality of water	Potability
		Sanitation services	Type of toilet Private or shared facilities Odour problems Cost of service
6	General health	Food and nutrition	Percentage of nutritional problems recorded at clinic
		Other diseases	Number of household members with pre-existing respiratory problems Prevalence of HIV/AIDS in the community/area Prevalence of TB in the community/area Prevalence of communicable diseases in the community

5.2.5 Description of indicators and how they can be used to measure vulnerability

This section describes each of the vulnerability themes, indicators and the 34 measures used to measure them. It provides support and substantiation for each of the themes, indicators and measures selected as components of the urban vulnerability index. Literature sources, which guided the development of the theoretical framework, as well as data from Cato Crest household surveys, were used to provide evidence of vulnerability and the applicability of each indicator chosen.

Demographics

Gender and age have been used as instruments for the indication of vulnerability in low-income households. These two aspects of a community's demography are significant indicators of vulnerability as they are known to influence a household's access to resources and health.

According to the World Health Organisation (WHO, 2002), the oppressed position of women in poverty leads to poorer health in many ways including a weak position in ensuring safer sex practices. Social exclusion and vulnerability in South Africa follow gender and racial lines with certain groups of the population (such as rural people, women and the youth) being more vulnerable to social exclusion than others (Department of Social Development, 2000). The HIV/AIDS statistics for Durban confirms this trend in that the highest prevalence of HIV/AIDS within the age group 15 to 35 years is for females, indicating that females in this age group are more vulnerable to infection (Smith, 2001). This is discussed in more detail at the end of this section.

Rakodi, *et al* (2000, p 156) found that "women household heads were thought to be vulnerable because they have in the past, had poorer access to education and have as a result lower literacy rates. They own limited productive assets, especially land and have limited access to credit than men. Furthermore they tend to be ignorant of their rights and thus exploited and discriminated against in economic activities". Women are therefore more vulnerable in that they may be less likely to access the resources needed to feed, clothe and care for their household.

Although not directly related to environmental health or to health associated with air pollution, the presence of adult males in the household may contribute to a sense of safety by household members. Conversely, the absence of males, especially in areas where there is civil unrest or violence, may contribute to a household's insecurity which may in turn affect their sense of well-being or contribute to their anxiety and mental stress. Vulnerability due to gender is to be determined through the measures *ratio of males to females per household; gender of household head;* and *percentage of males older than 18 years per household.*

Gender is a very visible issue in Cato Crest with 42% of the surveyed households run by female heads. It was noted that those households which were headed by females contained other siblings and a number of dependent children, while some male headed households had fewer dependents and more household income.

According to Rakodi, *et al* (2000, p 156), young people in low income groups have been described as "helpless, frustrated and dangerous" due to the fact that they lack practical training necessary to secure employment. Other areas of deficiency include the lack of exposure to the world of work and business, access to credit, information on employment and where to go for assistance. The age profile of households is an important element to consider when measuring vulnerability in that it provides a measure of the potential for the household to access employment and therefore sufficient income to sustain the livelihoods of each household member. Households made up of young members may lack the earning opportunities due to lack of skills and training, inability to access credit, lack of respect in the community due to their age and therefore inability to access community assistance networks, or they may be ignorant of the dangers of certain environmental and household health hazards such as indoor air pollution.

Households with many young children are also more dependent on others for care and may prevent a caregiver from being involved in economic activities which will generate an income necessary to pull the household out of a state of poverty.

The two measurements used to provide an age profile of each household are *age of household head* and *average age of household.* In Cato Crest the mean age of households is 28 years of age with 15% of households run by pensioners (people over 60 years of age).

Livelihoods

The issue of livelihood can be measured through the use of the indicators of employment, income, dependency on care and education.

Unemployment

According to poverty and vulnerability literature (Coburn, *et al.,* 1994; Amis, 1995; Wratten, 1995; Moser, 1998 and Rakodi, *et al.,* 2000), rates of unemployment are important determinants of urban poverty and vulnerability. Employment status can be associated with an increase in health problems by affecting the level of exposure of adults, children and infants to indoor air pollution in their homes.

Unemployment and the subsequent lack of income may restrict a household from using electrification as their energy source. This would therefore force the household to use an alternative fuel such as kerosene which emits toxic pollutants into the indoor air environment. Furthermore, unemployment may result in an individual spending an extended period of time in the home as opposed to the work environment where indoor air pollution may not be such a hazard. Unemployment and lack of income can also prevent a household from accessing the required foods and nutrients for maintaining a health body.

Another negative health effect of unemployment is the increase of HIV infection. According to Zawaira (1999), one of the root causes of HIV/AIDS is associated with rising unemployment.

The employment status of the household is determined through the measurement of the *number of household members over 18 years of age who are unemployed* (expressed as a percentage).

Income

Income distribution is an indicator of vulnerability which can be measured using three measures, namely *monthly household income, per capita income* and *number of people contributing to household income.*

Monthly household income provides an indication of the potential of the household to maintain a certain standard of living. The average household income in Cato Crest was R2068.00 per

month. The extent of income poverty in this area is high and this indicator provides an indication of the lack of income at the household level.

Per capita income describes the income generated per household as a ratio of the number of people in the household. It is calculated by dividing the total monthly household income by the number of adult equivalents resident in a particular household. Children are considered to be half an adult in terms of income consumption. This indicator provides an idea of the amount of income generated by each household and the pressure of human resources on this income. In Cato Crest, only half the number of households maintains a per capita income above the poverty line which is set at R476.30 per capita (Vermaak, *et al.,* 2001). The other 50% of households do not maintain a standard of income above the per capita poverty line.

Economic dependency is regarded by the traditional poverty experts as the highest measure of poverty. This indicator can be measured by calculating *the percentage of people contributing to household income* and provides a measure of the pressure placed in individuals in bringing home the income needed to sustain their livelihoods.

Dependency on care

The issue around *dependency on care* arose through the identification of a number of young children in the household who were not at school. While questions on child care were not asked in the study, it is expected that these children were dependent on another family member, child carer or friend to care for them. This creates a large burden on the potential earner who should be freed to pursue economic activities. Two measures can be used to provide an indication of the level of dependency on care. These are:

- *Ratio of adults to dependents (i.e. ratio of household members older than 15 years to ratio of children under 15 years of age) and;*
- *Number of children under 15 years of age who don't attend school.*

Education

According to the World Health Organisation (2002), lack of education limits the ability of the poor to identify and take appropriate action to improve their own health and secure their basic

needs. Education, both formal and informal, is regarded as a process by which human beings and societies can reach their full potential (UN, 1995) and is a critical element in meeting basic human needs.

Education at the household level is measured by calculating the ratio of people reaching grade 12 to the number of people of potential age (17 years and over). This gives an indication of the potential for individuals to enter the formal employment sector based on a recognized level of education.

In the informal areas of Cato Manor less than a fifth (18.3%) of the economically active age group completed grade 12, in comparison to a third (32.8%) in the formal areas.

Physical exposures

The issues relating to overcrowding, air pollution and waste have been grouped within the theme of physical exposures.

Overcrowding

Over-crowding is responsible for unsanitary conditions and allows for the prolific spread of disease. Both poor ventilation and inadequate sized housing helps in the transmission of disease such as tuberculosis, influenza and meningitis. Risks of household accidents may increase and the burden to safeguard children from fires and stoves becomes greater (Hardoy, *et al.*, 2001). Overcrowding has also been recognised as an influence on quality of life. The Port Elizabeth household environment and health report recorded crowding as one of the major reasons for dissatisfaction with housing conditions (Thomas, *et al.,* 1999).

Overcrowding is determined through measuring *number of people per household* and *number of people per square metre.* The majority of houses in informal settlements consist of only one small room, making for very crowded conditions.

Crowding was one of the first issues to be identified in the household survey in Cato Crest. Eighteen percent of households consist of more than 5 members per house with the average

household size being 3.69 members (Vermaak, *et al.*, 2001). This is high considering that a high proportion of houses consist of only one room.

Air Pollution

People living in unserviced settlements are exposed to environmental hazards such as air pollution and respiratory infections. Apart from not having the option of electrification as an energy source, informal households lack the income to pay for electricity or other "cleaner" energy sources and have to rely on "dirty" fuels. In addition, the lack of an electricity supply has also encouraged people to make illegal electricity connections – many of which are installed incorrectly and are a source of risk.

Lack of a clean energy source in Cato Crest has resulted in the community utilising kerosene for cooking purposes, thereby exposing themselves to dangerous gaseous compounds that are known to be associated with detrimental health effects. Poorly designed stoves and smoky fuels further exacerbate the problem.

One of the dangerous pollutants which arises from kerosene combustion, nitrogen dioxide, has been shown to be associated with increased susceptibility to respiratory infection (Goings, *et al.*, 1989; WHO, 1997 and Becker and Soukup, 1999, cited in Law, 1999). Children and infants, and adults to a lesser degree, become more susceptible to viral and bacterial attack through inhalation and therefore have an increased incidence of both viral and bacterial diseases (Law, 1999)

This study is interested in understanding the compounding impact of urban poverty on the current risks imposed on individuals from indoor air pollution. Apart from overcrowding leading to poor ventilation, the measure: *percentage of household sleeping in cooking area* is a measure of the percentage of the household who may be exposed to indoor air pollution for longer periods of time than those members of the household who vacate the room in which meals are cooked. In a health risk assessment, exposure periods have been factored into the risk calculation and are therefore represented in the measurement of risk to chemical hazards.

The measure *percentage of windows which open* is a measure of the degree to which indoor air pollution may be dissipated or contained within the house. The longer the air pollution remains in the house, the longer the exposure period will be. This too has been factored into health risk calculations.

Waste

Unsanitary conditions encourage the proliferation of disease. Waterlogged soil from waste water is ideal to transmit diseases like hookworm and is a breeding ground for mosquitoes. Burning and dumping problems in informal settlements seem to be related to the lack of adequate waste removal services (Thomas, *et al.*, 1999). People living in unserviced settlements are exposed to disease-carrying vectors such as rats, mice and flies which proliferate in uncollected waste and refuse. The diseases associated with these conditions affect a person's immunity which may in turn lead to an increase in susceptibility to indoor air pollution or other environmental health hazards.

Two measures which are used to indicate access to waste services and the potential risk of exposure to unsanitary conditions are *frequency of removal* and *cost of service.*

Frequency of removal indicates the potential for uncollected waste to lie around and be spread by dogs and other scavengers. *Cost of service* provides a measure of the cost of the service to users and may imply a restriction to the use of the service should costs be high.

Externalities

Low-income communities are exposed to a variety of hazards which arise from both the type of building structure they live in as well as the location of the house.

Building materials

Building materials contribute to water leakages, development of mould leading to poor respiratory health and allergic responses, and the lack of windows (or small windows) leads to poor ventilation which prevents harmful pollutants from being dispersed. Two conditions that are essential to support biological growth (such as moulds and fungi) are nutrients and

moisture. Rising damp from unsealed walls and poorly constructed roofs are significant causes of damp in informal dwellings and provide a suitable substrate for mould growth.

There is a close link between damp and mould in homes and health conditions. Respiratory problems and other symptoms suggestive of infections and stress have been found to be more common in children in damp dwellings (Thomas, *et al.,* 1999).

The measures that were used to describe the potential health hazards arising from the building structure include:

- *Presence or absence of damp; and*
- *Type of materials used (brick, wood, mud, plastic, asbestos, etc).*

Location of dwelling

According to the United Nations (UN, 1995), poor living conditions are associated with poverty, homelessness, poor health, social exclusion, family instability and insecurity, violence, environmental degradation, and increased vulnerability to disasters.

Apart from household building materials, informal settlements are characterised by high-risk locations, and are often found on marginalised areas. The lack of facilities associated with these informal settlements compound the risk to environmental hazards and prevent the community from gaining access to knowledge (through the provision of libraries and information centres), and prevent the development of a sense of community through the provision of meeting places for formal and informal gatherings.

Marginalised sites can be associated with those located in high-risk locations such as next to hazardous waste sites, industrial areas or quarries. The descriptive measure *location of dwelling* has been selected for depicting potential hazards associated with the location of the dwelling.

Services

The lack of services in low-income communities can contribute to environmental degradation and exposure of individuals to a variety of health hazards. Access to and quality of water services as well as sanitation services have been considered in this indicator framework. The vulnerability measures associated with the lack of energy services have been covered by providing measures for air pollution.

Access to water supply

Water contaminated by sewage may expose users to a wide range of diseases such as cholera or typhoid. Infants and children are particularly vulnerable to ill-health and death from the consumption and the use of contaminated water (Hardoy, *et al.*, 2001). Apart from the risk of infectious water-borne diseases, standing water around standpipes can allow proliferation of mosquitoes. Storage and handling of water for drinking, personal and hygiene purposes is also a health concern.

The definition of a basic water supply has been given in the draft White Paper on Water Services (DWAF, 2002). According to the White Paper, a minimum of 25 litres potable water per person per day is required for a basic supply. The source should be within 200m of the house and should not be interrupted for more than 7 days per year. The supply should provide a minimum flow of 10 litres per minute (at communal water points) and should pose no health risks to the users (DWAF, 2002). Furthermore the White Paper proposes that a basic water supply should provide for appropriate education in respect of effective water use.

The measures that have been proposed to indicate access to water services have been derived from the definition contained in the White Paper. They are:

- *Number of litres accessed per day* – which indicates whether an acceptable volume of water can be accessed to provide a basic supply;
- *Proximity to source* – which will determine whether the water source is easily accessible;
- *Reliability* – a qualitative measure of interruption of the supply; and
- *Cost of service* – which indicates whether the service is paid for or not.

These measures are not all quantitative measures. Reliability is a subjective measure which is determined through questioning users of their perception of the reliability of the service. In the Cato Crest survey, many users described the service as "sometimes scarce" suggesting that their water service is occasionally unreliable.

Water quality

Water quality is determined through measuring the *potability of the water supply*. Potability can be determined either through a quantitative measure of the chemical and microbiological quality of the water or through the more subjective questioning of water users of their perception of the water quality.

In Cato Crest, there are no households who collect water from rivers or streams. They all have access to water from piped sources. However, contamination of water supplies is a particular problem in areas where sanitation facilities, waste disposal services and wastewater removal systems are absent (Mathee, *et al.,* 1999).

Only 32% of households in Cato Crest have access to piped water inside their dwellings, while the remaining 68% of households access water from yard taps, a water carrier or public tap. Water cuts and the slow flow of water on some days may be insufficient to protect health (Mathee, *et al.,* 1999). The WHO has recognised the need for an individual water supply to be installed so that poor urban communities may increase their water usage to levels adequate for health protection (WHO, 1992, cited in Mathee, *et al.,* 1999).

Sanitation services

Lack of adequate sanitation may expose communities to water-borne diseases such as cholera or typhoid (Hardoy, *et al.,* 2001). Access to sanitation has been used as a good universal indicator of human development (UN, 1995). Access to adequate, reliable and safe sanitation services is one of the eight elements of primary health care and is therefore a significant indicator of potential risk of disease

In South Africa, a basic sanitation service has been defined in the draft White Paper on Water Services (DWAF, 2002). A basic sanitation service should provide for the appropriate health and hygiene education necessary, it should provide toilets acceptable to end users, be safe, reliable, environmentally sound, easy to clean, private, protected against weather, well-ventilated, low in odour and prevent flies and other disease carrying pests (DWAF, 2002).

The measures that have been selected to indicate the provision of a basic sanitation service for low-income communities are:

- *Type of toilet* – the options are a flush system, ventilated pit latrine, other pit latrine or bucket system;
- *Private or shared facilities* - indicating privacy and potential for overuse;
- *Odour problems* – which indicate unpleasant living conditions; and
- *Cost of service* – which indicates whether the service is paid for or not.

In Cato Crest, 91% of households have access to "other pit latrines" as their sanitation service. Forty-nine percent of these households have to share their pit latrines with neighbours. If the average household size is close to 4 individuals per house, then 49 % of individuals could have to share their facilities with another 7 people. Only 51% of households have the privacy of their own sanitation facilities.

Some survey questionnaires have noted the problem associated with odours from pit latrines which add to their discontentment with living in the area. Cato Crest residents do not pay for their sanitation service, indicating that the service is affordable.

General Health

Apart from the selected indicators above, there are other important social and economic issues which households are faced with. These issues include food and nutritional deficiencies, incidence of respiratory disease, prevalence of HIV/AIDS and other communicable diseases.

Nutritional deficiencies

Moser (1995) includes an individual's access to adequate nutrients and health care as one of the important determinants of well-being. The body's defense mechanisms rely on an adequate supply of vitamins and minerals which are the basic building blocks of a healthy body. Good nutrition can improve a person's immune system while poor nutrition undermines the immune system increasing the risk of infection.

Low-income communities often lack the resources to purchase or grow the necessary spectrum of foods which will provide the household with a well-balanced diet. Nutritional deficiencies and the inadequate intake of certain micronutrients can lead to malnutrition and the lowering of resistance to certain diseases (Rios, *et al.*, 1993). For example, studies have shown that people with a vitamin C deficiency may be more susceptible to impaired air quality, as vitamin C inhibits the oxidation reactions of nitrogen dioxide (NO_2) in the body (WHO, 1998, cited in Oosthuizen and John, 2002). Long-term malnutrition has also been shown to increase susceptibility of the developmental effects of toluene (ATSDR, 2000a, cited in Oosthuizen and John, 2002).

There are many more examples of malnutrition and susceptibility to diseases which are not mentioned in this study. However, there is conclusive scientific evidence to show that nutritional deficiencies can influence the body's defense mechanisms and result in a greater burden of disease (Chase, *et al.*, 1980; Looker, *et al.*, 1989; Moss, *et al.*, 1989, cited in Rios, *et al.*, 1993).

It is difficult to determine malnutrition or nutrient deficiencies at the household level due to difficulties in measurement and lack of data. It may therefore be more appropriate to measure nutritional deficiencies at the community level by accessing clinic records. Nutritional complaints recorded at the Ekhuphileni Clinic in Cato Manor in 2000 amounted to 3.8% of problems recorded (Thomas, 2001). It is therefore suggested that an appropriate indicator of possible nutritional deficiencies would be *percentage of nutritional problems recorded at clinic.* Although this figure does not seem high in Cato Manor, it may be that the

consequential effects of nutrient deficiencies (i.e. a higher incidence of disease) are being recorded and out-weigh the measure of nutritional deficiencies.

Respiratory health

People with pre-existing chronic respiratory problems are more susceptible to exposure to NO_2 and other respiratory toxicants. Studies have shown that NO_2 can increase susceptibility to respiratory infection making children and infants in particular, more susceptible to viral and bacterial attack through inhalation, causing an increased incidence of both viral and bacterial diseases (Goings, *et al.*, 1989; WHO, 1997 and Becker and Soukup, 1999, cited in Law, 1999).

For example, tuberculosis impairs the ability of the lung to eliminate particulates and the air borne toxicants which bind to particulate surfaces. This condition therefore increases a tuberculosis sufferer's susceptibility to lower levels of air pollution (Rios, *et al.,* 1993).

It is suggested that susceptibility to exposure to other respiratory toxicants can be measured at the household level through calculating the *number of household members with pre-existing respiratory problems.*

HIV/AIDS

The burden of HIV/AIDS is heavy on low-income households. It is recognized as a driver of vulnerability (in that it affects a person's defense mechanisms) and as a consequence of vulnerability (in that HIV infection and the onset of AIDS is perpetuated by a variety of physical, social and economic determinants of low-income livelihoods) (Zawaira, 1999).

Like many threats in developing countries, the root causes of HIV/AIDS are associated with conditions of poverty, illiteracy, and rising unemployment (Zawaira, 1999). HIV/AIDS is a key contributing factor to social vulnerability at both household as well as macroeconomic levels, increasing susceptibility to natural and other threats (Zawaira, 1999). It is suspected that NO_2 exposure of HIV infected individuals could lead to acceleration of the AIDS

epidemic through earlier onset of the disease and earlier susceptibility to viral and bacterial infection.

Studies have shown that the onset of AIDS in an HIV positive individual can be accelerated by exposure to high levels of nitrogen dioxide arising from combustion of fuels such as kerosene (Law, 1999). Studies have shown significant reductions in the number of natural killer (NK) cells and cytotoxic T lymphocyte cells after NO_2 exposure. The cytotoxic T lymphocyte (CD8+) is responsible for the suppression of viral replication, in particular HIV replication (Kundu and Merigan, 1991; Hsueh, *et al.*, 1994; Famularo, *et al.*, 1997; Rosok, *et al.*, 1997, and Stranford, *et al.*, 1999, cited in Law, 1999). It is suspected that this could lead to a more rapid onset of HIV/AIDS through more rapid conversion from an asymptomatic to symptomatic stage in NO_2 exposed infected individuals as viral replication is not restricted (Law, 1999).

HIV/AIDS has numerous impacts on the health and quality of life of individuals, families, households and communities and is an important but often unrecognised driver of socio-economic risk (Zawaira, 1999), placing a large demand on financial and institutional resources.

Some of the impacts of HIV/AIDS are mentioned here:

- Lowered life expectancy - AIDS has an impact on life expectancy. In Zimbabwe, the AIDS pandemic has lowered life expectancy from 71 years to 41 years (Zawaira, 1999). In South Africa, the predicted life expectancy for 1994 and 2000 has decreased from 59 years to 48 years (World Bank, 2002). There are numerous social and economic implications of lowered life expectancy.

- Dependency on care for sick individuals – The social burden and economic stress of caring for sick individuals are great and are even greater in households which lack the financial resources to provide adequate health care.

- Dependency on care for infants and children – HIV/AIDS has left hundreds of infants and children without mothers and fathers. The burden placed on other family members

(particularly older children and the elderly) have social and economic consequences. The results are a number of children and pensioner-headed households.

- Increased social stigma associated with the knowledge of HIV status.

- Vulnerability of women to the disease – As primary caretakers of sick family members, women face a stronger likelihood of exposure to infected body fluids, increasing their own risk of infection (Zawaira, 1999).

- Vulnerability of individuals to respiratory disease - Immuno-compromised individuals may be more susceptible to respiratory irritants and toxicants and therefore more likely to develop health effects than healthy individuals.

- The increased number of sick members in the household exposes members to more diseases and therefore produces a higher loading of disease in the home which in turn may lead to an increased susceptibility to indoor air pollution.

HIV/AIDS is a very important determinant and consequence of vulnerability and has been vastly researched. In Cato Manor, HIV/AIDS statistics show that HIV prevalence has increased from 41.4% in 1999 to 45.3% in 2000 with the highest prevalence in the 20 to 29 year age group (Smith, 2001).

The measure that has been selected to describe HIV/AIDS as an underlying factor of vulnerability is *prevalence of HIV/AIDS in the community.* The success of this measure is obviously determined by the availability of the sensitive information on HIV status in the community.

Other communicable diseases

Individuals with pre-existing diseases are more susceptible to additional hazards that they may be exposed to. Furthermore, vulnerable communities often do not have access to vaccines and anti-bacterial drugs which make them more vulnerable to infection as well as increasing the

length of recovery from an existing illness. For the purpose of this study, the prevalence of tuberculosis and diarrhoea have been chosen to represent the potential pressures that may exist in households exposed to additional environmental hazards such as indoor air pollution.
According to the South African Health Review (HST, 1996), tuberculosis (TB) is the most frequently notified disease in South Africa and is rising with the proliferation of HIV/AIDS. A strong correlation exists between the presence of HIV/AIDS and the presence of TB in individuals. Distribution of TB in South Africa indicates strong geographical and racial disparities being influenced strongly by socio-economic status (DACE, 2003). *Prevalence of TB in the community* is therefore an important indicator of vulnerability and well-being as it provides not only an indication of health status, but provides a link with socio-economic status.

Diarrhoea is a symptom of infection from a variety of water-borne diseases caused by a number of microorganisms affecting the intestinal tract. It is caused by ingestion of food or water contaminated with faecal waste containing disease-causing organisms. The incidence of diarrhoea has been associated with unserviced households which are reliant on untreated water sources.

The measure used to describe the incidence of diarrhoeal diseases at the household level is *evidence of diarrhoeal diseases in the household* and *prevalence of communicable disease in the community* is used to measure vulnerability at the community level.

5.2.6 Conclusion: Indicators of vulnerability

The list of indicators that have been described in the above section all have a direct or indirect influence on the levels of vulnerability of low-income households to health hazards and have been selected on this basis.

As discussed previously, the indicators were decided upon after consideration and review of the following:

- Appropriate literature on factors of vulnerability;

- Ground-truthing these factors with data collected from a low-income community through household surveys; and
- Review of health and environment studies in low-income communities in South Africa.

The resultant vulnerability indicator set has been grouped into 6 themes or areas of focus covering demographics, livelihoods, physical exposures, externalities, access to services and general health.

It must also be stressed that the indicator set has been developed to determine the compounding influence of vulnerability and therefore heightened risk to households that are being exposed to toxic pollutants in the indoor environment. It is not just an indicator set which measures poverty or "income-based vulnerability", but the indicators have been selected on the basis of the links between vulnerability factors and air pollution health effects.

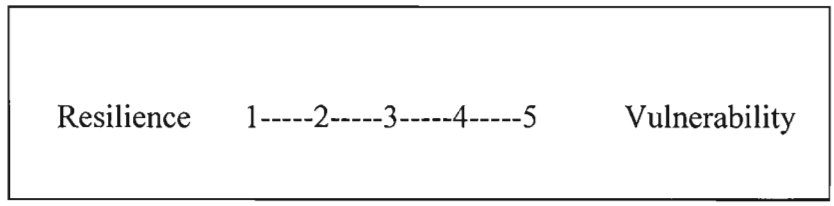
5.3 AGGREGATION OF INDICATORS WITHIN THE VULNERABILITY INDEX

This study aimed to develop a vulnerability index which has now been shown to include a number of vulnerability indicators and 34 measures used to determine the level of vulnerability at the household level. Each of the proposed indicators and measures tells a particular story about the state of vulnerability at a point in time within the household. However, a composite measure of vulnerability has not been established and is the content of this section.

The scoring and weighting of vulnerability measures within the vulnerability index is a study on its own. It is suggested that this index may provide the content for further research into the aggregation of indicators within a vulnerability indicator framework. This section therefore only proposes one way in which this aggregation may be attempted and therefore tests the vulnerability index in estimating the cumulative risks to air pollution.

Methodologies for scoring and weighting indicators

Each of the indicators and measures that have been selected for the vulnerability index should in some way provide some description of a part of the state of vulnerability and defenselessness of each household. However, in order to provide an estimate of the contribution of these vulnerability factors to household risk, the measures of vulnerability have been quantified within a scoring system (Figure 5.1). This has been achieved by assigning a score of 1 to 5 to each measure. A score of 1 corresponds to the best possible standards or conditions while a score of 5 indicates severe deprivation or vulnerability, severe health hazards and few physical and human resources (Klasen, 1997). This section therefore attempts to test whether a composite measure of vulnerability can be created from this indicator set.



(Source: Adapted from Coetzee, 2002)

Figure 5.1: Vulnerability scale for each indicator or measurement indicating movement towards or away from vulnerability.

Not all of the indicators are able to provide quantitative measurements using the data collected in this study. Those attributes of a household which cannot be measured to provide a single measurement have been given a score on the vulnerability line based on an understanding of the influence that the attributes have on moving the household towards or away from vulnerability.

The scores for each measure have been subjectively determined and are displayed in Table 5.10. The purpose of this scoring exercise is to provide a common denominator for each of the vulnerability factors so that household vulnerability levels can be compared. This scoring exercise, however, is not easy. A large degree of subjectivity is required. For example,

what percentage of males in each household can render the household vulnerable? It is understood that males can influence household income in a positive way by providing higher salaries, but the presence of males in some households can create tension and additional stress due to acts of physical, emotional or substance abuse. The score that has been provided, therefore, is highly subjective and is open for criticism. What should be understood however is that the purpose of this index is to establish which households are suffering from additional or cumulative risks brought on by their exposures to additional stressors or their defencelessness. It is used for comparing households to each other and is therefore a comparative tool which assigns the same scores to the same attributes in each household.

In scoring each measure, a number of questions regarding the linkages between vulnerability factors arises and provides some confusion. For example, literature studies have shown than young people are vulnerable because they lack the training needed to secure employment (Rakodi, *et al.,* 2000). With this understanding it would probably be appropriate to assign a high vulnerability score to households with an average household age of less than 20 years of age. However, HIV/AIDS statistics have shown that the prevalence of HIV/AIDS is highest within the productive age profile of 20 to 34 years of age (Smith, 2001). This implies that households with a high number of residents in the 20 to 34 year age group may be more vulnerable than those with a high number of young inhabitants.

Section 5.4 attempts to populate the index with data obtained from the household survey and will allow a comparison of households based on their vulnerability scores. The next section will further attempt to illustrate the value in recognising the contribution of the composite measure of vulnerability to an understanding of risks to air pollution. It must be noted that this is a first attempt to generate this index and further research will need to be conducted to ensure more reliable results.

Table 5.10: Components of a Composite Measure of Vulnerability (adapted from Klasen, 1997)

THEME	INDICATOR	MEASURES (Environmental, social & economic)	Score				
			1 (least vulnerable)	2	3	4	5 (most vulnerable)
Demo-graphics	Gender	Ratio of males to females per household Gender of household head Percentage of males older than 18yrs per household	1:1 Male >80%	<1:1 - 61-80%	All males - 41-60%	>1:1 - 21-40%	All females Female <20%
	Age	Age of household head Average age of household	35-45 20-40	45-55 -	25-35 -	18-25 and 55-60 -	<18 or >60 <20 or >40
Livelihoods	Unemployment rate	Percentage unemployed of employable age (>18yrs)	<20%	21-40%	41-60%	61-80%	>80%
	Income distribution and dependency	Monthly household income Per capita income Percentage of household contributing to HH income	>R4500 >R1250 50%	3500-4500 R850-1250 40%	R2500-R3500 R550-850 30%	R1500-R2500 R476-550 20%	<R1500 <R476 <10%
	Dependency on care	Ratio of adults to dependents (Ratio of children >15yrs:<15yrs) Number children under 15yrs who don't go to school	1:1 0	1:2 1	1:3 2	1:4 3	>1:4 4 or >4
	Levels of education	Percentage of household achieving grade 12 (of potential age)	>80%	61-80%	41-60%	21-40%	<20%
Physical exposures	Overcrowding	Number people per room Number people per household	<2 1-2	4 3-4	6 5-6	8 7-8	>8 >8
	Air pollution	Percentage of household sleeping in cooking area Percentage windows which open	0% >80%	1-25% 61-80%	26-50% 41-60%	51-75% 21-40%	76-100% <20%
	Waste	Frequency of removal Cost of service	Twice a week No cost	Once a week -	Twice a month -	Once a month -	No removal High
Externalities	Building materials	Presence of damp Type of materials/construction	No damp Formal	- semi-formal	Some damp Informal -blocks	- Informal –mud & wood	Much damp Informal with plastic/scrap

THEME	INDICATOR	MEASURES (Environmental, social & economic)	Score				
			1 (least vulnerable)	2	3	4	5 (most vulnerable)
Services	Access to water supply	Number litres accessed per day	>25 litres/day	-	-	<25 litres/day	No water
		Proximity to source	<200m	200-500km	500-1km	>1km	No water
		Reliability	no shortages	Some	frequent	Constantly	No water
		Cost of service	No cost	shortages	shortages	short.	High
				-	-	-	
	Quality of water	Potability	Treated	-	Treated but stored	-	Untreated
	Sanitation services	Type of toilet	Flush	VIP	Other pit latrine	Bucket	No toilet
		Private or shared facilities	Private	-	-	-	Shared
		Odour problems	none	-	-	-	Severe
		Cost of service	none	-	-	-	High
General health	Food and nutrition	Percentage of nutritional problems recorded at clinic	<1%	2-4%	5-10%	11-20%	>20%
	Other diseases	Number of household members with pre-existing respiratory problems	<20%	21-40%	41-60%	61-80%	>80%
		Prevalence of HIV/AIDS in the community/area	zero prevalence	1-15%	16-30%	31-45%	>45%
		Evidence of other communicable diseases in the household	No evidence	-	-	-	Some evidence
		Incidence of other communicable disease in the community	No incidence	-	Low incidence	-	High incidence

5.4 APPLICATION OF VULNERABILITY INDEX TO HOUSEHOLDS IN CATO CREST

In order to establish whether or not the vulnerability index will be significantly useful or accurate in determining heightened levels of risk in informal communities, it was proposed to attempt to populate the index with existing data and apply the index to ten households which were monitored for indoor air pollution. This section attempts to briefly illustrate the applicability of the index but does not provide enough evidence or data for all of the indicators and measures. Further research, which is outside the scope of this study, would need to be conducted to obtain the vulnerability index.

5.4.1 Developing a composite vulnerability score for each household

It was not possible to provide data or information for all of the indicators and measures because the household survey was conducted before the vulnerability index was created and was not conducted for the purpose of populating the index. Where possible, scores were assigned to each of the measures for 10 households in Cato Crest. These scores are displayed in Appendix 4. Individual scores for each household are displayed in Table 5.11 below.

Table 5.11: Vulnerability scores per characteristic for 10 households in Cato Crest

HOUSEHOLD NUMBER	CHARACTERISTIC						VULNERABILITY SCORE
	Demo graphics	Livelihoods	Physical exposures	Exter-nalities	Service	General Health	
1	16	22	7	Unable to measure	5	Unable to measure	50
2	4	17	8		5		34
3	15	21	4		5		45
4	10	17	9		5		41
5	10	22	8		1		41
6	6	8	6		1		21
7	4	16	4		5		29
8	14	22	7		1		44
9	8	16	7		5		36
10	13	21	9		5		48

The vulnerability scores detailed within each characteristic or theme (i.e. demographics, livelihoods, physical exposures, externalities, services and general health), provide a measure of the most vulnerable characteristics within each household. For example, household 1 has the highest vulnerability score for demographic and livelihood characteristics while the scores for the other characteristics (physical exposures and services) are more the less the same as for the rest of the households. The vulnerability scores are graphically represented in Figure 5.2.

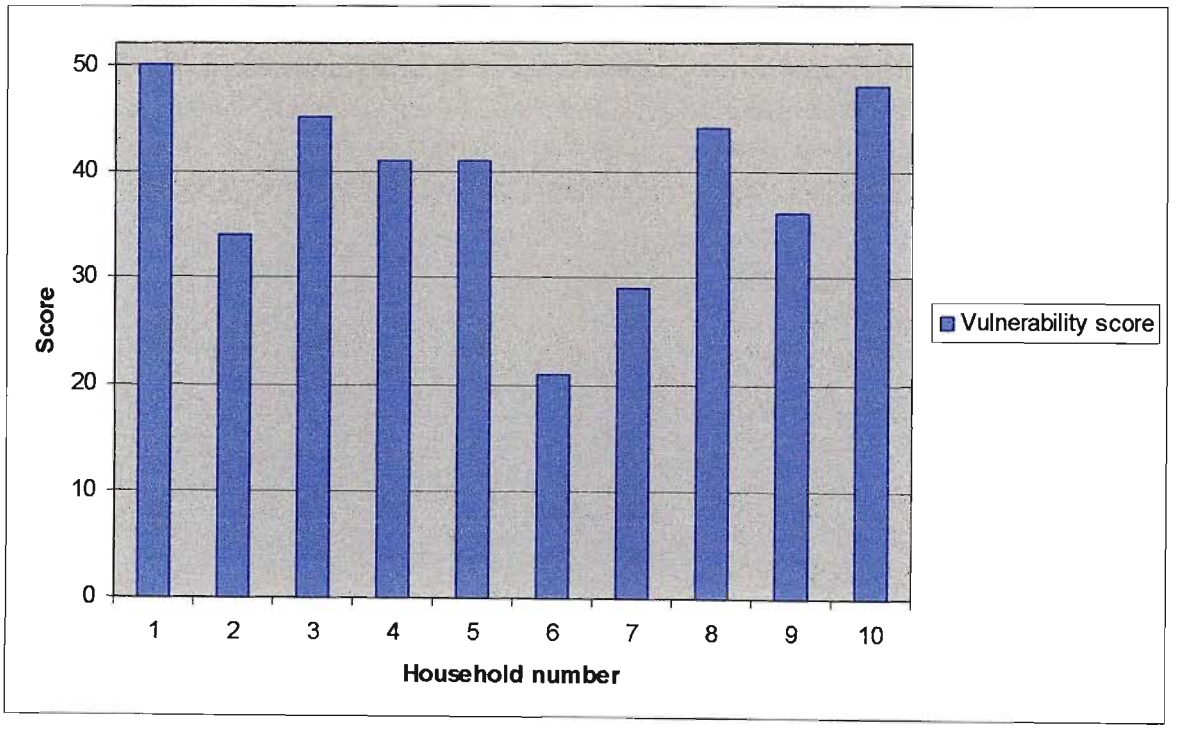


Figure 5.2: Vulnerability scores in selected households

The results of the scoring exercise show how levels of vulnerability differ for each household. Household 1 has the highest vulnerability score, followed by household 10.

5.4.2 Health Risk Assessment results of indoor air pollution

As discussed in Chapter 4 (section 4.2.3) health risk assessment results of a study conducted by Muller (2001) were used to show the health risks associated with exposure to kerosene combustion in low-income households. The calculation of the hazard quotients prepared through Muller (2001) represents the data on the hazard component within the risk equation

RISK = HAZARD X VULNERABILITY. By examining both the risk to households from air pollution (the HQ component of the formula) and the risk to households from other stressors (the vulnerability index), it may be possible for a more holistic understanding of risk to be established. This risk would reflect, to a certain extent, how different factors and problems become aggregated. It therefore attempts to quantify the nature of cumulative risk.

In Muller (2001), individual risk scores for air pollution were calculated for the same ten households in Cato Crest. The risk scores (or hazards quotients) were calculated for the pollutants nitrogen dioxide (NO_2), benzene and toluene and represent the potential health risks associated with exposure of adults, children and infants to kerosene combustion pollutants. For the purpose of this exercise, only nitrogen dioxide and benzene risk results have been used and are displayed in Table 5.12.

Table 5.12: Hazard quotients calculated for 24-hour NO_2 and benzene exposure in ten households in Cato Crest (taken from Muller, 2001)

Number of household	Nitrogen dioxide HQs				Benzene HQs			
	Adult	Child	Infant	TOTAL	Adult	Child	Infant	TOTAL
1	1.5	1.9	3.6	7.0	0.6	0.7	1.4	2.7
2	1.3	1.7	3.2	6.2	0.5	0.7	1.3	2.5
3	1.2	1.5	3.1	5.8	0.6	0.8	1.5	2.9
4	1.4	1.8	3.4	6.6	0.9	1.2	2.3	4.4
5	1.4	1.7	3.3	6.4	0.1	0.2	0.3	0.6
6	1.5	1.9	3.6	7.0	0.02	0.02	0.04	0.08
7	1.4	1.7	3.3	6.4	0.5	0.7	1.3	2.5
8	1.6	1.9	3.7	7.2	0.2	0.3	0.5	1
9	2.1	2.6	5	9.7	0.6	0.7	1.4	2.7
10	1.3	1.6	3.1	6.0	0.2	0.3	0.5	1

A hazard quotient greater than 1 represents a potential health risk. All the hazard quotients (presented in Table 5.12) which have been calculated for exposure to nitrogen dioxide are above 1, with the minimum HQ being 1.2 and the maximum being 5 for an infant in household 9. These results mean that not only sensitive individuals, but also some healthy individuals will begin to experience adverse health effects from indoor air pollution (Muller, 2001). All individuals in all of the households are therefore likely to experience adverse health effects associated with acute NO_2 exposure.

Although the health risks for benzene are not as high as those calculated for nitrogen dioxide, several of the hazard quotients calculated for benzene exposure indicate that it is likely that sensitive individuals will begin to experience adverse health effects associated with acute benzene exposure. Hazard quotients greater than 1 were calculated for infants in households 1, 2, 3, 7 and 9 with household 4 experiencing benzene hazard quotients greater than 1 in both children and infants.

In order to show cumulative risk of exposure to indoor air pollution for all individuals in a household, the hazard quotients for adults, children and infants for each of the pollutants have been added together and are displayed in Table 5.12 in the columns titled "TOTAL". The "total" HQ for nitrogen dioxide therefore has a threshold of 3 as it represents the addition of 3 HQs namely, adults, children and infants. These totals have been graphically presented in Figure 5.3. A "total" hazard quotient greater than 3 therefore represents a potential risk to health. The "standard" risk score for the addition of both benzene and nitrogen dioxide (represented by a blue line on the graph) is set at six. This has been calculated by adding together the hazard quotient of 1 for all three individuals in the household for both pollutants (i.e. 1 x 3 individuals x 2 pollutants = 6). This means that the sum of all hazard quotients greater than 6 will indicate a potential health hazard to all individuals in the household from both NO_2 and benzene exposure.

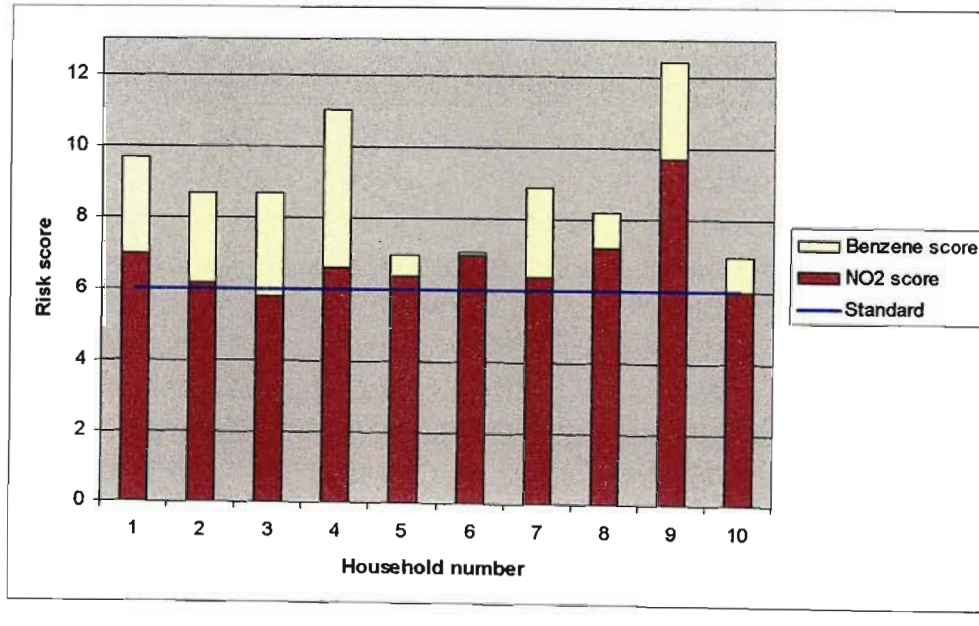


Figure 5.3: Nitrogen dioxide and benzene additive scores for all individuals in selected Cato Crest households

Figure 5.3 shows that the additive health risk scores of both NO_2 and benzene are likely to cause adverse health affects in all individuals in all households. These effects will mainly be attributed to the high levels of NO_2 emitted in the households, but benzene scores contribute to heightening this risk. The added scores show that household 9 has the greatest likelihood of adverse health effects, followed by households 4, 1, 7, 3, 2, 8, 6, 5, and 10.

5.4.3 Compounding risks to human health in selected Cato Crest households

The formula: CUMULATIVE RISK = HAZARD x VULNERABILITY has been used throughout this study to represent the total or cumulative risk of households to both air pollution and urban vulnerability. In this section, the air pollution hazard risk scores (displayed in section 5.4.2) and the vulnerability scores (displayed in section 5.4.1) have been multiplied to produce a cumulative risk score for each household (Table 5.13).

Table 5.13: Characterisation of cumulative risk from indoor air pollution in selected households in Cato Crest using the determined hazard quotient and vulnerability scores for each household.

Household	Hazard quotient		Vulnerability score	CUMULATIVE RISK (NO_2 + benzene x vulnerability)
	NO_2	Benzene		
1	7.0	2.7	50	485
2	6.2	2.5	34	295.8
3	5.8	2.9	45	391.5
4	6.6	4.4	41	451
5	6.4	0.6	41	287
6	7.0	0.08	21	148.7
7	6.4	2.5	29	258.1
8	7.2	1	44	360.8
9	9.7	2.7	36	446.4
10	6.0	1	48	336

The cumulative risk scores for each household has been graphically depicted in Figure 5.4

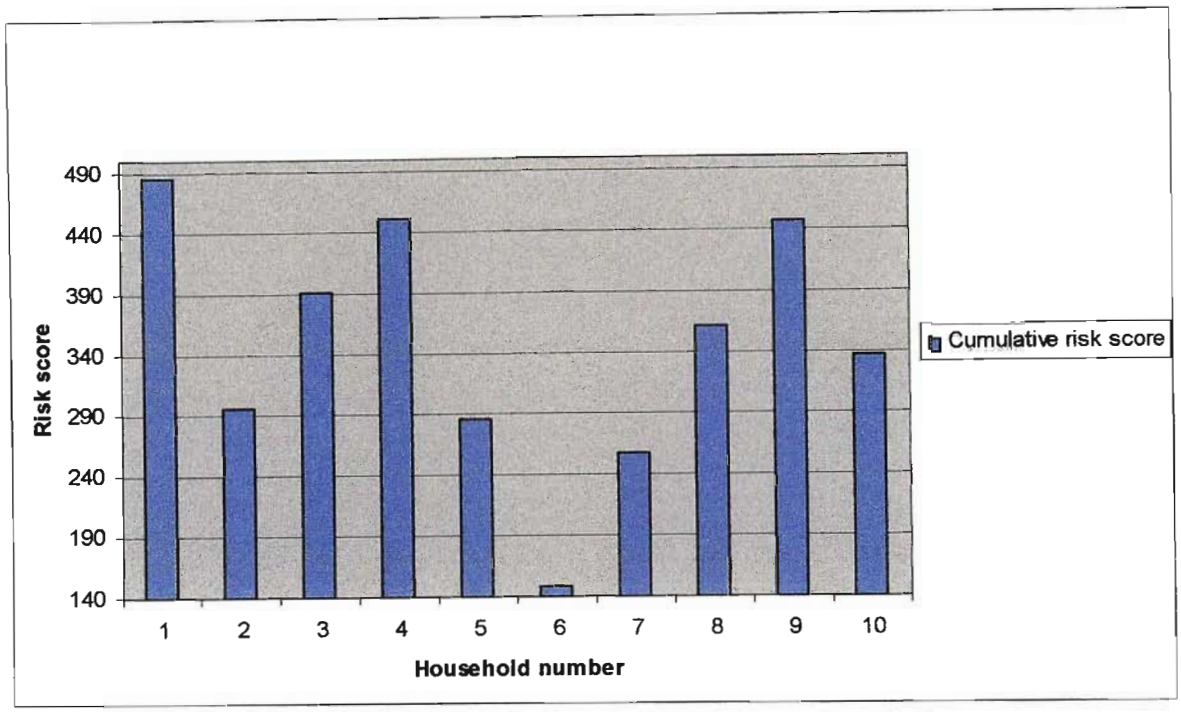


Figure 5.4: Cumulative risk scores for all households

The multiplication of the vulnerability score and the health risk scores not only increases the household cumulative risk score but it also changes the vulnerability order amongst the households. For example, when the vulnerability score for household 1 is multiplied with the sum of the NO_2 and benzene quotients, it raises the value of cumulative risk above all households, making household 1 the most vulnerable household to cumulative risks of air pollution (see ranking in Table 5.14). Another example can be illustrated using the results of household ten's risk scores. According to the health risk calculations for NO_2 and benzene, this places household 10 the least likely household to experience adverse health effects due to exposure from indoor air pollutants (see Figure 5.3 and Table 5.14). However, household ten appears to have the second highest vulnerability score. When the vulnerability score is multiplied by the HQ, it raises the cumulative risk to household members in this household up to a ranking of six on the list (see Figure 5.4 and rankings in Table5.14).

Table 5.14: Household ranking

Household	HQ: Household rank	Level of vulnerability: Household rank	Cumulative risk: Household rank
1	9	1	1
2	4	10	4
3	1	3	9
4	7	8	3
5	2	4	8
6	3	5	10
7	8	9	2
8	6	2	5
9	5	7	7
10	10	6	6

This exercise has illustrated one way in which factors of vulnerability (which are captured and measured through the vulnerability index), can be quantitatively combined into an equation for risk. Due to the number of vulnerability indicators in the index, the vulnerability scores are high and dominate the equation. Further studies are necessary to determine whether the vulnerability score can be standardized. One way in which this can be achieved is through dividing the vulnerability score by ten. This will reduce the vulnerability score into the same orders of magnitude than those of the combined hazard quotients.

5.5 CONCLUSION

This chapter details the results of a method developed and used to prepare a vulnerability index which can be used to include factors of vulnerability into risk assessments of indoor air pollution.

The approach taken to identify vulnerability factors in low-income communities began with a broad evaluation of literature on poverty and vulnerability. Thereafter the approach was to ground-truth the identified factors with local data from the informal community of Cato Crest. This analysis provided confirmation of the factors which had been chosen from the literature survey and highlighted a number of local factors which were significant to communities in the South African context. South African health studies were also reviewed in order to guide the

selection of factors according to their contribution in heightening risk to environmental health hazards.

The composite list of issues and factors which were derived from these selection procedures were converted into indicators and measures which can be used to provide a "snap-shot" of the state of vulnerability of informal communities to health hazards. The latter two sections of this chapter attempted to show how the resultant list of indicators could be aggregated into a composite vulnerability index. A method for scoring each vulnerability measure was attempted and some difficulties were mentioned. Finally, primary data collected from the Cato Crest survey was used to populate the index in an attempt to show how the vulnerability index and health risk assessment scores can be combined to estimate the probable cumulative risk to individuals at the household level.

CHAPTER 6: CONCLUSION

Health Risk Assessments are valuable tools which are being used extensively to determine the potential health risk associated with environmental exposures. They seek to understand the levels of exposure of a particular pollutant or environmental hazard on an individual and coupled with toxicological data on dose-response relationships, they characterise the health risks of exposure to that particular pollutant. Health risk assessments are being used to determine the potential health risks associated with the use of alternative fuels such as kerosene (paraffin) in poor communities. These assessments focus on a few pollutants of concern and determine the likelihood of exposure to these pollutants and the potential health risks.

Environmental hazards, however, seldom occur alone. Studies have shown that low-income (and often marginalised) communities are subjected to multiple environmental exposures (Rios, *et al.,* 1993; Wisner, 1998 and Hardoy, *et al.,* 2001). Informal communities are more likely to develop on marginalised land, where possible environmental hazards such as toxic waste, contaminated water or industrial pollution are predominant. These communities also lack the appropriate infrastructure and services which result in a number of environmental pollutants affecting the health of those living in the area.

Apart from the multiple environmental hazards which low-income communities are being constantly exposed to, there are a number of socio-economic factors which affect the way in which these communities respond to these exposures and their resultant health effects. Low-income communities are more vulnerable to disasters and environmental hazards because they live at a closer interface with their environment. They are therefore closer to the shocks and stresses imposed by that environment (Oelofse, 2002; Oelofse, 2003). They are also more vulnerable in that they lack the appropriate mechanisms to cope, withstand and recover from the impact of a hazard.

The issues of poverty and vulnerability are inextricably linked and include both a lack of income and resources, and defencelessness (Chambers, 1995). Low-income communities have

higher unemployment rates, resulting in the perpetuation of poverty. Health care facilities are often lacking or too costly to access, education levels are low, housing is inadequate resulting in overcrowded conditions leading to an increased rate of infection of diseases from other household members. These factors, and others, all contribute to heightening the health impacts experienced by individuals living in these areas.

As discussed at the beginning of this chapter, health risk assessments (HRAs) determine the potential health risks to exposure from a single pollutant. Although some studies are underway to facilitate an assessment of risk from multiple pollutants (Oosthuizen and John, 2002), these studies do not include the myriad of social, demographic, economic, institutional and infrastructural-related factors which contribute to a heightening of the risks to human health. Health risk assessments, therefore, should consider a number of these factors in their assessments in order to determine the cumulative risks resulting from exposure of these vulnerable communities to environmental hazards. Cumulative risks to health result not only from a single pollutant but from a number of other factors which lower immunity, cause additional health effects and prolong ill-health in an individual.

This study attempted to develop a methodology for the inclusion of factors of vulnerability into the assessment of risks to human health from indoor air pollution. The vulnerability index can be used to enhance the HRA method so that it includes both risks to chemical and biological hazards and measures of vulnerability. These measures of vulnerability and deprivation are mostly social in nature and require the experience and tacit knowledge of a social scientist. As a natural scientist, having to consider the more subjective, non-quantifiable aspects of vulnerability was a great challenge, albeit very necessary to do so. This study is a first attempt aimed to bring the social factors into a quantifiable form through a technical and deductive procedure (not very different to traditional natural science procedures).

This procedure was designed after considering a method that was used to develop a suite of indicators and measures for sustainable forest management (INR, 2002). The method that was used in this project provided some ideas for the process used to identify and select vulnerability factors and indicators. Particularly, the use of filters in the forestry project

stimulated the idea to filter the vulnerability factors identified from the literature, through a number of filters or sieves in order to refine the list of factors into appropriate health-related vulnerability indicators. The process was a systematic one which provided the opportunity to either add or take away factors which contributed to or had no effect on vulnerability.

The three sieves or selection procedures which were used to generate factors of vulnerability were literature sources, primary household data from Cato Crest and health studies of low-income communities in South Africa. The resultant list of vulnerability factors were logically and systematically grouped into six "themes" which represented similar characteristics. These themes were demographics, livelihoods, physical exposures, externalities, access to services and general health. The themes represent an indicator framework which is an important attribute of the index. When data are collected for a particular indicator it can be grouped with other data representing similar characteristics within that theme and can provide a picture of the level of vulnerability within that theme. For example, by grouping the indicators of overcrowding, air pollution and waste into a common theme, a picture of the physical exposures to individuals may be created. Similarly, grouping the indicators of employment, income, dependencies and education provide a picture of the state of vulnerability of the livelihoods of individuals and households. The grouping of indicators into themes can highlight which set of attributes or living conditions (or vulnerability factors) are significantly influencing or heightening the cumulative vulnerability of households to environmental risks.

From the set of vulnerability factors which had been selected, a number of indicators were chosen to represent each factor. From this indicator set, a number of measures were then identified in order for the index to provide a measurable composite index of vulnerability at the household level.

Although this index was developed at the household level, interventions into improving quality of life or alleviation of poverty occurs at the community level. This represents a challenge for the application of the index. It may be possible to measure community vulnerability by taking a representative sample of households from the community and

applying the index to each – provided the community is homogenous. The average vulnerability risk score would therefore represent the community's risk score.

The indicator set has been developed to determine the compounding influence of vulnerability and therefore heightened risk to households that are being exposed to toxic pollutants in the indoor environment. It is not just an indicator set which measures poverty or "income-based vulnerability", but the set of indicators have been selected on the basis of the links between vulnerability factors and air pollution health effects. These links have proven difficult to determine in this study. The index development process has raised a number of difficult questions about the inter-relationships between environmental hazards, social factors and consequent health impacts. One question which was continually being asked in the selection process was: what is the link between this factor and its contribution to affecting human health? Literature sources and primary data have been used in all instances to provide support for the selection of appropriate indicators but some of these selections have been based on subjective analysis and experiences of the author. They are therefore open to criticism and debate. When dealing with complex interactions between human receptors and environmental systems, much subjectivity may be involved and difficulties in measuring these interactions are common.

This thesis acknowledges that definitions of vulnerability include coping mechanisms. However the focus of this study, due to data constraints, resulted in a greater emphasis on vulnerability factors other than coping mechanisms. The use of a household survey, which was the content of another project, was a limitation in this study in that the household questionnaires lacked some of the necessary questions which were needed to understand the full extent of vulnerability at the household level, specifically aspects of social capital such as coping mechanisms and social networks. The style of questioning was also close-ended and provided some valuable inputs but a more open-ended style (perhaps in the form of focus groups) would have been more appropriate to probe for conditions of poverty and vulnerability in the household. The style of the questionnaire resulted in a number of data gaps which would have been useful to have. For example, no mention of social networks or support

systems was made, making it difficult to establish which coping mechanisms were available in each household.

The development of a vulnerability index required the measurement of all indicators of vulnerability. This was not easy to achieve. This study attempted to provide a scoring system for each vulnerability measure in order to provide an aggregated measure of vulnerability at the household level. While the production of an aggregated measure or "single value of vulnerability" is attempted in this thesis, one must recognise the shortcomings of such an approach. Vulnerability is a complex and multi-faceted phenomena comprising numerous interrelationships between factors. The development of a single vulnerability score may detract from these interrelationships and much of the complexities between systems may be lost during an iterative selection procedure.

The household vulnerability scores which were prepared were based on literature, common sense and a large amount of subjectivity. The scoring and aggregation of the vulnerability index was not a primary objective of this study but was only attempted to show how aggregation could be achieved. This could provide valuable content to another study aimed to score, aggregate and test measures of vulnerability at the household level as well as to explore the limitations of such an approach. Further research is also required to test and refine the index with data from an informal community in South Africa.

The vulnerability index that has been developed can be used together with the results of a health risk assessment of indoor air pollution to allow for the underlying vulnerability factors of low-income communities to be recognised and quantified into the measure of risk to human health. Applications of the vulnerability index in air pollution management could also be attempted. A vulnerability assessment of a community may be used together with a traditional health risk assessment in identifying risk to current air pollution levels. The index would therefore be instrumental in guiding the decision-making process in setting appropriate air quality standards in those vulnerable hot spot areas.

This study has shown that there are a number of environmental hazards which low-income communities are being constantly exposed to. Apart from this barrage of hazards, these communities lack the resources required to cope with the resultant health effects. Attempts to assess the health risks of exposed individuals must consider other social, economic and biophysical factors which impact their health. This vulnerability index is a first attempt in this direction. It is proposed to provide an inclusive, measurable picture of the state of vulnerability in low-income communities in order for cumulative risks to air pollution to be established. Although social capital has not been thoroughly examined in this report, it must be emphasised that aspects of human capital such as coping mechanisms, social networks, shared values and the ability to form relationships and associations are critical factors underpinning vulnerability and should be examined in future work.

This study has shown that a holistic approach to health risk assessment is required when dealing with interventions to address impacts of air pollution. This approach requires the skills of both physical and social scientists in order to recognise and account for all of the factors which contribute to making the whole greater than the sum of its parts.

REFERENCES

Amis, P. 1995: Making sense of urban poverty, *Environment and Urbanisation*, 7(1), p145-157.

Binedell, M. and Law, E. 2000: *Time activity pattern survey.* Lead Programme in Technologies for Enhanced Environmental Management, Report no. P4-3, CSIR, Durban.

Binedell, M., Muller, E. and de Vos, B. 2001: *Results of indoor air quality monitoring in Cato Crest households,* Lead Programme in Technologies for Enhanced Environmental Management, Report no. P5-5, CSIR, Durban.

Binedell, M. and van der Voort, I. 1999: *Health risk assessment of potential health risks associated with the proposed Strategic Fuel Fund (SFF) transport and oil storage facilities, Table Bay/ Milnerton: a case study*. CSIR Report no. JW630, Stellenbosch.

Blaikie, P., Cannon, T., Davis, I. and Wisner, B. 1994: *At risk: natural hazards, people's vulnerability and disasters,* Routledge, London.

Briggs, D., Corvalan, C. and Nurminen, M. 1996: *Linkage methods for environmental health analysis: General guidelines*, World Health Organisation, Geneva.

Chambers, R. 1995: Whose reality counts? *Environment and Urbanisation*, 7(1), p173-204.

Claasen, M. 1999: *Risk assessment concepts*, EIA lecture notes, CSIR, Pretoria.

CMDA 1995: *Greater Cato Manor structure plan, first draft*, Cato Manor Development Association, Durban.

CMDA 2000: *Cato Manor development project: Status report 2000*, Cato Manor Development Association, Durban.

CMDA 2001: *Cato Manor development project overview*, [Online]. Available: http://www.cmda.org.za/overview.

Coburn, A.W., Spence, R.J.S. and Pomonis, A. 1994: *Vulnerability and risk assessment*, Cambridge Architectural Research Limited, Cambridge.

Coetzee, E. 2002: Urban vulnerability: A conceptual framework. In: Nomdo, C and Coetzee, E. (eds), *Urban vulnerability: perspectives from southern Africa.* Periperi publications, University of Cape Town, Cape Town.

Crookes, D. 2000: *Strategic assessment of the baseline economic context in Cato Manor*, Lead Programme in Technologies for Enhanced Environmental Management, Report no. P3-3, CSIR, Durban.

DACE 2002: *Key environmental indicators: background information document*, Mpumalanga State of the Environment 2003, Department of Agriculture, Conservation and Environment, Mpumalanga.

DACE 2003: *Mpumalanga State of the Environment 2003*, Department of Agriculture, Conservation and Environment, Mpumalanga.

DEAT 2002: *National core set of environmental indicators for state of environment reporting in South Africa: Phase 2: Identification of issues and criteria*, Department of Environmental Affairs and Tourism, Pretoria.

Department of Social Development. 2000: *State of South Africa population report,* [Online], Available: http://population.pwv.gov.za/state.htm.

DWAF 2002: *Draft white paper on water services: Water is life, sanitation is dignity*, draft for public comment, Department of Water Affairs and Forestry, Pretoria.

Genthe, B. 1998: *Specialist study on the potential health impacts of the proposed wastewater treatment facility on the West Bank of East London,* CSIR report no. ENV/S-I 98003, Environmentek, Stellenbosch.

Hardoy, J.E., Cairncross, S. and Satterthwaite, D. 1990: *The Poor die young: Housing and health in third world cities*, Earthscan Publications Ltd., London.

Hardoy, J.E., Mitlin, D. and Satterthwaite, D. 2001: *Environmental problems in an urbanising world,* Earthscan Publications Ltd., London.

Hindson, D. and Pupuma, F. 1996: *Cato Manor: Report on the state of the environment and development in the Durban Metropolitan Area*, Durban.

Holloway, A. 1999: Introducing Periperi publications, *Urban vulnerability: perspectives from southern Africa.* Periperi publications, University of Cape Town, Cape Town.

Hounsome, R., Binedell, M., Madonsela, N.V., Napier, M., Hansson, C. and Ahman, M. 2002: *Sustainable development in poor urban communities,* Lead Programme in Technologies for Enhanced Environmental Management, Report no. P9-1, CSIR, Durban.

HST 1996: *1996 South African health review*, Health Systems Trust, [Online]. Available: http://www.hst.org.za/sahr.

INR 2002: *Draft principles, criteria, indicators and standards for sustainable forest management of natural forests and plantations in South Africa,* Institute of Natural Resources, investigational report number 231, Committee for Sustainable Forest Management and Department of Water Affairs and Forestry, Pretoria.

ISDR 2002: *Living with risk: A global review of disaster reduction initiatives,* preliminary version, July 2002, International Strategy for Disaster Reduction.

Jones, A. P. 1999: Indoor air quality and health, *Atmospheric Environment*, 33, p4535-4564.

Jones, S., Aitken, R. and Luckin, L. 1996: *Power, posterity and poverty: An ethnographic study of the social determinants of fuel use in Cato Manor, Durban*, Agency for Cultural and Policy Research, Department of Anthropology, University of Natal, Durban.

K&M Environmental 1997: *Operating instructions for nitrogen dioxide monitor and OVM-1 badge,* USA.

Klasen, S. 1997: Poverty, inequality and deprivation in South Africa, *Social Indicators Research*, 41, p51-94.

Kotze, A. 1999: A new concept of risk, in Holloway, A (ed) *Risk, sustainable development and disasters: Southern perspectives.* Periperi publications, University of Cape Town, Cape Town.

Law, E. 1999: *Quantification of the human health risks of NO_2 pollution in Johannesburg and Cape Town*, CSIR Report number ENV-P-I-99010, Pretoria.

Madonsela, N, V. and Binedell, M. 2001: *Cato Manor: Integration of biophysical aspects*, Lead Programme in Technologies for Enhanced Environmental Management, Report no. P7-1, CSIR, Durban.

Marsh, J. and Oelofse, C. 1998: *Risk assessment: Environmental training manual for development facilitators,* University of Cape Town, Cape Town.

Mathee, A., Palmary, I. and de Wet, T. 1999: *Aspects of environmental health in South African informal settlements,* Lead Programme in Technologies for Enhanced Environmental Management, Report no. P2-2, CSIR, Durban.

Mathee, A., Barnes, B. and de Wet, T. 2001: *The state of environment and health in Alexandra*, Lead Programme in Technologies for Enhanced Environmental Management, Report no. P3-6, CSIR, Durban.

Mathee, A. and von Schirnding, Y. E. R. 1996: Living conditions and environmental health status in two informal settlements in the Cape Peninsula, *Development Southern Africa*, 13(1), p129-139.

Matooane, M. 2000: *Report on human health risk assessment of exposure to sulphur dioxide and nitrogen dioxide in Greater Cato Manor,* Lead Programme in Technologies for Enhanced Environmental Management, Report no. P5-1, CSIR, Durban.

Meuller, C.C. 1995: Environmental problems inherent to a development style: Degradation and poverty in Brazil, *Environment and Urbanisation*, 7(2), p67-84.

Moser, C. 1995: Urban social policy and poverty reduction, *Environment and Urbanisation*, 7(1), p159-171.

Moser, C. 1998: Asset vulnerability framework: Reassessing urban poverty reduction strategies, *World Development*, 26(1), p1-19.

Muller, E. 2001: *Quantification of the human health risks associated with kerosene use in the informal settlement of Cato Manor, Durban,* Unpublished masters thesis, School of Life and Environmental Sciences, University of Natal, Durban.

NRC 1994: National Research Council, *Science and judgement in risk assessment*, National Academy Press, USA.

Oelofse, C. 1999: *Environmental considerations and the right to adequate housing*, Report prepared for the Built Environment Support Group, University of Natal, Durban.

Oelofse, C. 2002: Dimensions of urban risk, in Nomdo, C and Coetzee, E (eds), *Urban vulnerability: perspectives from southern Africa.* Periperi publications, University of Cape Town, Cape Town.

Oelofse, C. 2003: *Integrating social theory into urban environmental risk assessment in South Africa: A case study of Hout Bay, Cape Town*, Local Environment, in press.

Oelofse, C. and James, N. 2001: *Sustainability indicators*, LA Training Manual, Environmental Evaluation Unit, University of Cape Town, Cape Town.

Oelofse, C., Scott, D., Duenez, R., Houghton, J. and Oelofse, G. 2002: *Ecological modernization or alternate approaches: New tools for sustainability in South Africa*, United Nations Development Report for South Africa, UNDP, Pretoria.

Oosthuizen, R. and John, J. 2002: *Step report on trends in air quality and health,* CSIR report number ENV- P- I- 2002-003, Pretoria.

Pillay, S. and Webster, M. 1997: *A biophysical assessment of the Greater Cato Manor structure plan: The terrestrial environment*, Strategic Environmental Assessment (SEA) of the Greater Cato Manor Draft Structure Plan, Cato Manor Development Association, Durban.

Potgieter, F.E., Venter, D., Thomas, E.P., Seager, J.R., McGranahan, G. and Kjellen, M. 1999: *Port Elizabeth 1000 household environment and health survey*, Port Elizabeth household environment and health series report no. 1, National Urbanisation and Health Research Programme, Medical Research Council, Cape Town.

Rakodi C., Gatabaki-Kamau, R. and Devas, N. 2000: Poverty and political conflict in Mombasa, *Environment and Urbanisation*, 12(1), p153-170.

Rich, J. 2000: *Baseline community profile of Cato Manor*, Lead Programme in Technologies for Enhanced Environmental Management, Report no. P3-4, CSIR, Durban.

Rios, R., Poje, G.V. and Detels, R. 1993: Susceptibility to environmental pollutants among minorities, *Toxicology and Industrial Health,* 9(5), p797-820.

Robinson, G. M. 1998: *Methods and techniques in human geography*, John Wiley and Sons Ltd., England.

Satterthwaite, D. 1999: *The links between poverty and the environment in urban areas of Africa, Asia and Latin America*, International Institute for Environment and Development, Human Settlements Programme, United Kingdom.

Smith, A. 2001: *HIV/AIDS statistics*, Department of Virology, University of Natal, Durban.

Terblanche, A.P.S., Opperman, L., Nel, C.M. E., Reinach, S.G., Tosen, G. and Cadman, A. 1992: Preliminary results of exposure measurements and health effects of the Vaal Triangle Air Pollution Health Study, *South African Medical Journal*, 81 (6), p550-556.

Thomas, E.P., Seager, J.R., Viljoen, E., Potgieter, F., Rossouw, A., Tokota, B., McGranahan, G. and Kjellen, M. 1999: *Household environment and health in Port Elizabeth, South Africa,* Urban Environment Series Report no. 6, Stockholm Environment Institute, South African Medical Research Council and Sida.

Thomas, E.P. 2001: *Cato Manor health and environment report,* Lead Programme in Technologies for Enhanced Environmental Management, Report no. P6-2, CSIR, Durban.

UN 1995: *Indicators of sustainable development: Guidelines and methodologies*, United Nations, [Online]. Available: http://www.un.org.za/esa/sustdev/indisd/isdms2001/isd-ms2001isd.htm.

UNEP 2002: *Global Environment Outlook 3: Past, present and future perspectives,* Earthscan Publications Ltd., London.

USEPA 1992: *Guidelines for exposure assessment*, United States Environmental Protection Agency, [Online]. Available: http://oaspub.epa.gov/eims/eimscomm.getfile?p_download_id=4544

USEPA 2002a: *Biological pollutants in your home*, United States Environmental Protection Agency, The Consumer Product Safety Commission and The American Lung Association, USA.

USEPA 2002b: *Mold Basics*, United States Environmental Protection Agency, [Online]. Available: http://www.epa.gov/iaq/pubs/index.html #MOLDS.

Vermaak, K., Gumede,S., Dallimore, A. and Stewart, R. 2001: *Cato Manor environmental study,* Lead Programme in Technologies for Enhanced Environmental Management, Report no. P8-2, CSIR, Durban.

WHO 2000: *World Health Organization ambient air guidelines*, [Online]. Available: http://www.who.int/peh/air/qualitygd.htm.

WHO 2002: *Health and sustainable development: Meeting of senior officials and ministers of health, summary report,* Johannesburg.

Williamson, A. 2000: *Strategic environmental assessment of Cato Manor: Institutional component,* Lead Programme in Technologies for Enhanced Environmental Management, Report no. P4-2, CSIR, Durban.

Winchester, P. 1992: *Power, choice and vulnerability,* James and James Science Publishers Ltd., England.

Wisner, B. 1998: Marginality and vulnerability, *Applied Geography,* 18(1), p25-33.

World Bank 2002: *2002 World development indicators CD-ROM*, World Bank, [Online]. Available: www.worldbank.org/poverty/data/povmon.htm.

Wratten, E. 1995: Conceptualising urban poverty, *Environment and Urbanisation*, 7(1), p11-36.

Zawaira, F. 1999: HIV/AIDS: The unmitigated disaster, in Holloway, A (ed), *Risk, sustainable development and disasters: Southern perspectives.* Periperi publications, University of Cape Town, Cape Town.

Zummo, S. M. and Karol, M.H. 1996: Indoor air pollution: Acute adverse health effects and host susceptibility, *Journal of Environmental Health*, 58(6), p25-29.

Zunckel, M., D'Abreton, P. and Mitchell, I. 2000: *A methodology for cumulative effects assessment for air quality studies*: Richards Bay as a case study, CSIR Report no. ENV-D-I 2000-001, Durban.

PERSONAL COMMUNICATIONS

Gielink, S., March 2001: Communications Manager, Cato Manor Development Agency, Durban.

APPENDIX 1

FORMULAE USED IN THE CALCULATION OF CHRONIC AND ACUTE RISK FROM NON-CARCINOGENIC POLLUTANTS

Formulae used in the calculation of chronic and acute risk from non-carcinogenic pollutants (USEPA, 1992)

Chronic risk

The *chronic* exposure rate equation for the inhalation exposure pathway is:

$$ADD = \frac{C \times IR \times ED}{BW \times AT}$$

Where

ADD	=	average daily dose of the chemical ($\mu g\ kg^{-1}\ day^{-1}$)
C	=	concentration of the chemical in the atmosphere ($\mu g\ m^{-3}$)
IR	=	inhalation rate in $m^3\ day^{-1}$
ED	=	exposure duration (days)
BW	=	average body weight of receptor over the exposure period (kg)
AT	=	averaging time, the period over which exposure is averaged (days).

Exposure duration (ED) is defined as the length of time that receptors are exposed to the contaminants. It is calculated from the exposure event or time, exposure frequency, and duration of exposure using the following equation:

$$ED = ET \times EF \times DE$$

Where

ED	=	exposure duration (days)
ET	=	exposure time or event ($hrs\ day^{-1}$)
EF	=	exposure frequency ($days\ year^{-1}$)
DE	=	duration of exposure (yrs)

The HQ for *chronic* risk is estimated from:

$$HQ = \frac{ADD}{DRV}$$

Where

HQ	=	hazard quotient
ADD	=	average daily dose
DRV	=	dose-response value (RfC, MRL or REL)

RfC = Reference Concentration – defined as "an estimate (with uncertainty) of the concentration that is likely to be without appreciable risk of deleterious effects to the exposed population after continuous lifetime exposure" (NRC, 1994)
MRL = Minimal Risk Level (used by Agency or Toxic Substances and Disease Register, (ATSDR))
REL = Reference Exposure Level (used by Californian EPA).

Acute Risk

Acute (non-cancer) health effects are determined through the calculation of the average hourly dose or AHD. AHD is determined through the following equation:

$$AHD = \frac{C \times IR}{BW}$$

Where

AHD = average hourly dose for inhalation ($\mu g\ kg^{-1}\ hr^{-1}$)

C = concentration of the chemical ($\mu g\ m^{-3}$)

IR = inhalation rate ($m^3\ hr^{-1}$)

BW = body weight (kg)

The exposure duration and averaging time are omitted from the equation as they are both 1 hour for acute exposure.

The HQ for *acute* risk is therefore estimated from:

$$HQ = \frac{AHD}{DRV}$$

Where

HQ = hazard quotient

AHD = average hourly dose for inhalation ($\mu g\ kg^{-1}\ hr^{-1}$)

DRV = dose-response value (RfC, MRL or REL)

APPENDIX 2

HOUSEHOLD SURVEY QUESTIONNAIRE

CSIR – CATO MANOR

0.1 Field Worker Name _____

0.2 Date of Interview |_D_|_D_|_M_|_M_|_Y_|_Y_|

0.3 Household Surname _____

0.4 House number CC_____

0.5. Home Language of Household |___|

1=Zulu, 2=Sotho, 3=Tswana, 4=Xhosa, 5=Tonga, 6=Shangaan, 7=Pedi, 8=Afrikaans, 9=English

97= Refuse to Answer 98=Do not know 99=Not applicable

1. DEMOGRAPHICS

1.1. *Name of household members (list all household members.*	*1.3.* *What is [..]'s relationship to the H/h HEAD?* **1= Head 2= Spouse of head 3= Child of head 4= Sibling of head 5= Parent of head 6=Grandparent of head 7= Other relative 8= Lodger / Tenant 9= Domestic 10= Gardener 11= Other employee**	*1.4.* *Gender?* **1= Male 2=Female**	*1.5.* *Age in Years at* **next** *birthday?* In years	*1.6.1* *What is highest level of education completed by [..] ?* **0=Adult no schooling -99=Pre-school Answer in grades 13 = Tertiary Education**	*1.7.* Vocational status: *What is [..]'s main activity?* **Codes at bottom of page**	*1.8.* *How often is [..] paid?* 1= Daily 2=Weekly 3=Monthly Enter 99 for not applicable if not earning an income	*1.9.* *How much income does [..] receive ....(time period)?* **In Rands**	*1.10.* *How much of this money does [..] Contribute to this household per month* *In Rands*
1.1.1	*1.3.1*	*1.4.1*	*1.5.1*	*1.6.1.1*	*1.7.1*	*1.8.1*	*1.9.1* **R**	*1.10.1* **R**
1.1.2	*1.3.2*	*1.4.2*	*1.5.2*	*1.6.1.2*	*1.7.2*	*1.8.2*	*1.9.2* **R**	*1.10.2* **R**
1.1.3	*1.3.3*	*1.4.3*	*1.5.3*	*1.6.1.3*	*1.7.3*	*1.8.3*	*1.9.3* **R**	*1.10.3* **R**
1.1.4	*1.3.4*	*1.4.4*	*1.5.4*	*1.6.1.4*	*1.7.4*	*1.8.4*	*1.9.4* **R**	*1.10.4* **R**
1.1.5	*1.3.5*	*1.4.5*	*1.5.5*	*1.6.1.5*	*1.7.5*	*1.8.5*	*1.9.5* **R**	*1.10.5* **R**
1.1.6	*1.3.6*	*1.4.6*	*1.5.6*	*1.6.1.6*	*1.7.6*	*1.8.6*	*1.9.6* **R**	*1.10.6* **R**
1.1.7	*1.3.7*	*1.4.7*	*1.5.7*	*1.6.1.7*	*1.7.7*	*1.8.7*	*1.9.7* **R**	*1.10.7* **R**
1.1.8	*1.3.8*	*1.4.8*	*1.5.8*	*1.6.1.8*	*1.7.8*	*1.8.8*	*1.9.8* **R**	*1.10.8* **R**
1.1.9	*1.3.9*	*1.4.9*	*1.5.9*	*1.6.1.9*	*1.7.9*	*1.8.9*	*1.9.9* **R**	*1.10.9* **R**

Vocational Status codes:

1= Baby, pre-school – home or crèche	***2= Scholar / student - attending***	***3= School-going age, - not attending***	***4= Retired***	***5= Labour disabled - not seeking work***	***11= pensioner***
6= Housewife / help – unpaid work	***7= Unemployed – not seeking work***	***8= Unemployed – seeking work***	***9= Working - mainly in informal sector***	***10= Working - mainly in formal sector***	

97= Refuse to Answer 98=Do not know 99=Not applicable

Other Household Information

2.1	**How many households are living on this homestead plot?** *Enter raw number*	
2.2	**Is this household the main household or a tenant household?** *1=main 2=tenant*	
2.3	**When did this household move into this area where you are living now?** *Write in year*	
2.4	**How long has this household been living in this present house?** **Write in number of years, if less than one year write in <1**	
2.5	**Please list three positive things about living in this area?** 1. _____ 2. _____ 3. _____	
2.6	**Please list three negative things about living in this area?** 1. _____ 2. _____ 3. _____	

3. Water, Sanitation, Waste

	(a) **Where do you get your water for ...?**	(b) **How much do you get each time (litres) ?**	(c) **Do you buy your water?** *1=yes* *2=no*	(d) **If you pay for it, how much does it cost, per litre?**	(e) **How often do you get water?**
3.1 Drinking				R	
3.2 Cooking				R	
3.3 Washing				R	
3.4 Water for garden				R	

For Part A

1=Piped – internal
2=Piped - yard tap
3=Water carrier/tanker
4=Piped - public tap/kiosk
6=Borehole/well
7=Rainwater tank
8=Flowing river/stream
9=Dam/stagnant water
10=Protected spring

For Part E

1=Every Day
2= 2-5 times per week
3= Once a week
4= Once a fortnight
5= Once a month
Other (Specify) _____

97= Refuse to Answer

98=Do not know

99=Not applicable

3.5	**If people were to drink from the rivers around here, are they likely to become ill?** *1=Yes 2=No If no, go to question 3.7*	
3.6	**If yes, why would they get ill?** _____	
3.7	**Do children play in the rivers around here?** *1=yes 2=No 3=are no rivers around here*	
3.8	**What kind of toilet does the household use?** *1=None (bush-rubbish dump-sand dunes)* *2=Flush toilet* *3=Improve pit latrine with ventilation (VIP)* *4=Other pit latrine* *5=Bucket toilet*	
3.9	**Where is the toilet?** *1=Inside dwelling* *2=Outside dwelling – household use only* *3=Outside dwelling – shared with other households*	
3.10	**If you had/have no toilet, where would/do you go?** *1= In the bush, veld* *2= Use a neighbours* *3= Use a communal toilet* *4= Use stream or river* *Other (Specify)* _____	
3.11	**How do you store rubbish at home?** *1=Bin, 2=Bag, 3=Rubbish pit* *Other (Specify)*	
3.12	**How long does the bag or pit take to fill up?** *1= 1-2 days, 2=3-5 days, 3= More than 5 days*	
3.13	**How do you dispose of the full bags/bins?** *1= Throw it in the veld, 2=Throw it is waste containers to be collected, 3= Throw it in a rubbish pit, 4=Burn it Other (Specify)* _____	
3.14	**If a refuse removal facility exists in your neighbourhood, do you use it?** *1= Yes 2= No if no, skip to 3.17*	
3.15	**If you have a refuse removal system in your neighbourhood, how often do you use it?** *1= Every day, 2= Twice a week, 3= Once a week, 4=Once a month*	
3.16	**Do you pay for this service?** *1= Yes 2=No*	
3.17	**Do you recycle any waste materials (e.g.) glass plastic?** *1=Yes 2=No*	
3.18	**What are the main problems regarding services (water, sanitation, refuse removal?)** _____ _____	

97= Refuse to Answer 98=Do not know 99=Not applicable

4. Energy Use

Which type of fuel is used for each of following activities?									
4.1a	Cooking, heating water			Lighting		4.1c	Heating for warmth		6.1
1= Electricity, 2= Wood, 3= Gas, 4= Paraffin/kerosene, 5= Open fire, 6=Candles, Other (specify)									

4.2	***Check 4.1a, if mentioned paraffin/kerosene or wood (if not, skip to section 5)*** What type of stove is used? 1=Paraffin burner with wick ("sekeni"), 2= Paraffin primer and pump Other (Specify)_____	
4.3	Approximately how old is the stove? Answer in years	
4.4	Approximately how many hours per day is the stove being used? Enter in number of hours	
4.5	Approximately how many meals per day are cooked in this household: **On weekdays** **On weekends**	***Weekdays*** ***Weekends***
4.6	Where is the cooking done mostly? *1= Indors 2=Outdoors*	

5. Air Quality

5.1	**Do you have to open windows or doors of the house to let out smoke?** *1=yes 2=no if no go to 5.3*	
5.2	**If yes, how often** *1= Every day, 2=2-3 times a week, 3=2-3 times a month 4=Seldom*	
5.3	**How many members of your household sleep in the same room where the meals are cooked?** *Enter in raw number*	
5.4	**How many members of your household are present indoors or in the kitchen during the cooking of meals?** *Enter raw number (enter 99 if cook outside)*	

Do you light a fire inside your home: *1=yes, 2=no*								
5.5a	**In winter**		**5.5b**	**In summer**		**5.5c**	**All year**	

5.6	**Is there anybody who lives in the house that smokes?** *1= Yes, 2= No if no skip to next section*	
5.7	**If yes, how often do they smoke indoors** *1= Several times a day, 2= Once or twice a day, 3= Once or twice a week, 4=Once or twice a month*	

97= Refuse to Answer 98=Do not know 99=Not applicable

6. Soil Quality

6.1	**Do you experience any problems with soil erosion in your yard?** *1= Yes, 2=No*	
6.2	**Is the soil in your yard good enough to grow good crops and vegetables if you were to have enough water** *1= Yes, 2= No, 3= Unsure*	

7. Security

7.1	**Do you feel safe in your home?** *1=yes, 2=No*	**During the day**	**During the night**

8. Healthcare

8.1	**Where do you go when you are sick?** *1=Clinic or hospital* *2=private doctor* *3=Traditional healer* *4=Nowhere,* *5. Other (specify)*_____	
8.2	**How much do you pay for one consultation? (Answer in Rands)**	

THANK YOU FOR YOUR TIME

97= Refuse to Answer 98=Do not know 99=Not applicable

APPENDIX 3

COMPLETED HOUSEHOLD QUESTIONNAIRE FOR HOUSEHOLD CC1[2]

[2] The household number has been changed in order to ensure the confidentiality of household data

CSIR – CATO MANOR

0.1 Field Worker Name _Mbali_____

0.2 Date of Interview |_0_|_6_|_0_|_2_|_0_|_3_|

0.3 Household Surname _____**Confidential**_____

0.4 House number _____**Confidential**_____

0.5. Home Language of Household |**01**|

1=Zulu, 2=Sotho, 3=Tswana, 4=Xhosa, 5=Tonga, 6=Shangaan, 7=Pedi, 8=Afrikaans, 9=English

1. DEMOGRAPHICS

1.1. *Name of household members (list all household members.*	*1.3.* *What is [..]'s relationship to the H/h HEAD?* **1= Head 2= Spouse of head 3= Child of head 4= Sibling of head 5= Parent of head 6=Grandparent of head 7= Other relative 8= Lodger / Tenant 9= Domestic 10= Gardener 11= Other employee**	*1.4.* *Gender?* **1= Male 2=Female**	*1.5.* *Age in Years at* **next** *birthday?* **In years**	*1.6.1* *What is highest level of education completed by [..] ?* **0=Adult no schooling -99=Pre-school Answer in grades 13 = Tertiary Education**	*1.7.* Vocational status: *What is [..]'s main activity?* **Codes at bottom of page**	*1.8.* *How often is [..] paid?* 1= Daily 2=Weekly 3=Monthly Enter 99 for not applicable if not earning an income	*1.9.* *How much income does [..] receive ....(time period)?* **In Rands**	*1.10.* *How much of this money does [..] Contribute to this household per month* **In Rands**
1.1.1 Bonyekile	*1.3.1* **01**	*1.4.1* **02**	*1.5.1* **40**	*1.6.1.1* **05**	*1.7.1* **10**	*1.8.1* **03**	*1.9.1* ***R 900***	*1.10.1* ***R 500***
1.1.2 Thandeke	*1.3.2* **03**	*1.4.2* **02**	*1.5.2* **17**	*1.6.1.2* **10**	*1.7.2* **02**	*1.8.2* **99**	*1.9.2* ***R 00***	*1.10.2* ***R 00***
1.1.3 Phindile	*1.3.3* **03**	*1.4.3* **02**	*1.5.3* **13**	*1.6.1.3* **06**	*1.7.3* **02**	*1.8.3* **99**	*1.9.3* ***R 00***	*1.10.3* ***R 00***
1.1.4 Philile	*1.3.4* **03**	*1.4.4* **02**	*1.5.4* **07**	*1.6.1.4* **01**	*1.7.4* **02**	*1.8.4* **99**	*1.9.4* ***R 00***	*1.10.4* ***R 00***
1.1.5 Andile	*1.3.5* **03**	*1.4.5* **02**	*1.5.5* **03**	*1.6.1.5* **-99**	*1.7.5* **01**	*1.8.5*	*1.9.5* ***R***	*1.10.5* ***R 00***
1.1.6	*1.3.6*	*1.4.6*	*1.5.6*	*1.6.1.6*	*1.7.6*	*1.8.6*	*1.9.6* ***R***	*1.10.6* ***R***
1.1.7	*1.3.7*	*1.4.7*	*1.5.7*	*1.6.1.7*	*1.7.7*	*1.8.7*	*1.9.7* ***R***	*1.10.7* ***R***
1.1.8	*1.3.8*	*1.4.8*	*1.5.8*	*1.6.1.8*	*1.7.8*	*1.8.8*	*1.9.8* ***R***	*1.10.8* ***R***
1.1.9	*1.3.9*	*1.4.9*	*1.5.9*	*1.6.1.9*	*1.7.9*	*1.8.9*	*1.9.9* ***R***	*1.10.9* ***R***

Vocational Status codes:

1= Baby, pre-school – home or crèche	***2= Scholar / student - attending***	***3= School-going age, - not attending***	***4= Retired***	***5= Labour disabled - not seeking work***	***11= pensioner***
6= Housewife / help – unpaid work	***7= Unemployed – not seeking work***	***8= Unemployed – seeking work***	***9= Working - mainly in informal sector***	***10= Working - mainly in formal sector***	

97= Refuse to Answer 98=Do not know 99=Not applicable

For Part A		For Part E
1=Piped – internal	*7=Rainwater tank*	*1=Every Day*
2=Piped - yard tap	*8=Flowing river/stream*	*2= 2-5 times per week*
3=Water carrier/tanker	*9=Dam/stagnant water*	*3= Once a week*
4=Piped - public tap/kiosk	*10=Protected spring*	*4= Once a fortnight*
6=Borehole/well		*5= Once a month*
		Other (Specify) _____

3.5	**If people were to drink from the rivers around here, are they likely to become ill?** *1=Yes 2=No If no, go to question 3.7*	**01**
3.6	**If yes, why would they get ill?** ***The water is not clean*** _____	
3.7	**Do children play in the rivers around here?** *1=yes 2=No 3=are no rivers around here*	**02**
3.8	**What kind of toilet does the household use?** *1=None (bush-rubbish dump-sand dunes)* *2=Flush toilet* *3=Improve pit latrine with ventilation (VIP)* *4=Other pit latrine* *5=Bucket toilet*	**04**
3.9	**Where is the toilet?** *1=Inside dwelling* *2=Outside dwelling – household use only* *3=Outside dwelling – shared with other households*	**03**
3.10	**If you had/have no toilet, where would/do you go?** *1= In the bush, veld* *2= Use a neighbours* *3= Use a communal toilet* *4= Use stream or river* *Other (Specify)* _____	**02**
3.11	**How do you store rubbish at home?** *1=Bin, 2=Bag, 3=Rubbish pit* *Other (Specify)*	**02**
3.12	**How long does the bag or pit take to fill up?** *1= 1-2 days, 2=3-5 days, 3= More than 5 days*	**03**
3.13	**How do you dispose of the full bags/bins?** *1= Throw it in the veld, 2=Throw it is waste containers to be collected, 3= Throw it in a rubbish pit, 4=Burn it Other (Specify)* _____	**03**
3.14	**If a refuse removal facility exists in your neighbourhood, do you use it?** *1= Yes 2= No if no, skip to 3.17*	**01**
3.15	**If you have a refuse removal system in your neighbourhood, how often do you use it?** *1= Every day, 2= Twice a week, 3= Once a week, 4=Once a month*	**03**
3.16	**Do you pay for this service?** *1= Yes 2=No*	**02**

97= Refuse to Answer 98=Do not know 99=Not applicable

APPENDIX 4

VULNERABILITY SCORES FOR SELECTED CATO CREST HOUSEHOLDS

Appendix 4: Vulnerability scores for each measure in the vulnerability index for ten selected Cato Crest households

	HOUSEHOLD NUMBER									
MEASURE	1	2	3	4	5	6	7	8	9	10
Ratio of males to females per household										
Gender of household head	5	1	5	5	1	1	1	1	1	5
Percentage of males older than 18yrs per household	5	1	5	1	3	1	1	3	2	5
Age of household head	1	1	4	3	5	3	1	5	4	2
Average age of household	5	1	1	1	1	1	1	5	1	1
Percentage unemployed of employable age (>18yrs)										
Monthly household income	5	5	5	5	5	2	4	5	3	5
Per capita income	5	5	5	5	5	1	3	5	3	5
Percentage of household contributing to HH income	5	1	4	1	5	1	3	4	4	4
Ratio of adults to dependents (Ratio of children >15yrs:<15yrs)										
Number children under 15yrs who don't go to school	2	1	2	1	2	1	1	3	1	2
Percentage of household achieving grade 12 (of potential age)	5	5	5	5	5	3	5	5	5	5
Number people per square metre										
Number people per household	3	1	2	2	4	1	1	5	2	2
Percentage of household sleeping in cooking area	2	5	1	5	3	1	1	1	3	5
Percentage windows which open										
Frequency of removal	2	2	1	2	1	4	2	1	2	2
Cost of service										
Presence of damp										
Type of materials/construction										
Number litres accessed per day										
Proximity to source										
Reliability										
Cost of service										
Potability										
Type of toilet										
Private or shared facilities	5	5	5	5	1	1	5	1	5	5
Odour problems										