IDENTIFYING THE PREVALENCE OF AND PATHWAYS TO DIARRHOEAL DISEASE IN RURAL KWAZULU-NATAL AND THE IMPLICATIONS FOR EVALUATING THE IMPACT OF WATER SUPPLY SCHEMES ON COMMUNITY HEALTH.

by

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ABSTRACT

Since the establishment of a democratic South Africa in 1994, a number of rural water supply schemes have been implemented. A specific aim of these schemes is to improve the health of the population. The underlying assumption is that a supply of reticulated water will improve the quality of water used by the community, reduce the exposure of the community to contaminated water supplies, and reduce water related diseases, in particular diarrhoea.

This research thesis focuses on two rural water supply schemes in KwauZulu-Natal: Mpolweni and Vulindlela, both being developed by Umgeni Water, the regional water utility. These communities depended variously on rivers, rain harvesting, and springs for their water supply. For sanitation, the majority of people used unimproved pit latrines.

This research thesis is based on information gathered from the communities prior to the installation of the water supply schemes. It focuses on the linkage between water supply and health by examining diarrhoeal morbidity as a measurable disease outcome and by identifying possible pathways to the prevalence of diarrhoea.

Questionnaire and observational surveys were undertaken of 181 households in Mpolweni and 100 households in Vulindlela. From these surveys, the prevalence of diarrhoea in Vulindlela households was found to be 40.4% and in Mpolweni to be 49%. Children under the age of five years old are the most vulnerable, with 20.1% of children in Mpolweni and 21.3% of children in Vulindlela reported as having had diarrhoea in the recall period prior to the surveys.

The Mpolweni study considered eighty exposure variables, finding an association between diarrhoeal disease and sixteen of these variables (p value < 0.05). The Vulindlela study considered fifty-five exposure variables, of which eight were considered significant (p value < 0.05).

In regard to water and diarrhoea:

- no association was found between the prevalence of diarrhoea and the source of water in either Mpolweni or Vulindlela.
- using water to wash nappies was associated with diarrhoeal disease in Vulindlela. However, it is postulated that it is the faecal contamination in the nappy, rather than the water, that is problematic. No association between water use and diarrhoea was established in Mpolweni.
- poor disinfection of stored water supplies was associated with diarrhoeal disease in both Mpolweni and Vulindlela. In addition, the use of plastic storage containers to store water at the household provided additional risk in Mpolweni. However, once the reticulated system is installed, the communities are likely to continue to store water due to a distrust of the reliability of water supply.

The above surveys form the baseline for additional studies currently being undertaken by Umgeni Water that are intended to measure the effectiveness of the water supply schemes on community health.

However, from this thesis, it is concluded that many of the risk factors associated with diarrhoeal disease in both Vulindlela and Mpolweni will not directly be addressed by the introduction of the water supply schemes.

PREFACE

The work described in this dissertation was carried out in the Centre for Environment and Development and in Umgeni Water from January 1997 to December 1999 under the supervision of Prof. Rob Fincham (Centre for Environment and Development). It is derived from two studies: Mpolweni and Vulindlela, funded by Umgeni Water and the Water Research Commission, respectively. Dr. Quentin Espey provided additional supervision for the Mpolweni study, when he held the position of Senior Scientist at Umgeni Water and for the Vulindlela project, where he currently sits as a steering committee member of the Water Research Commission (WRC) panel overseeing this project.

The author now holds the position of Water Quality Officer at Umgeni Water. She is the Project Manager for both the Mpolweni and Vulindlela studies. The baseline information from these two studies, which was gathered between 1997 and 1999, forms the basis for this thesis. Both studies are still ongoing.

This dissertation represents original work by the author and it has not otherwise been submitted in any form for any degree or diploma to any University.

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CHAPTER 1: INTRODUCTION

The following introduction provides an historical perspective to the linkage between water supply and health, and shows how Umgeni Water came to consider health criteria as an evaluation tool for developing water supply schemes. The research objectives are described, which hinge on two projects: Mpolweni and Vulindlela. Together, these provide a basis for investigating, contrasting and confirming the results of the study.

1.1 Historical Perspective

The morbidity and mortality associated with water borne infection are of great concern to most developing countries. In 1989, the World Health Organisation (WHO) suggested that 200 million more people were drinking contaminated water that posed a health risk than in 1975 and that, at any one time, half the hospital beds in the world were occupied by people with water related diseases (WHO, 1990). In 1993, it was estimated that 3 million children died as a result of diarrhoeal diseases, mainly spread by contaminated water and food (WHO, 1996). To the issues regarding human health was the added concern that environmental conditions were also deteriorating.

Health authorities generally believe that health can be improved by providing an adequate water supply and sanitation. In a speech to the WHO Regional Planning Meeting (Africa 2000 Initiative for Water Supply and Sanitation, Zimbabwe, October 1999) Ebrahim Samba, WHO's Regional Director, had some simple words of advice for people in an area affected by an outbreak of the infectious disease Cholera: "Get yourselves clean water and good sanitation. The solution is not to bring doctors or cholera vaccines but potable water and sanitation." (WHO, 1999).

In South Africa, just under one third of the population (12 million people) does not have access to an adequate supply of potable water, and one half of the population (21 million) lacks basic sanitation (Department of Water Affairs and

Forestry, 1994). It is estimated that there are approximately 24 million incidences of diarrhoea per year in South Africa, of which 2.8 million require treatment at health care facilities and 43 000 people die (Pegram *et al,* 1997). The South African Government and water-related agencies are undertaking a vigorous campaign to provide 'water for all' (Umgeni Water, 1998a).

These factors led Umgeni Water, a South African supplier of bulk water, to consider using health criteria as an evaluation tool for the development of its water supply schemes.

1.2 Umgeni Water

Umgeni Water is a water authority based in Pietermaritzburg, KwaZulu-Natal, South Africa. Umgeni's core business is the treatment and distribution of water. Over 300 million kilolitres of water per year are delivered to an area of operation that covers 24 000 km^2 in Kwazulu-Natal, including the cities of Pietermaritzburg and Durban, as well as many rural areas. Umgeni owns and manages eleven large storage dams, eleven major water-works and five wastewater works (Umgeni Water Environmental Report, 1997-1998).

In 1998, the Board of Umgeni Water adopted an environmental health policy to oversee its core activities. The objectives of the policy, which were developed by the author for the company, are described in figure 1a, below.

Umgeni Water is currently developing two large water supply schemes in the KwaZulu-Natal Midlands to supply reticulated water to the communities of Mpolweni and Vulindlela. These projects form the basis for introducing and testing the environmental health policy in an operating situation.

- The incorporation of Health Impact Assessment studies on all large water and sanitation projects
- Specifically designing water and sanitation delivery systems to reduce health risk
- Assessing and minimizing the negative impacts of all Umgeni water operational activities and structures on the health of people in the Umgeni Water operational area
- Positively influencing the actions of people on water through continued health and hygiene education within the context of water protection and conservation
- Intersectoral co-operation with the role-players in the health and environment fields
- Supporting internal and external research to improve the knowledge base on which decisions on health and integrated catchment management are based.

Fig 1a: Umgeni Water Environmental Health Policy (Umgeni Water, 1997-1998)

An assessment of water supply schemes relies on the availability of comprehensive disease surveillance data. The reporting and surveillance systems for waterborne disease in South Africa were considered inadequate to give a true reflection of the extent of diarrhoeal disease in the study areas (Pegram, 1997). Additional information was deemed necessary to provide a benchmark against which to measure the intervention.

1.3 The Research Journey

In 1997, in the spirit of inter-sectoral co-operation, Umgeni Water embarked on a project to quantify the prevalence of diarrhoea in the Mpolweni area of Kwazulu-Natal, and to postulate whether the use of untreated surface water from the surrounding Mpolweni and Mgeni rivers was a contributing factor. A baseline study was carried out, for which the author was part of the research team and for which the results are used for the first component of this dissertation. The infrastructure for the provision of treated water to Mpolweni was to be built between January 1997 and December 1998. RDP[1] levels of water provision were to be made available to the community. At the time, it was intended that, once the water scheme was complete, a further study would be carried out to retroactively determine the benefits and impacts of the water supply intervention on the community. This further work has not to date been carried out.

In the same time frame, the Water Research Commission[2] agreed to fund a study on the impact of water supply schemes on community health. It was felt that the single study area of Mpolweni was insufficient to provide the data for a rigorous analysis of this issue. A second project in Vulindlela, a large rural area near Pietermaritzburg, was initiated. The author was the Manager of the Project Team. The Vulindlela baseline study was carried out in January 1999, the results of which were used for the second component of this dissertation. At the time of writing, the follow up Vulindlela surveys are continuing. The overall Vulindlela Study is expected to be completed during 2000.

Both Mpolweni and Vulindlela lie in the KwaZulu-Natal Midlands (see figure 1b).

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[1] RDP: Reconstruction and Development Programme developed by the South African Government, which prescribed the minimum levels of service, such as water service delivery, to be available for all people of South Africa

[2] Water Research Commission is an organization that supports water and sanitation related research in South Africa.

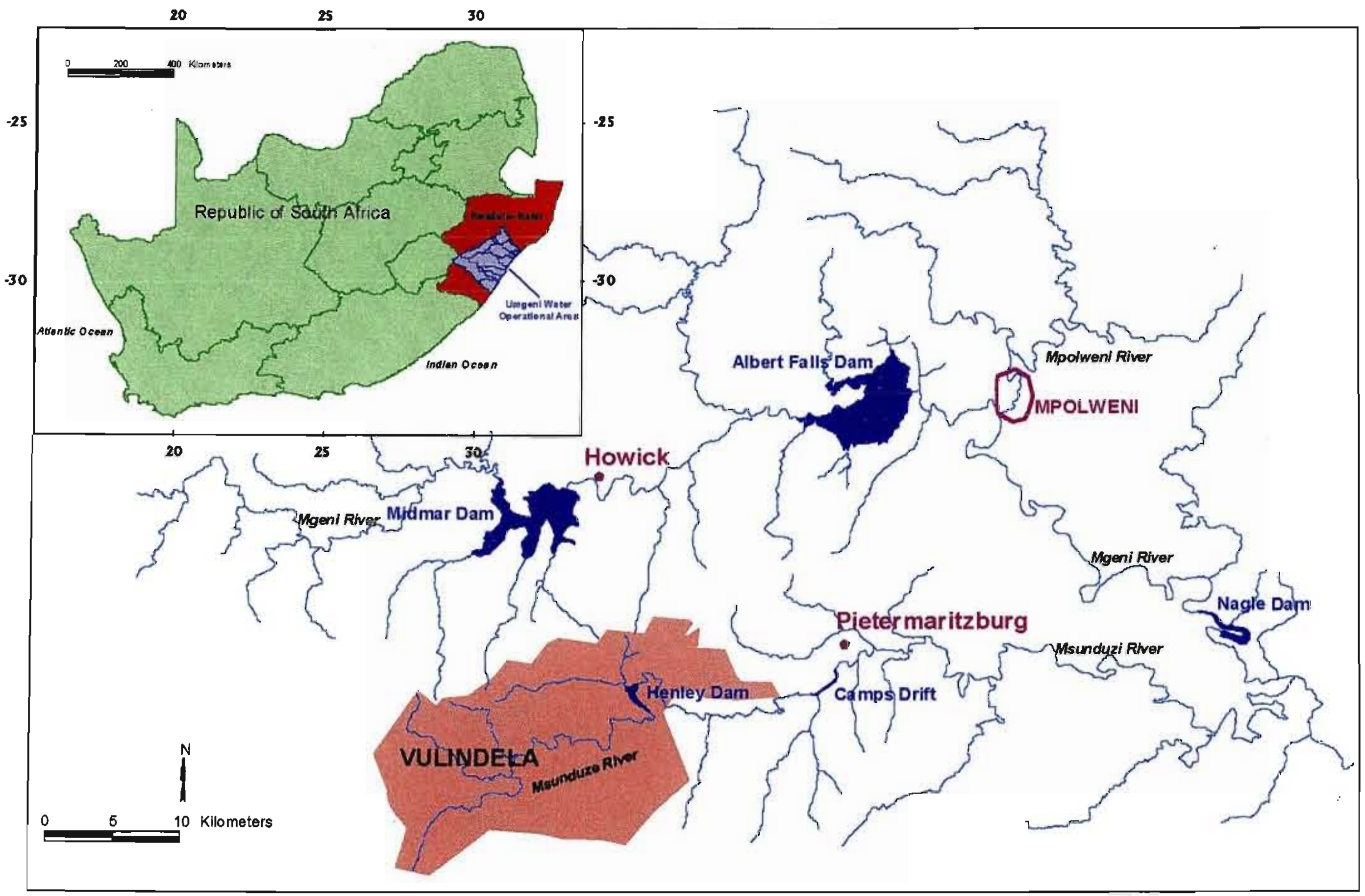


Figure 1b: Map of Study Locations in South African Context.

1.4 Study Aims and Objectives

The Umgeni Water Health Policy, and the intention to carry out health assessments on future water projects, are seen as a means to incorporate health considerations into project design. The use of Health Impact Assessments (HIA) for prospective developments has recently been made government policy in the United Kingdom (Birley, 1999). There is however little experience with HIA in South Africa.

To develop a framework for future work in health impact assessment in South Africa, research is required in:

- Developing criteria for consideration in the HIA of water supply schemes
- Assessing the extent of diarrhoeal disease amongst rural communities
- Examining the current prevalence of diarrhoea as related to the water resources in the area, directly or indirectly (the pathways to diarrhoea)
- Evaluating epidemiological methodologies as a tool for assessing the impact of water supply schemes on community health.

The overall aim of this thesis is to examine and draw conclusions from the baseline analysis of the two project areas, Mpolweni and Vulindlela, where health impact assessment projects are currently underway. The total scope of these studies is shown in Fig 1c and the shaded areas represent the basis for this dissertation.

The specific objectives of this research dissertation are to:

- Describe the socio-economic and environmental situation in the communities, prior to the installation of the water supply scheme
- Establish the prevalence of diarrhoea in the study areas, prior to the installation of the water supply scheme
- Examine of the pathways to diarrhoeal disease in each of the study areas
- Evaluate the appropriateness of the baseline studies for considering the health impact of the water supply scheme interventions with respect to diarrhoeal disease as an indicator of health.

The evaluation of the effectiveness of the interventions on diarrhoeal disease morbidity and mortality is a challenging task, as the linkages between water and health are complex. Many contend that the introduction of a water supply scheme does not necessarily result in improved health (Birley, 1995). This statement is more widely discussed with reference to previous work, which is initiated in the literature review chapter 2, but is also woven through the discussion and the results of this dissertation.

The methodologies adopted for Mpolweni and Vulindlela are described in chapter 3: section 3.1 describing the background, history, study site description and methodology being used for the Mpolweni study, and section 3.2 adopting a similar format for the Vulindlela area.

The results of the socio-economic and environmental analysis are presented in chapter 4, the results of the prevalence of diarrhoea are presented and discussed in chapter 5. The results relating to pathways to diarrhoea (risk factors) are presented and discussed in chapter 6.

The appropriateness of the baselines studies is considered in chapter 7.

FIG 1c: SCHEMATIC OF MSC DISSERTATION IN THE CONTEXT OF THE MPOLWENI AND VULINDLELA STUDIES

Mpolweni Observational Cross-Section Design

MPOLWENI BASELINE ANALYSIS Sample size: 181 households	MPOLWENI FOLLOW-UP UMGENI WATER·AMANZI
Mpolweni Before Water Reticulation	Mpolweni After Water Reticulation

Vulindlela Stepped Wedge Design

Site/area	Baseline before UW	Survey 2	Survey 3	Survey 4	Survey 5
Mthoqotho Sample size: 25 households	Before UW	UMGENI WATER·AMANZI	UMGENI WATER·AMANZI	UMGENI WATER·AMANZI	UMGENI WATER·AMANZI
Khobogwane Sample size: 25 households	Before UW	Before UW	UMGENI WATER·AMANZI	UMGENI WATER·AMANZI	UMGENI WATER·AMANZI
Shange Sample size: 25 households	Before UW	Before UW	Before UW	UMGENI WATER·AMANZI	UMGENI WATER·AMANZI
Mafakatini Sample size: 25 households	Before UW	Before UW	Before UW	Before UW	UMGENI WATER·AMANZI

MSc. Dissertation	
MPOLWENI	VULINDLELA

CHAPTER 2: LITERATURE REVIEW

Given the importance and complexities of the linkages between water and health, this literature review was carried out aiming to:

- Summarize the key debates around the issues and problems that are experienced in assessing the effect of water supply on human health
- Review the situation in South Africa
- Set the parameters for the current study.

The review demonstrated that society had intuitively expected that providing a potable supply of water will improve the health of recipient communities, and that the effectiveness of the intervention in addressing diarrhoeal disease in the recipient community should be demonstrable. It is common to hear the phrase that millions of children are dying annually due to waterborne disease. In fact, in a speech at the prestigious "Stockholm Water Symposium", the keynote speaker was reported to have compared the deaths due to waterborne disease to that of a Jumbo Jet crashing every minute for 24 hours with no survivors (Bailey, 1999a). If this is the case, then it seems logical that the morbidity and mortality associated with diarrhoea, a common waterborne disease, should decrease considerably by simply providing a supply of potable water.

However, Blum and Feachem cast doubt on this when they reviewed 50 studies that were carried out between 1950 and 1980 in all parts of the world. The authors identified several methodological problems in measuring the impact of water supply and sanitation on diarrhoeal diseases (Blum and Feachem, 1983). Any one of these factors could inhibit the ability to draw definitive conclusions relating to the impact of the intervention on human health, as discussed below.

2.1 The Evaluation of Water Supply Scheme Interventions.

For many decades, health authorities had assumed that water supply schemes improved the health of recipient communities (Van Der Lee, 1999). But, while science continued to try and find rational answers that would link water supply and health, the development fraternity grew skeptical of the linkage. In 1975, the World Bank convened a panel of experts to discuss the assessment of the impact of water and sanitation on human health. The panel concluded that the Bank should no longer undertake the funding of long-term longitudinal studies[3], as these had proved to be costly exercises that had shown little success in measuring the impact of water supply and sanitation (Cairncross, 1999).

However, not long after, the World Health Organization declared 1980 to 1990 to be the *International Drinking-Water Supply and Sanitation Decade,* the objective of which was to improve the health of populations that received the interventions of water and sanitation.

At this time, the case-control methodology[4], was introduced to measure the effectiveness of interventions. However, as a means of evaluating the success of the Decade, it had limited success. Attempts to evaluate the effectiveness of water supply schemes on human health continued to be criticized for being poorly designed, and producing meaningless or useless results.

2.2 The Role of Epidemiology.

Studies in the Water Decade relied heavily on epidemiological methodologies (Feacham, 1984). Over 2000 years ago, Hippocrates contended that

[3] A Longitudinal Study observes a cohort of people, or other variables, over a period of time.
[4] Case-control methodology: a comparison of possible disease causes between a group of people with a disease and a group without the disease.

environmental factors could influence the occurrence of disease (Last, 1994). However, it was the work of John Snow that popularized the concept of epidemiology. Snow found that the risk of cholera in London was related to the water supplied by a particular company. In the process, he clarified and defined the role of polluted water in the transmission of cholera, a diarrhoeal disease (Last, 1994).

The 1988 World Health Assembly recognized the role of epidemiology in its resolution: The Global Strategy for Health for All. Member states were urged to make greater use of epidemiological data to identify the causes of disease with particular emphasis on modifiable environmental factors and to apply epidemiology to prevent disease and promote human health. (Beaglehole *et al*, 1993).

The challenge in environmental epidemiology is to define the exposure (which in this research study is the introduction of the new water supply), measure it, and assess it's affects, while also taking into consideration problems due to confounding, multiple exposures, and inconsistent and variable dose-response relationships. The outcome (which in this study is diarrhoea) is used as an indicator to measure the effects of the exposure (a change in water supply).

It can be said that every disease is either caused by the environment or by genetic factors (including ageing). The relative contributions of the different factors to a disease (such as diarrhoea) are difficult to measure because of multi-factorial causation. In addition, individual characteristics modify the effect of the environmental factors. Figures 2a and 2b identify some environmental and individual characteristics that require consideration (Beaglehole *et al,* 1993).

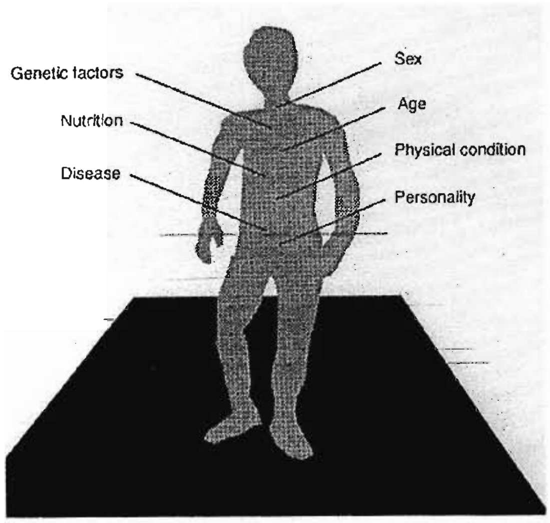


Fig 2a: Individual characteristics that affect human health

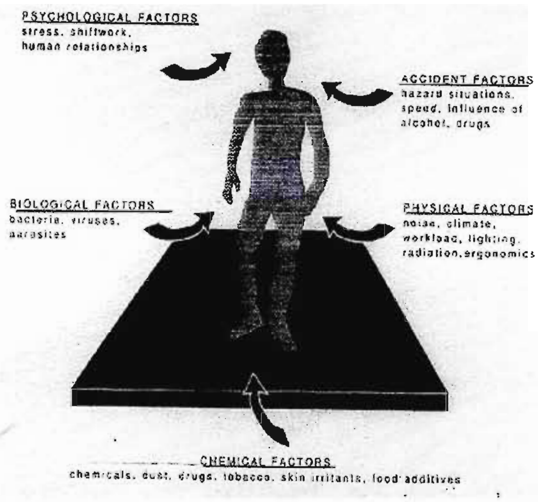


Fig 2b: Environmental characteristics that affect human health

A review of the results of studies that were carried out during the Water Decade concluded that epidemiological studies did not prove to be a satisfactory operational tool for the evaluation of water and sanitation interventions (Cairncross, 1990).

However, almost a decade later, the methodological flaws inherent in epidemiological studies designed to show how and why improved water quality and quantity impact on human health are still present. As described in the next chapter, a review of recent studies highlights five areas of debate in evaluating the impact of water supply schemes on health.

2.3 Key debates: Issues and Problems in Assessing the Effect of Water Supply on Human Health.

From various studies (Blum and Feachem, 1983; Cairncross, 1990; Esrey, 1996; Payment *et al* 1991; Black, 1996; and others), there are five major areas of debate regarding the evaluation of the impact of water supply on human health:

- Efficiency of water supply schemes in reducing diarrhoea
- Choice of diarrhoea as an indicator of health
- Confounding variables (pathways) in diarrhoeal disease
- Bias in study surveys
- Project design.

These are examined in more detail below:

2.3.1 Efficiency of water supply schemes in reducing diarrhoea

It is widely acknowledged that a complex relationship exists between water quality, water quantity, sanitation, hygiene and human health, which is extremely difficult, if not impossible, to accurately quantify (Caimcross, 1992; Baqui, 1991; Blum and Feacham, 1983). The general assumption is that an improved water supply, either individually or in conjunction with improved sanitation, will yield positive benefits to the community, resulting in reductions in disease transmission (Cairncross, 1994). A number of descriptive and analytical epidemiological studies have examined the role of improved water supplies (Khan, 1981) or the combination of improved water and sanitation (Esrey and Habicht, 1986; Esrey *et al*, 1991; Ghenthe and Seager, 1996). The studies showed variable benefits, ranging from a marked decrease in reported diarrhoeal disease to no benefit at all.

During the International Water Decade (1980-1990), Esrey accumulated evidence of the impact of varying degrees of improved water supply interventions on several diseases and quantified the percentage reduction due to the impact. In a meta-analysis of 144 studies, he showed that improved water quality resulted in an average 15% reduction in morbidity, while improved quantity had a greater impact with an average 20% reduction in morbidity. The synergistic effect of water and sanitation, sanitation alone and health education were all more effective in reducing morbidity than water supply. In the studies that reported a health benefit due to water supply, the water was piped directly to the home (Esrey, 1991).

Shuval *et al* (1981) proposed that there is a threshold at which the effectiveness of water and sanitation investments is realized. At both the lower end of the socio-economic spectrum and the higher end of the spectrum investments in water and sanitation do not show substantial benefits. It is suggested that a point of saturation is reached beyond which further significant health benefits cannot be reached.

The Intersectoral Action for Health Committee (WHO, 1986) estimated that safe and sufficient water supplies and sanitation would reduce infant and child mortality by more than 50% and prevent a quarter of all diarrhoeal episodes. They also estimated the impact of water on specific diseases, summarized as follows:

Table 2.1: Projected reduction in morbidity after the introduction of a treated water supply (WHO, 1992).

Diseases	Reduction in Morbidity (%)
Cholera, typhoid, leptospirosis, scabies, dracunculiasis	80-100
Trachoma, conjunctivitis, yaws, schistosomiasis	60-70
Tularaemia, paratyphoid, bacillary and amoebic dysentery, gastro-enteritis, louse-borne diseases, diarrhoeal diseases, ascariasis, skin infections	40-50

Cairncross (1999) concludes that existing literature on impact studies does indicate that improved water supply will result in improved hygiene, which may be reflected in increased water consumption. In the absence of this behavioral change, the benefits that may accrue from an improved water quality alone are minor and even negligible in many settings.

2.3.2 Choice of diarrhoea as an indicator of health

The second debate focuses on indicators used in studies of this nature which (after Blum *et al*, 1983) include:

- Incidence rates of diarrhoea and /or dysentery
- Prevalence rates of excretion of one or more bacterial or protozoan enteric pathogens
- Prevalence rates of intestinal helminthes infections
- Nutritional status
- Prevalence rates of eye or skin infections, and
- Mortality rates.

Although indicators such as nutritional status (Esrey, 1986) and total mortality (Merrick, 1983) have been used in studies to evaluate the health impact of water supply and sanitation projects, the most widely used indicator is still diarrhoeal morbidity. The reason for this may be that the cost of epidemiological studies is large and the expertise to carry out such studies is limited. In addition, the conditions under which many communities in the developing world live do not lend themselves easily to measuring the height and weight of individuals and most studies rely on questionnaire surveys to gather data.

Gastroenteritis is a major cause of morbidity worldwide (Cairncross, 1999). Despite analytical progress with the introduction of molecular biology and sero-typing, 30-70% of episodes of diarrhoea have no identified pathogen (Marx, 1998). The use of indicators such as the prevalence rates of excretion of bacterial, viral, protozoan or helminthes infections should, therefore, be considered with caution. In a separate study, the writer recently carried out an investigation into a rural community where several deaths had occurred due to dysentery, which were believed to be water related. The pathologist reports on the fecal analyses indicated that no pathogens were isolated.

It has been shown that, while the introduction of potable water has been successful in reducing mortality in children under five in developing countries, the impact on diarrhoeal morbidity (the subject of investigation) is questionable (Blum *et al,* 1983). In turn, the point prevalence of diarrhoeal disease, which is calculated as the proportion of individuals in a study (usually cross-sectional) who were reported to have experienced any phase of an episode of diarrhoea in a pre-determined period, has proved to be an inexpensive and effective indicator of measuring morbidity related to water and sanitation interventions (Thomas and Newman, 1992).

Etiology of acute diarrhoea among communities in developing countries

Water-borne diseases are typically associated with enteric pathogens that are transmitted via the fecal-oral route, either through infected food or contaminated water supply.

The extrapolation from one country to another of the importance of various pathogens potentially transmissible by water and their risk of infection is problematic (Grabow, 1996). However a systematic review of the etiology of acute diarrhoea in children (the segment of the population most vulnerable to diarrhoeal disease) in developing countries identified that the pathogens most strongly associated with disease was rotavirus, *Shigella* spp and *enterotoxigenic E. coli* (Huilan *et al*, 1991). Rotavirus are recognized as a major cause of severe gastro-enteritis in infants and children worldwide, and have been estimated to be responsible for up to 70% of hospitalizations for diarrhoea (Cook, 1990). This is also the case in South African studies, where the prevalence of rotavirus is the most important viral pathogen associated with sporadic gastroenteritis in hospitalized patients in South Africa (Wolfaardt, 1997).

In 1992, Taylor *et al* investigated two successive outbreaks of gastro-enteritis in South Africa to identify the etiological agents. Neither pathogenic bacteria nor parasites were evident in either outbreak. In both instances, SRSV UK3/Hawaii virus was implicated as the cause of diarrhoeal disease (Taylor *et al*, 1993).

While the prevalence of diarrhoea is accepted as an indicator of community health and the etiology of diarrhoeal disease is well described, the definition of diarrhoea and the confounding variables in measuring diarrhoea pose a great challenge.

Definition of diarrhoea.

If studies are to be accurately compared, all health indicators need to be precisely defined. A review of the literature on diarrhoeal disease reveals considerable variability in the definition of diarrhoea. Diarrhoea is not a single disease and has many different causes and etiologies. The use of different definitions has led to the mis-classification of the effects of the disease burden and has limited the comparability of many studies.

Whether community-based epidemiological studies of diarrhoea should rely on the mother's report or should be formulated by specific objective criteria (such as a specified number of loose/liquid/bloody/mucoid/watery stools-per-day) is a difficult issue on which to reach an agreement. Most would not argue against the notion that the mother of a child probably knows best when a child's bowel movement is "out of sorts" within the norm for a specific cultural setting. However, without a predefined definition, it is not possible to either compare or evaluate studies.

Baqui *et al* (1991) in comparing operational definitions of diarrhoea with mother's perceptions of diarrhoea, concluded that "three or more loose stools or any number of loose stools containing blood in a 24 hour period" was acceptable as the best definition for a diarrhoeal episode. Multiple episodes of diarrhoea were considered as distinct if separated by at least two diarrhoeal-free days.

2.3.3 Confounding variables and pathways in diarrhoeal disease.

This third area of debate is focused on the use of diarrhoea as an indicator to evaluate the health impact of an intervention. It has one considerable major draw back: there are many pathways that may lead to diarrhoea in a population and, unless these pathways are described and controlled for confounding variables, they will distort the study results. An understanding of all the pathways to diarrhoeal disease is necessary.

The ecological pathways and potential confounding variables to diarrhoeal disease are complex and inter-related. In many studies, researchers have identified pathways and risk factors that will cause diarrhoea, some of which are discussed below.

Molbak *et al* (1997) followed an open cohort of 1,314 children from Guinea-Bissau for three years, conducting weekly diarrhoea recall interviews. Fifty-seven possible pathway variables were considered. Seven were associated with an increased incidence of diarrhoea: male sex, being weaned from breast milk, not being looked after by the mother, head of household being less than 30 years old, eating cold left-overs, and drinking water from unprotected public water supplies. Molbak also identified previous diarrhoeal episodes as an important risk factor in the prevalence of diarrhoea. This has implication for the case-control methodology, which is the preferred methodology of present health impact studies. It is commonly found that "controls" for diarrhoeal disease studies develop diarrhoea and revert to cases, thus completely confounding the study (pers comm. Jagals, 1999). In selecting controls, one consideration should be that the individual has not had diarrhoea in the previous 12 months.

Malnutrition as a risk factor has been investigated in several studies and, in some, it was identified as a risk factor (Baqui, 1993), while other studies failed to find an association. Knight carried out a case-control study in rural Malaysia of risk factors for the transmission of diarrhoea in children aged 4-59 months. The risk factors identified were: drinking unboiled water, eating left-over food, bottle-feeding, animals inside the house, and the absence of water for washing hands after using latrines (Knight, 1992).

Further common confounding variables applicable to most epidemiological studies include: seasonal rainfall, socio-economic status, years of education of the main caregiver, birth order of the child, and the number of people living in the house (Knight, 1992).

The provision of a safe water supply is an important but not the only contribution in breaking the chain of diarrhoeal disease. There is the need however to ensure that the quantities, the quality and the manner in which water provision is introduced is contributing toward health improvement.

2.3.4 Bias in study surveys

This fourth area of debate is focused on study questionnaires and survey personnel, who must be vigilant if bias is not to be introduced in the study. While recall bias can be limited, the problems with manipulation and perception are more difficult to cope with.

Recall bias

In various studies, the recall period for questions related to diarrhoeal morbidity has varied between 24 hours and 12 weeks. Recall periods exceeding 48 hours are considered to be a methodological problem (Blum *et al,* 1983). It has been shown that the reporting of diarrhoeal disease decreases with the increase in days asked to recall information. In other words, when the recall period is more than three days, under-reporting of diarrhoea is to be expected. Several studies have found that the reported duration of episodes of diarrhoea were inaccurate and statistical analysis of the studies had to make adjustments for an increased number of diarrhoeal episodes reported as starting or stopping on or near the day of the interview in cross-sectional or longitudinal studies (Baqui *et al*, 1991; Boerma, 1991).

Cultural bias

The accuracy of response to health related questionnaires is dependent on the degree of cultural and personal shame associated with reporting positive results. For example, the issue of regarding HIV/AIDS as a notifiable disease is problematic because, if the true response is perceived to be shameful, inaccurate responses will cause studies to be erroneous (Colvin, 1998). In the same way, if communities associate the presence of diarrhoea in their family to reflect negatively on the cleanliness of the individual or household, erroneous answers will be recorded and studies will be biased.

In addition, individual risk of exposure can affect self-reporting of symptoms by as much as ten-fold, especially when the individual has a preconceived notion of risk associated with the exposure (Fleisher, 1997).

2.3.5 Project design

The fifth and last major area of debate focuses on project design. Epidemiologists study the occurrence and cause of disease in human populations and apply this knowledge to the prevention and control of health problems. Conversely an intervention, such as the development of a water supply scheme, is perceived to be a possible disease control mechanism and environmental epidemiologists have attempted to quantify this. Observational and experimental epidemiological studies are both used to determine associations between water interventions and health outcomes (Black, 1996). He also suggests that the promotion of experimental methods at the expense of observational methods (analytical case-control and cohort) has limitations.

Environmental interventions are problematic to evaluate. While randomized controlled trials are regarded as the best methodology to use, interventions such as the introduction of a water supply scheme are not always introduced on a random basis. Economic, political, environmental and even health considerations impact on the decision of where and when to build a water supply scheme. It is however important that these confounding variables be identified and controlled.

As previously stated, descriptive disease surveillance surveys, analytical cohort and cross-sectional studies have been criticized as producing meaningless results in trying to evaluate the effectiveness of water supply interventions and case-control studies became the preferred methodology. The criticism is based on the lack of adequate control, one-to-one comparison, failure to record facility usage and failure to analyze by age (Cairncross, 1999).

Many studies have failed to provide adequate controls (Blum *et al*, 1983). Without adequate controls, the benefits or impacts identified as an outcome cannot necessarily be associated with the intervention under study. In addition, the comparability of the control and the sample under study must be established. Baseline studies may be required to assess the situation prior to the introduction of the study. Failure to do so will result in many confounding factors rendering the results of the study useless (Blum *et al,* 1983).

One-to-one comparison is a common methodological error in evaluating the impact of water supplies on health (Blum *et al*, 1983). To minimize costs, a single village with the intervention is commonly compared with the village prior to the installation of water reticulation. Unless households within the village are independent and the implementation of reticulation can be shown to not be village-wide, several clusters of the intervention need to be compared with several clusters without the intervention.

2.4 Review of the Situation in South Africa

Developing countries bear a heavy burden of diarrhoea where, on any given day, 10% of all children aged 0 to 4 years will be suffering from diarrhoea (Cairncross, 1990). Diarrhoea and other water related epidemics in the developing nations are typically blamed on polluted river and ground water resources, as this are the source of most drinking water. In the developed nations, waterborne epidemics are blamed on poor or negligent water management.

South Africa lacks a comprehensive surveillance system for diarrhoeal disease and, hence, there is little accurate information available on the prevalence of water-borne diseases in the country. Recent work by Pegram *et al* (1997) indicates that diarrhoeal disease in South Africa annually causes about 43,000 deaths, 3 million incidences of illness requiring treatment, and a cost of at least R 4 billion (Pegram *et al*, 1997). However, it may be expected that the risk of waterborne disease in South Africa is no different from any other country and, possibly, may be higher, due to pollution of the limited water sources and the dependability of many rural communities on those polluted water sources (Grabow, 1996)

The legacy of skewed resource allocation throughout South Africa's history has resulted in a society where development is not homogenous. Large sectors of the population still live in conditions with no formal water supply and unimproved sanitation (Netshiswinzhe, 1999). Such conditions contribute to illness and death. Cultural beliefs and poverty have kept communities from addressing these environmental causes of morbidity and mortality.

Following the election of South Africa's first democratic government in 1994, the Reconstruction and Development Program (RDP) was established to redress the lack of development within rural communities. The government response to the demand for potable and accessible water supplies became an important cornerstone of the RDP. This led to the construction of water supply schemes in many areas of South Africa, through which over 1 million more people will have access to potable water. Recent studies carried out by the Mvula Trust (Breslin, 1998) suggest that there is a need for a post construction audit process, as these water schemes have not extended the full benefit to the communities that they were designed to serve.

The South African White Paper on Water and Sanitation Supply (DWAF, 1994) defines the minimum level of service for water supply as follows:

- the nearest water supply point must be located within 200 m from an individual's dwelling
- the water should be available on a regular basis.

Most schemes have aimed to provide 25 litres per day per capita. However, there is little consideration for population density and often many people have to access a single standpipe. No education is provided on the problems associated with water storage. Unlike sanitation projects, the water supply intervention is seldom approached with a discussion on technical choices in water supply design. Decisions about how to build water supply schemes, where to positions taps, and the quantity of water to design for are usually desk-top studies with little community consultation (Breslin, 1998). However, these factors will clearly affect the water management and subsequent health of the community.

2.5 Concluding Remarks in Regard to Literature Review.

Most studies on the effects of water supply on human health over the past fifty years have been criticized as to their validity and usefulness. Lack of adequate control, poor project design, many confounding variables, cultural bias, health indicator recall, health indicator definition, failure to analyze by age and failure to record facility usage have been sited as rendering study results meaningless. The World Bank has suggested that financial support for further such epidemiological studies is not recommended. Eminent researchers in the field, such as Cairncross, are equally skeptical. While instinctively it is accepted that water and sanitation do improve health, there are many opinions as to how and why.

It has been proved that the quantity of water has a greater impact on health than water quality. An improvement to the proximity of water supply (piped water) not only increases the quantity of water used, but also removes the need for water storage, which may in turn reduce the proliferation of disease bearing vectors such as mosquitoes and flies.

Developing countries bear a heavy burden of diarrhoea where, according to Cairncross (1990), on any given day, 10% of all children aged 0 to 4 years will be suffering from diarrhoea. Diarrhoea and other water related epidemics in the developing nations are typically blamed on polluted river and ground water resources, as this are the source of most drinking water. In the developed nations, waterborne epidemics are blamed on poor or negligent water management.

Because of the varied results of international research in this field, more South African research is required to:

- Establish health criteria for consideration in the auditing of water supply schemes

- Establish the extent of diarrhoeal disease in the rural areas

- Identify the risk factors to diarrhoeal disease, which are extensively associated with the water resources and which are expected to improve with investment in water supply schemes.

The latter two factors provide the key objectives for this study.

CHAPTER 3: STUDY SITES AND RESEARCH METHODOLOGIES.

The Mpolweni and Vulindlela areas are both situated in the KwaZulu-Natal Midlands (see fig. 1b). This chapter provides the background, history and description of each site, and then examines the different methodologies being used in the health impact studies in each of the areas. The baseline surveys (the subject of this dissertation) for each area are then described.

3.1 Mpolweni: Background, History and Description

3.1.1 Objectives of the Mpolweni study.

The aim of the Mpolweni study is to evaluate the impact of the provision of a reticulated water supply on the health of the Mpolweni community. The baseline analysis was carried out in January-February 1997. Following completion of the water supply scheme in 1999, it is anticipated that a follow-up survey will take place, possibly in January 2001.

The objectives of the baseline study were to:

- Establish the summer incidence and prevalence of diarrhea in Mpolweni prior to the installation of the water supply scheme
- Examine the pathways to diarrhoeal disease in the community
- Quantify the cost of diarrhoea to the community.

3.1.2 Study site selection

A survey of potential Umgeni Water supply schemes was carried out and Mpolweni Water Supply Scheme was selected based on:

- The certainty that funding had been secured, and that the building of the scheme was imminent
- The relative safety of the area, amid unrest in the rural areas of KwaZulu-Natal
- The size of the scheme would ensure that all community members had access to water supply
- The isolated nature of the site, so that external factors and influences would have limited effect.

3.1.3 Background

Mpolweni, a rural community formerly known as Mpolweni Mission, lies in the southwest quadrant of the New Hanover Magisterial District, 35 km north of Pietermaritzburg on the New Hanover-Greytown Road in KwaZulu-Natal. The area lies at the confluence of the Mshwati, Mpolweni and Umgeni rivers. These rivers are the main source of water during the dry winter months.

3.1.4 History

The history of Mpolweni is briefly reviewed to provide a clearer understanding of the factors which have influenced Mpolweni's current situation.

The Mpolweni land is owned by the Reformed Presbyterian Church, which was formally part of the Church of Scotland. Residents had to meet strict criteria before being allowed to settle on the land. They had to be Presbytarian, be married and have been married in a Christian ceremony. Tenants paid R80 per year in rent for 1 acre of land. The land parcels were large enough to build a dwelling and to provide sufficient space for subsistence farming (Mngadi, 1998).

Negotiations are currently underway to hand over this land to the people of Mpolweni. Although not under tribal authority, the work of the development committee was facilitated by Chief Mngadi, until his recent death in August 1999. The management of the area is now in a state of flux and it is possible that a municipal structure will be established (Manzi, 1999).

Prior to 1990, residents enjoyed a reticulated water supply, for which they paid R60.00 per year (McKerrow and Verbeek, 1990). The water supply was discontinued in 1990 due to faction fighting in the area and the destruction of water supply infrastructure (Espey, 1997). Residents have since relied on river water from the Mgeni, the Mpolweni and the Mshwati rivers. During the rainy season many residents utilize water accumulated from roof runoff into water tanks.

3.1.5 Site Description

Built Environment

The 1996 population census for Mpolweni indicates that 3 497 people live within the boundaries of the area, which covers 2 200 hectares (SSA, 1998). There are 639 registered households divided into seven villages: Hlope/Newton, Mhlangeni, Mvundlweni, Mkhangala, Mseni, Ekukhuleni, and Thornton/Matshalini.

Mpolweni has one high school, two junior schools (higher and lower primary), five nursery schools, one mobile clinic, one community centre, three well established churches, and two small grocery stores.

Application has been made for a permanent clinic. The economic status of the area is low. A study in 1994 indicated that there was an unemployment rate of 75 % (McKerrow and Verbeek, 1995).

3.2 Methodogy of the Mpolweni Study

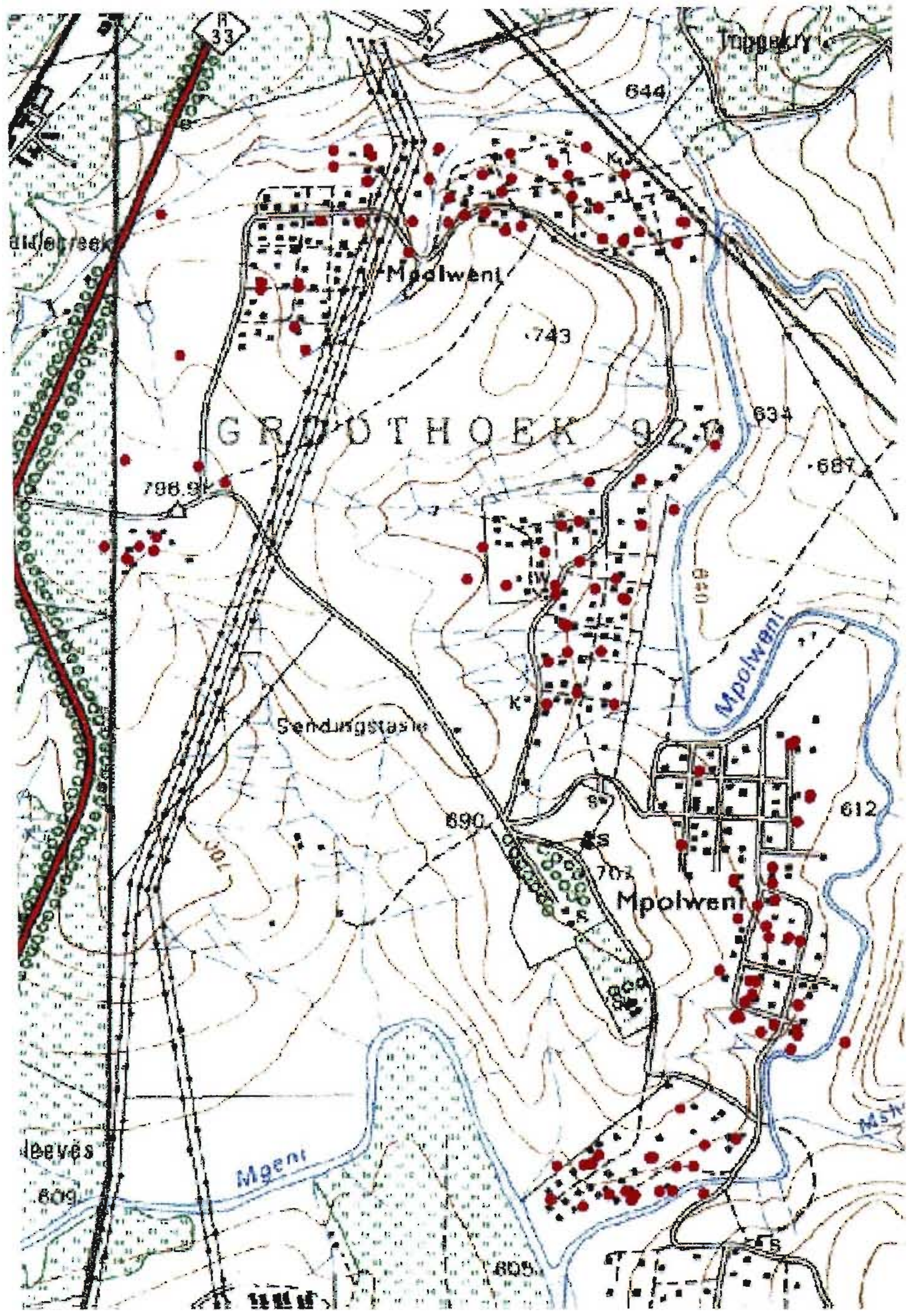
3.2.1 Study design

An observational cross-sectional study design was adopted. Cross-sectional studies are often used as a basis for public health planning with the advantage that they are relatively quick and inexpensive to carry out compared to case-control or cohort studies. Also called prevalence studies, cross-sectional studies are able to measure several exposures[5] and are the most convenient 'first step' in an investigation into the cause (Beaglehole and Bonita, 1993).

A combination of quantitative and qualitative methods was used for the research. The qualitative research methodology combined observational surveys (see appendix 1) together with photographic recording of household infrastructure. The quantitative data (see appendix 2) was gathered in the form of a structured questionnaire, with both open-ended and closed questions.

[5] An exposure is a factor in the environment with which a person comes into contact.

3.2.2 Mpolweni Sample Size



Indicates location of households sampled.

Fig 3a: Map of household sample distribution in Mpolweni.

In cross-sectional studies, the sample size depends firstly on the desired level of statistical significance of results, and secondly on the desired power of the study. In this study, it was decided that a 95% confidence interval with a margin of error at 5% was statistically significant.

The sample unit was identified as the dwelling. At least 180 out of a possible 639 dwellings needed to be included in the study. Sample households were identified using random selection on a 1: 10,000 ortho-photo map, from which 181 numbers were selected and the dwelling closest to each number was visited (fig 3a).

3.2.3 Data collection

The Mpolweni baseline survey was carried out over a two-week period in January 1997. January was identified as the optimum month in which to sample, as it is the period during which most diarrhoea cases are reported.

The surveys were carried out by three teams, each of two people. One person in the team was responsible for conducting the questionnaire. The questionnaire was administered in face-to-face interviews with a permanent mature adult; preference was given to the head female of the household, thought to be most familiar with the health of the residents of the household. The questions were asked in Zulu. The second person simultaneously at the same household assembled observational information. Pictures were taken of the house and toilet. The location of each home was identified with a geographic position system. The duration of each household visit was approximately 45 minutes. The teams worked systematically through the villages.

3.2.4 Water sampling

Although not initially part of the project, it was later decided that water quality samples of the household containers should be collected at a selected number of households. Twenty-five households were randomly selected by the survey personnel and water samples were taken from household containers and processed for analysis. The samples were analyzed for Coliforms, *E Coli*, and *F Streptococci* by Umgeni Water Analytical Services. As these samples were not representative of the study population, the results are considered to offer qualitative information on the microbial contamination of the stored water.

3.2.5 Data capture and statistical analysis

Data was coded and captured using Microsoft Excel program. Umgeni Water contracted Dr Fethi Ahmed from the University of Natal to oversee the analysis of the Mpolweni data.

3.3 Vulindlela: Background, History And Description

3.3.1 Background

Vulindlela is a rural area situated approximately 20km southwest of Pietermaritzburg. It covers an area of approximately 260km^2 with a population of 200,000. Vulindlela, which means "open the way", is made up of five tribal areas, namely: Mpumuza, Inadi, Nxamalala, Mafunze and KwaXimba. Each area is governed by an Amakhosi (Chief) with a tribal council.

The Vulindlela Water Supply Scheme is a Presidential Lead Project, one of twelve identified in 1994 as priority projects under the RDP program. The goal of the scheme is to provide a sustainable water supply of approximately

25 litres per capita per day within 200m of every homestead. The total cost of the scheme was estimated at R 200 million. The expected completion date was June 1999. In late 1999, the scheme was almost complete, though the connection to the reticulation line was still in progress.

The development of the scheme was carried out by Umgeni Water, in partnership with an executive steering committee made up of 14 members representing the 50 Vulindlela local water committees. All development decisions were made by this steering committee. It was also responsible to provide a liaison between the development/construction teams and the community at large.

The source of the water is the Midmar dam and the Midmar Water Works, which is also the supply point for the city of Pietermaritzburg and surrounding areas. Of special note is the size of the Vulindlela Water Supply Scheme which comprises the Groenekloof Pumpstation;nineteen reservoirs; 25 km of rising main and 68 km of gravity main (bulk lines); telemetry links between Midmar Works, the pumpststion and five reservoirs; 374 km of reticulation pipe work in twenty reticulation zones; and thirteen branch offices where water bills are paid.

The Vulindlela Health Impact Assessment (HIA) Project is an extensive eighteenth month study funded by the Water Research Commission to evaluate the impact of the water supply scheme on the health of the Vulindlela community.

3.3.2 History

The Vulindlela district was first demarcated in 1846 and consisted of four wards each under the control of a chief. These wards were in turn divided into sub-wards headed by indunas who are responsible to the chief. The land tenure system is along traditional grounds lines, although there is some evidence of decay (Alcock, 1988).

3.3.3 Built environment

Travel in Vulindlela is facilitated by the tarred road linking Pietermaritzburg and Bulwer, which is supplemented by graded gravel roads, together providing access to most areas. Busses and minibus-taxis are the main means of transport. The area is serviced by electricity, as well as telephones. There are several elementary and secondary schools and a network of clinics providing education and health care respectively. There is no industrial activity and a few small stores provide basic provisions.

The area comprises mixed settlement and grazing, mostly cattle and goats. Small-scale subsistence farming is scattered amongst residential wattle and daub homes. Commercial forestry constitutes a small area and is mainly located in the area adjacent to the Pietermaritzburg–Bulwer road.

3.4 Methodology of the Vulindlela Study

3.4.1 Study design

The Stepped Wedge Design was suggested as an appropriate study design for the Vulindlela Study (Colvin, 1998), due to the progressive nature of the development over time, see fig 1c. Confounding factors are minimized through the selection of settlements located in the same area. Characteristics, such as the sanitation infrastructure, quality of the local water resources, topography, natural physical characteristics, distance from urban areas, settlement density, socio-economic levels, demographic and educational profile characteristics are expected to be similar.

The analysis of data in any column in fig. 1c can be considered an observational cross-sectional study of a sample of four locations in the Vulindlela area. The analysis of the data over the period of the year (i.e. in each row of the table above) would be a longitudinal study of that population cluster.

The power of this methodology clearly lays in the combined analysis both longitudinally and cross-sectionally. Although there are only four clusters in the study, each cluster is being visited five times. Despite an extensive literature search no information could be found on the stepped-wedge-design being used on a non-medical trial. Only one reference was found for a hepatitis vaccination trial in Gambia in 1987 (Gambia Study Group, 1989). And hence the present study is in many ways ground breaking.

3.4.2 Sample size and site selection procedure

The selection of households to be surveyed was based on a stratified random approach. The selection was stratified due to the location of clinics, accessibility of the area, advice of the Vulindlela Water Supply Scheme Executive Committee and most importantly the rate of the Vulindlela Water Connection Program. Within this stratified selection, the household choice was made randomly (see fig 3b).

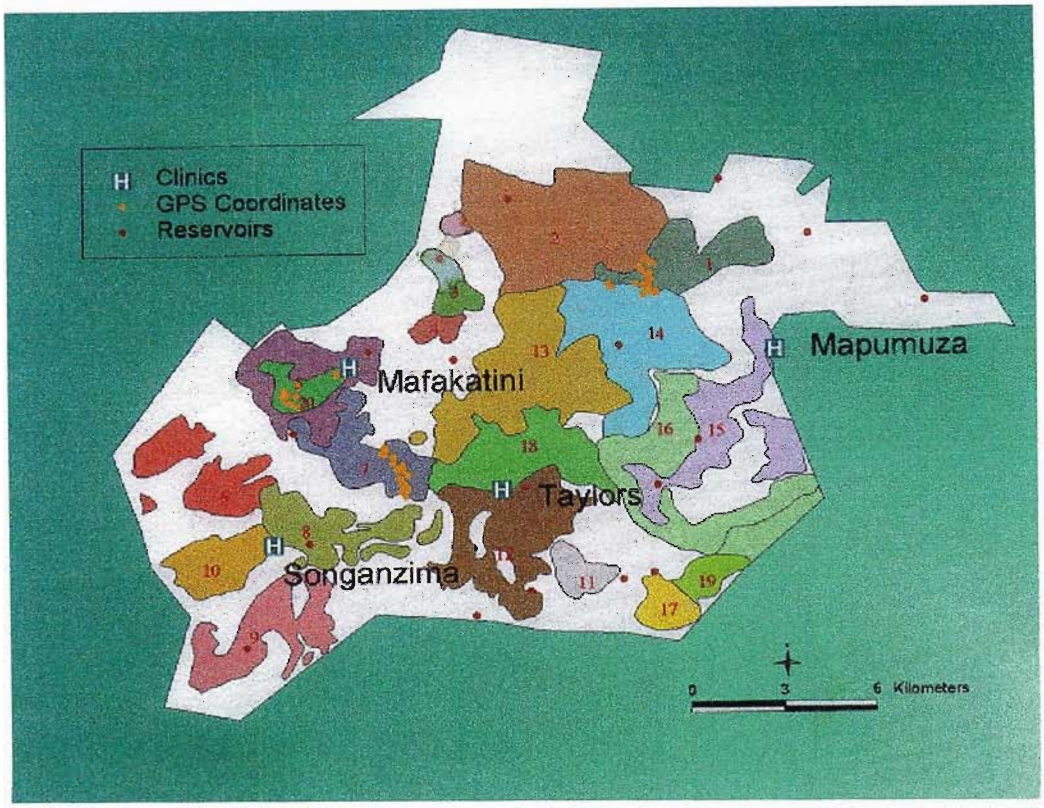


Fig 3b: Map of household sample distribution in Vulindlela

Indicates location of households sampled.

The number of households required for this project was based on an anticipated improvement in diarroeal prevalence of 15%[6] with a 95% confidence interval. The Epi-Info software package was used to process the data.

3.4.3 Data collection

A team of two research assistants was tasked to sample 100 households over a one-month period in January 1999. The first assistant, a Zulu speaking social scientist was responsible for administering the questionnaire (see appendix 4), which consisted of both closed and open questions. The same individual carried out all the questionnaire surveys, which provided

[6] The literature indicates that improvement in water supplies will result in a 15% improvement in the rate of diarrhoeal disease (Esrey *et al* 1996)

consistency and eliminated variability due to the researchers interpretation of answers to the questions. The questionnaire was administered in Zulu to the head female in the household. The surveys were based on a two-week recall period. The definition of diarrhoea was identified as: three or more loose/ liquid/ watery stools or any number of loose stools containing blood in a 24-hour period (Baqui *et al*; 1991).

The second research assistant carried out water sampling of the household container and, in the case where the water was carried to the household from a nearby source (a river, spring, communal tap or borehole), also sampled source. The water samples were stored at 5°C in a cool-box and transported to the Umgeni Water laboratory within 6 hours, where the analyses took place. A photographic record was made of the household and the sanitation infrastructure.

3.4.4 Water quality analysis

Water quality samples were collected from the storage containers and water sources of the 100 household sample in Vulindlela and transported in ice-coolers to the Umgeni Water Laboratory for analysis within 6 hours of collection. The samples were analyzed for Coliforms, *E Coli*, and *F Streptococci*. The analyses are considered reliable as Umgeni Water's laboratories and its methodologies are inspected and audited by independent auditors on an annual basis.

3.4.5 Data Capture and Statistical Analysis

The statistical unit of the Medical Research Council was responsible for the capturing and analysis of data. Epi-Info, a soft-wear package especially designed for epidemiological studies, was used to capture the data, which was transferred into the Statistical Analysis System version 6.1 for data analysis. The Chi-square, Students T-test and Fishers Exact test were used to analyse the data.

A probability of association was calculated (the p-value) to establish whether any of the variables surveyed could be considered as risk factors for diarrhoeal disease. A significance level cut-off of 0.05 was set. Any values lower than 0.05 were considered significant indicating a possible association that would need to be established through further research.

CHAPTER 4. RESULTS: SOCIO-ECONOMIC ANALYSIS.

The results of the baseline surveys are presented and discussed in three sections:

- The socio-economic situation in Mpolweni and Vulindlela (chapter 4)
- The prevalence of diarrhoea in Mpolweni and Vulindlela (chapter 5)
- The pathways to diarrhoea in Mpolweni and Vulindlela (chapter 6).

4.1 Mpolweni Situational Assessment.

Mpolweni, also known as Empolweni (meaning "a quiet cool place"), is appropriately named. It is a peaceful place where a population of approximately 5 000 people live on the banks of the Mpolweni and Umgeni River. The sample was 181 households, within which it was found that 1 481 people lived.

Mpolweni has a very stable population with only seven families (less than 5%) having moved into the area in the previous year. None of these recent arrivals live in shacks, an indication of the lack of informal infill housing and squatter settlements common to new entrants to many other areas in KwaZulu-Natal.

Indeed, when compared to South Africa (table 4.1), relatively few people live in shack dwellings, and 98% of the population live in homes constructed from one or a combination of, cement blocks, bricks and mud. The survey found that on average eight people were living in a household and that the average number of sleeping rooms per household was 3.8. The crowdedness index of 2.2 was calculated as the ratio of the number of people by the number of sleeping rooms per household in the study area. The number of people per household was found to be normally distributed, with 30% of the households being considered as over-crowded (more than 2 persons per sleeping room).

Table 4.1: Socio-economic indicators: Mpolweni and South Africa

(Community Agency for Social Enquiry, 1995)

Indicator	South Africa	Mpolweni
% of dwellings = shacks	9.5	2.27
Number of people per household	5	8
Average number of rooms per household	4	3.8
Crowdedness index	1.25	2.2
% of population five years old or less	16	11.37
% population older than 16	58.1	64
% with no formal education	15.1	17.54
Source of water = untreated river water	12.0	77.2
Toilet type = pit latrine	34.0	95

The age distribution of the sample from Mpolweni is represented in figure 4a. Mpolweni is considered an old population by South African standards. More than 64% of the population is older than sixteen in comparison to the South African average of 58%. The explanation for the relatively few young people seen in the study was that younger people had moved to the city in search of work (Mngadi, 1998).

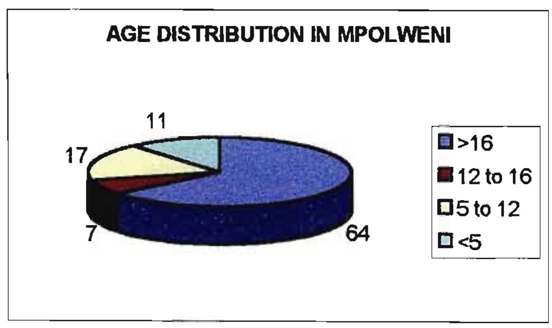


Fig 4a: Percentage Age Distribution in Mpolweni

The study found that the ratio of males to females in Mpolweni (see figure 4b) is similar to that recorded in the 1996 Census Statistics for KwaZulu Natal (SSA, 1998), with 54% percent of the population comprising women, which compares to provincial statistics of 52.7% female. As with most rural communities, it was found that generally women are the tenderers of the household water supply: 73.6% females vs. 26.4% male. Of those involved in the daily cooking regime, 85.5% are females and 14.5% males.

Of the sample population, 80% has had access to or is currently enrolled in primary, secondary or tertiary education. There is one high school and two junior schools located on a readily accessible gravel road in Mpolweni. The schools were found to be in a state of good repair, although few materials were available for teaching. Some rural schools have become the vent for community anger, with schools being trashed and scholars disruptive. This has not happened in Mpolweni, perhaps due to the influence of the church.

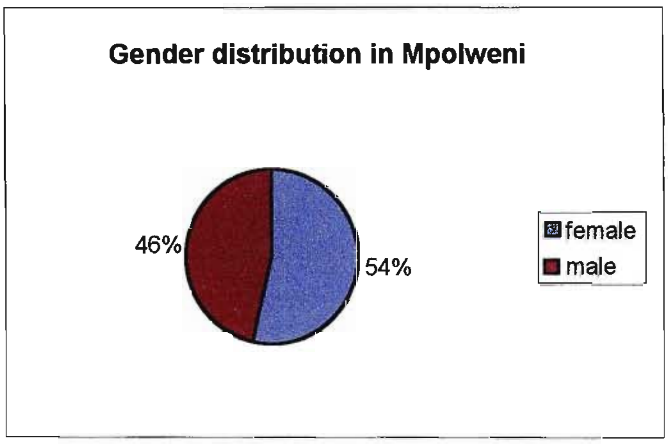


Fig 4b: Gender distribution in Mpolweni

Despite this good schooling record, 58.6% of the adults in the sample were unemployed. Mpolweni is located in an area that is surrounded by sugar farming and other agricultural enterprises that absorb some of the labor available from Mpolweni. The nearest industrial base is Pietermaritzburg, which itself has had closures in many small industries. Data on the average household income was not collected.

4.2 Vulindlela Situational Assessment

Vulindlela, meaning "open the way", is a rural area skirting greater Pietermaritzburg where the influences of urban life are being felt.

On average, each household comprises six persons, somewhat lower than the eight found in Mpolweni. The total number of people living in the 100 households sampled was 602 and the household density (crowdedness index), calculated in the same way as for Mpolweni, was found to be 1.3.

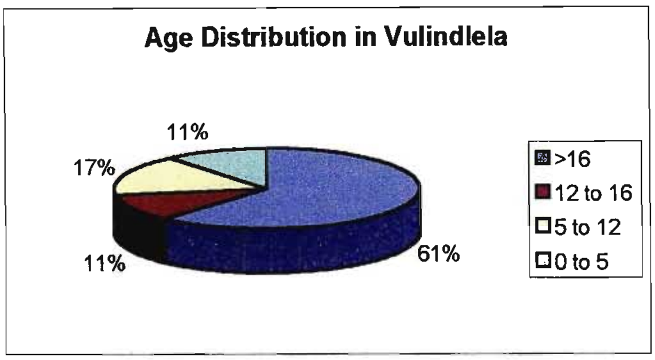
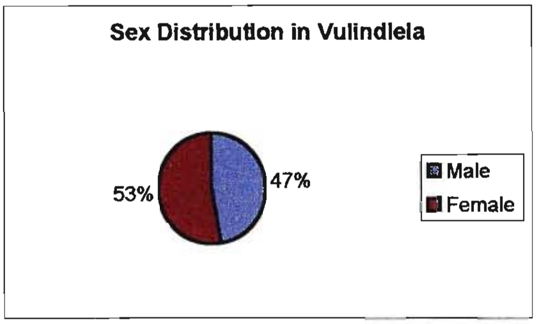
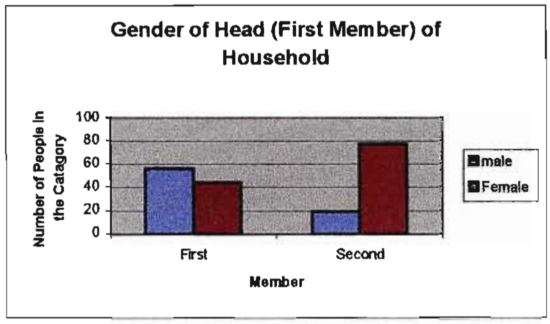


Figure 4c: Age distribution in Vulindlela

The age distribution in Vulindlela, as depicted in Figure 4c, is very similar to that found in Mpolweni. It is surprising to note the uniformity in the working age population (that older than 16 years of age) in KwaZulu-Natal. The age group that does differ between the two areas is the 12-16 year old group (i.e. those now at high school). One possible explanation is that, during the 1980's, Mpolweni experienced unrest resulting in a permanent breakdown of a previous water reticulation scheme and disruption to family life. The situation in Vulindlela was less volatile, possibly due to a greater homogeneity in political affiliation. With regard to gender, the study found that 53% of the population in Vulindlela are female and 47% are male.

In 56% of the households in Vulindlela, the head of the household is male. In 77% of the households, a female holds the position of second member of the household (fig 4d).





Figs 4d: Gender distribution in Vulindlela

The study found that at least 80 % of the sample had some form of education, while 9% had not attended any form of formal education. However, this includes those family members who have not yet reached school going age.

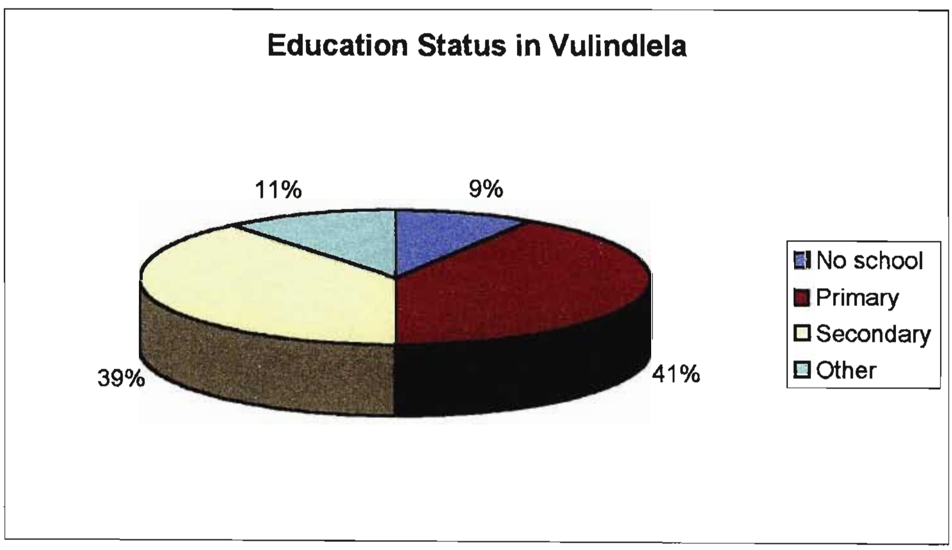


Fig 4e: Educational status in Vulindlela

The "other" category possibly includes those currently in tertiary education (Fig 4e).

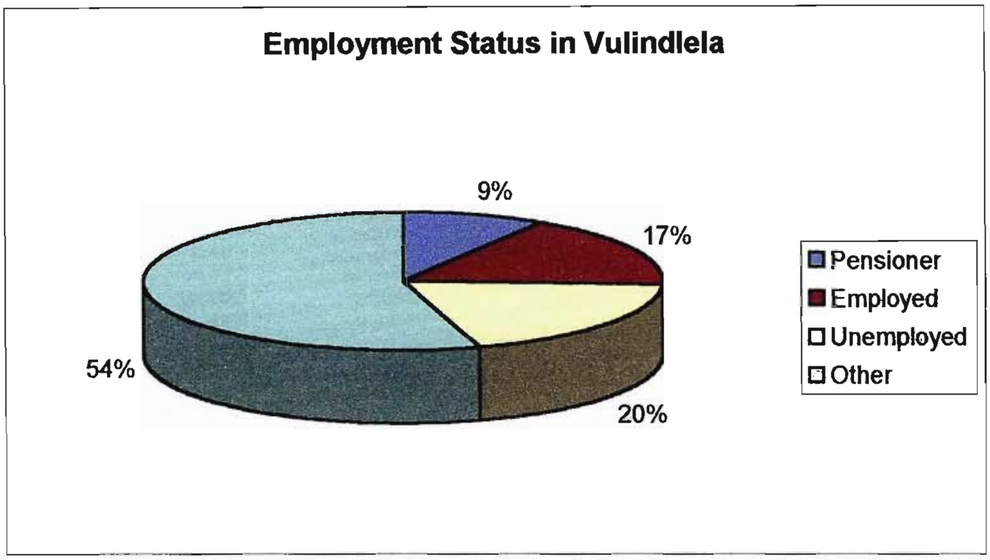


Fig 4f: Employment status in Vulindlela

Of the people sampled, 17% had employment of some type and included those who were formally self-employed formal, hawking, casual employed and permanent employed. It appears that the income from this group and the 9% who are pensioners support the remainder of the population. The people who are classified in the "other" category include those attending school, homemakers and those who were not employed or pensioning, but did not classify themselves as unemployed. The survey reported that the average household income was R522.

No families in the Vulindlela sample live in shacks. This is not surprising as the sample was stratified for those families who had applied and paid for their water connection, suggesting that the sample is possibly biased in favor of the more established members of the community. The majority (78%) of homes were made in the modern rural tradition using wattle, daub and mud blocks with galvanized iron and tin roofs. Other parameters include: 54% kept chickens, 28% kept cattle, 26% kept goats, and 57% kept dogs in or around the property. Nearly all the households had situated their pit latrines an average of 22 meters down slope of their own dwelling, an indication that there was an understanding of the health hazards associated with a toilet located upslope of the house.

CHAPTER 5: RESULTS: PREVALENCE OF DIARRHOEA

The measures of disease frequency are based on the fundamental concepts of prevalence and incidence. Epidemiologists have not come to complete agreement on definitions for these terms. The definition used in these studies is that used in the Dictionary of Epidemiology (Last, 1988), viz: the prevalence of diarrhoea is the ratio of the number of people with the disease to the number of people in the population observed at that time. Morris *et al* describes the "point prevalence" as the cross-sectional distribution of the burden of disease on a population. The population at risk for contracting diarrhoeal disease is taken as the whole study population.

5.1 Definition of Diarrhoea

As described in section 2.3.2, literature on diarrhoeal disease revealed considerable variability in the definition of diarrhoea. Diarrhoea is not a single disease and has many different causes and etiologies. The use of different definitions has led to the mis-classification of the effects of the disease burden and has limited the comparability of many studies. Multiple episodes of diarrhoea were considered as distinct if separated by at least two diarrhoeal-free days.

For Mpolweni, the questionnaire was silent on a definition of diarrhoea whereas, for Vulindlela, the baseline survey defined diarrhoea as three or more loose/ liquid/ watery stools or any number of loose stools containing blood in a 24-hour period (Baqui *et al*; 1991).

5.2 Prevalence of Diarrhoea at Household Level

Before carrying out the baseline study, Umgeni Water had already conducted a preliminary survey in January 1996 in Mpolweni (Espey, 1996). Statistical analysis of the results indicated that 56.4% of households had experienced at least one case of diarrhoea, 88% of households were dependent on untreated river water and that 35.8 % of households practiced some form of water sterilization. Yet, with a 95% confidence level, the study also identified no significant difference in the incidence of illness between those dependent on river water and those not dependent on river water. It was felt that, due to the high reported prevalence of diarrhoea and the dependency of most of the households on a single source of water, Mpolweni would provide a suitable location to evaluate whether a water supply scheme would reduce the prevalence of diarrhoea in a community (Espey *et al*, 1996).

The more rigorous baseline survey, on which this thesis is based, was carried out prior to the installation of the water supply scheme in January 1997. As the bulk infrastucture was already under construction, this may have introduced a study bias. The 1997 survey took greater cognizance of epidemiological principles, such as sample size, questionnaire design, and confounding variables.

The baseline survey found that slightly fewer people, 77.2 % of the population, were using the river as a source of water than in the preliminary study. However, in general, the results of the baseline study were remarkably similar to the preliminary study: 49% of the households reported having had one or more cases of diarrhoea in that household over the previous 6 months. The occurrence of a single case of diarrhoea per household is of the highest frequency. In one household, eight cases of diarrhoea were recorded.

The Vulindlela study differed from the Mpolweni study in that families were asked to report on incidents of diarrhoea in the household over the previous two weeks, rather than the previous six months. The baseline study in Vulindlela reported that 40.4% of the households had at least one member of the household experiencing diarrhoea in the previous two weeks. This is surprisingly similar to the results from Mpolweni, notwithstanding the time difference. This may, in turn, suggest that the results are affected by recall bias.

As there are no data on the full extent of diarrhoeal disease in South Africa, there is little basis for comparison of the above findings at the household level. In the World Health Report of 1997, the World Health Organization indicated that diarrhoeal disease is the leading cause of morbidity in all age-groups, with over 4 billion episodes occurring annually world-wide (WHO, 1997).

5.3 Prevalence of Diarrhoea at Individual Level

At the individual level, 191 persons out of a sample of 1 470 in Mpolweni had reported having diarrhoea at some point in the six months prior to the survey. The prevalence rate for diarrhoea in Mpolweni is therefore 13%.

In the Vulindlela survey, each household member residing in the home was listed and the respondent was asked whether that person had experienced diarrhoea in the previous two weeks.

The results indicate that 10% of individuals in Vulindlela had had diarrhoea in the previous two weeks (see Fig 5a). There may be some degree of under reporting in this survey, as it was found that in households with more that 9 persons, no one from the 10th member to the 20th member

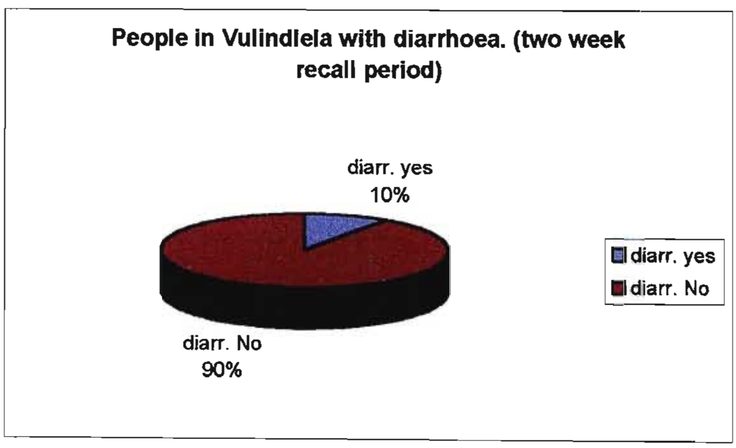


Fig: 5a Percentage incidents of diarrhoea in Vulindlela.

had had diarrhoea (see fig 5b). This is also of concern as many of these household members fall into the vulnerable group (0-5yrs) for diarrhoeal disease. It is possible that the survey was too lengthy, the respondent lost interest and/or the recall of detail on younger household members is vague.

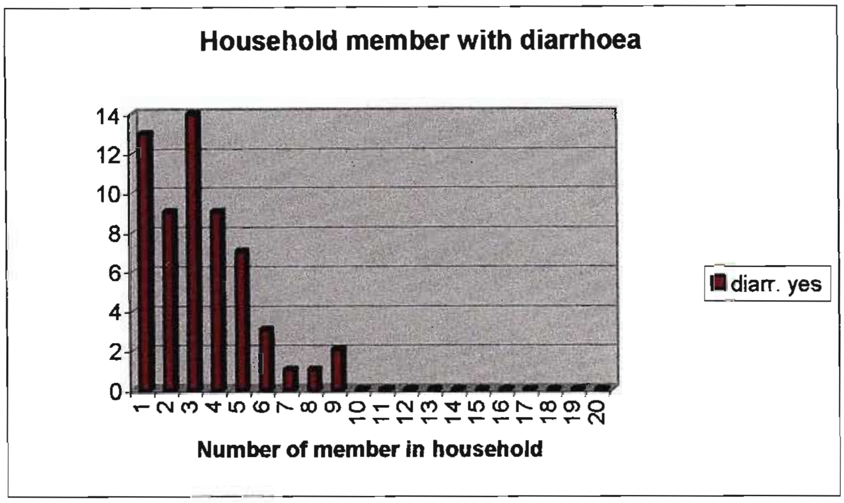


Fig. 5b: Reported household diarrhoea by members in Vulindlela

5.4 Prevalence of Diarrhoea in Children Aged 0 to 5 Years Old.

Several studies have examined the prevalence of diarrhoea in the age group of children under five (Wittenberg, 1997). One of the larger studies (Esrey, 1996) involved data collected from eight developing countries in Africa, Asia and South America. It was found that on average one in six children in this age group was experiencing diarrhoea at any point in time. Table 5.1 depicts the findings for the three African countries. On average, there is a 19.8% prevalence of diarrhoeal disease in children under five in these countries.

Table 5.1: Prevalence of Diarrhoea in African Children under five (Esrey,1996)

Country	Sample size	Prevalence %
Ghana	1615	17.3
Uganda	1944	18.1
Morocco	1929	25.1

Figure 5c depicts the results of the Mpolweni study. It was found that 20.1 % of children between the age of zero and five years were reported as having diarrhoea in the six months prior to the survey.

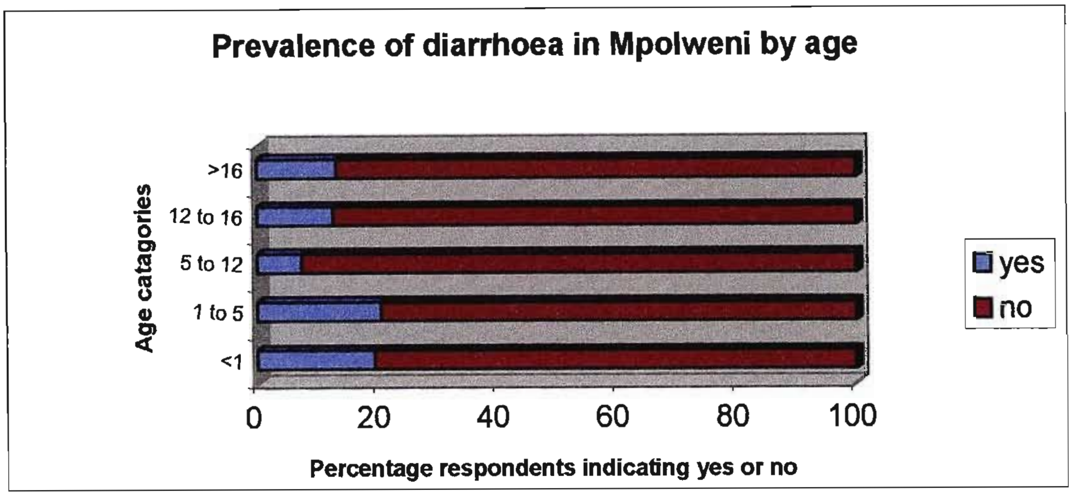


Fig 5c: Prevalence of diarrhoea in Mpolweni by age

In Vulindlela, the households were asked to recall incidents of watery and bloody diarrhoea in the children aged birth to five years over the two weeks prior to the survey. Of 126 children of this age in the study population, 31% of the households had one child, 15% of households had two children, 4% of households three children and one household had four children between zero and five years.

The study found that there were eight incidents of bloody diarrhoea, affecting eight different households; and thirty-four incidents of watery diarrhoea affecting eighteen different households. The prevalence of diarrhoea in Vulindlela in this age group was found to be 21.3% (see fig. 5d). The prevalence of diarrhoea in the two study populations in children less than five years old is remarkably similar.

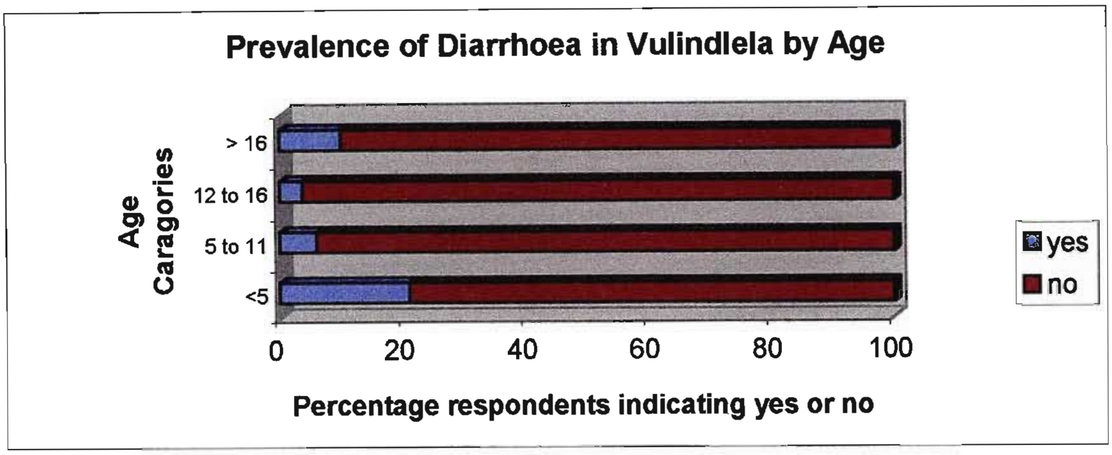


Figure 5d: Prevalence of Diarrhoea in Vulindlela by Age

To test the association between diarrhoeal disease and age the Chi-Square test was applied. For Mpolweni $p=0.005$ and for Vulindlela $p=0.004$ and hence the studies indicate a significant association between diarrhoea and age, with the most vulnerable group being children below the age of five.

The Cochran-Armitage Trend Test was applied to the Vulindlela baseline data. There is a decreasing trend of diarrhoea as age increases (trend test statistic = -1.214), but this trend could not be shown to be significant ($p= 0.250$).

5.5 Prevalence of Diarrhoea by Gender and Age

In regard to Mpolweni, of the reported cases of diarrhoea 68.1% were female. There is a noticeable difference in the prevalence of diarrhoea amongst boy and girl babies: the prevalence of diarrhoea in girls less than one year old is higher than for any other age, while the prevalence of diarrhoea in boys less than one year old is less than for any other age. See fig. 5e below.

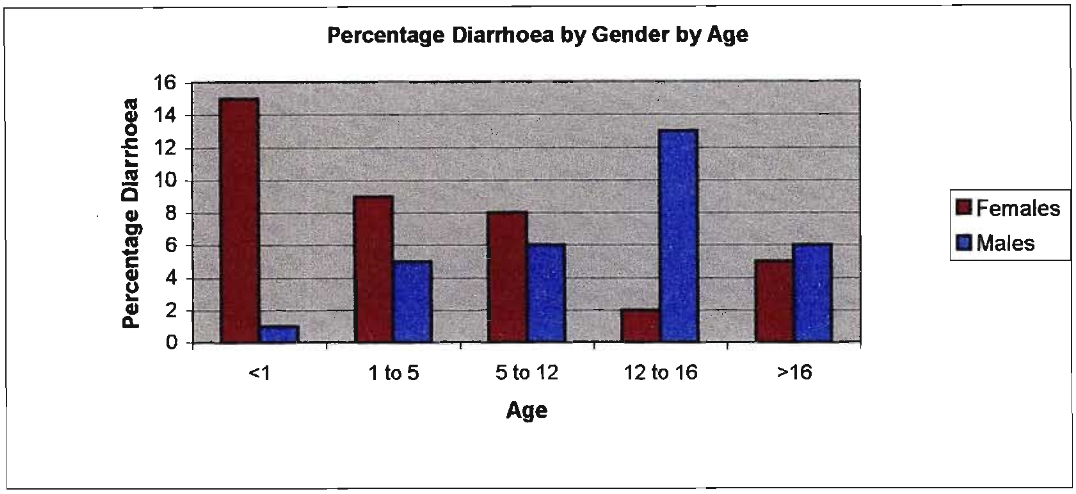


Fig 5e: Prevalence of diarrhoea in females and males by age in Mpolweni

One explanation for this difference is that boy and girl children are not treated the same. A discussion at the 1997 South African International Conference on Environmental Health (where some preliminary results were presented) Dr. Ruth Shabalala, WHO Environmental Director for Africa, indicated that in many communities boys receive better care from mothers than do girls and that this trend had been seen in other developing country studies (Shabalala, 1997). This is however speculative and the Mpolweni study was unable to apply any measure to support or challenge this theory. In fact, in Vulindlela, the multivariate analysis comparing diarrhoeal disease by gender and age presented a somewhat different picture (Fig 5f).

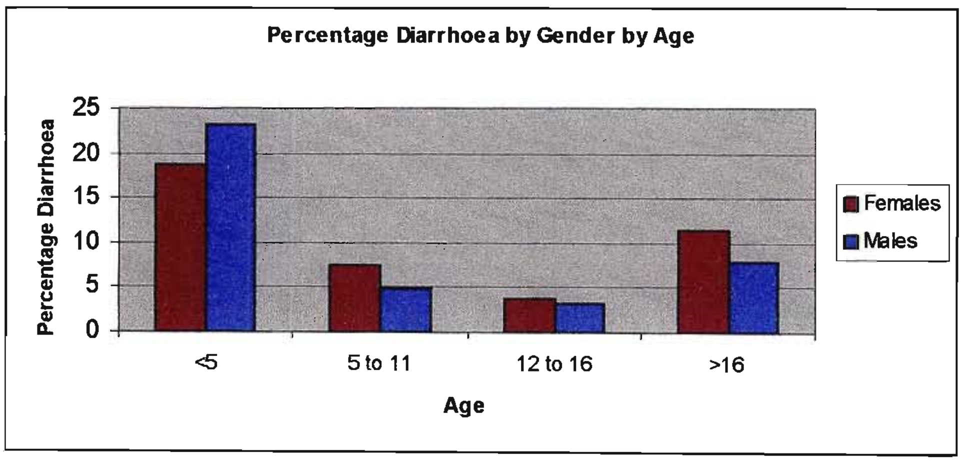


Fig. 5f: Prevalence of diarrhoea in females and males by age in Vulindlela

Males in the age group less than five years showed a higher prevalence of diarrhoea than females.

The Vulindlela study covered four tribal wards. The issue of diarrhoeal prevalence by gender and age was considered in each ward (table 5.2) and found not to be significant (table 5.3).

Table 5.2: Number of cases of diarrhoea by gender and age group in each ward in Vulindlela

Age group		< 5			5 to 11			12 to 16			> 16			Total by area		
Gender Breakdown		Male Yes	Female Yes	Total Sample	Male Yes	Female Yes	Total Sample	Male Yes	Female Yes	Total Sample	Male Yes	Female Yes	Total Sample	Male + Female Yes	Male + Female No	Total Sample
Areas Sampled	Lower Khobongwane	2	1	14	0	1	24	0	1	19	2	4	87	11	133	144
	Mafakatini	3	2	15	1	1	32	1	0	10	6	6	101	20	138	158
	Mthoqotho	0	2	19	0	1	26	0	0	11	2	5	90	10	134	146
	Shange	2	1	14	2	0	19	0	0	16	3	10	105	18	136	154
Total by age		7	6	62	3	3	101	1	1	56	13	25	383	59	541	602

Table 5.3: Results of multivariate analysis of Vulindlela study areas

Area	P Value
Khobongwane	0.39
Mafakatini	0.74
Shange	0.58
Mthoqotho	0.06

5.6 Seasonality of Diarrhoea

When considering the prevalence of diarrhoea at the household level in Mpolweni, 44.1% of the diarrhoea was reported as occurring during for the month of December 1996, the month prior to the survey; 18.4 % of the cases were reported for January 1997; and 17.8% of the cases for November 1996. Figure 5g shows the distribution of diarrhoea according to months of most illness. In the Mpolweni survey, the seasonality question was an open one and the respondent was simply asked to state the month in which each individual in the household had had diarrhoea. One problem with this approach is that the ability for a person to recall diarrhoeal disease events accurately over time is questionable.

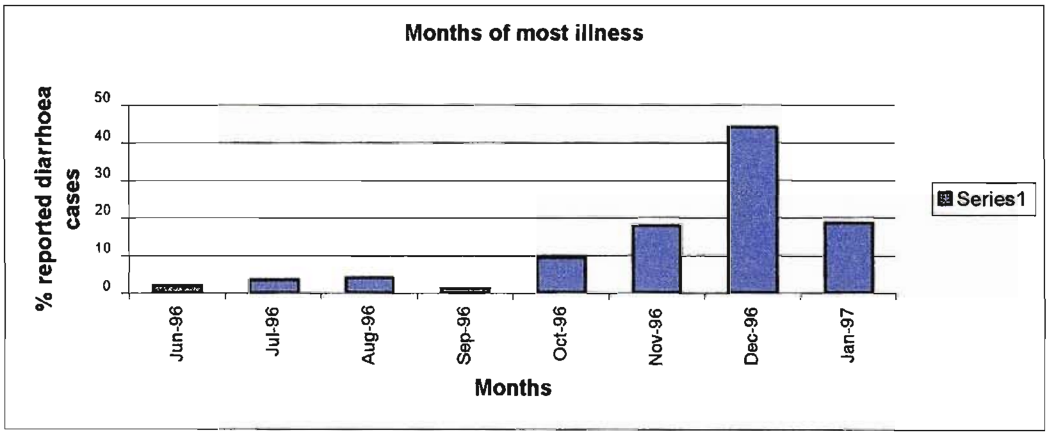


Fig. 5g: Seasonality of diarrhoea in Mpolweni

A slightly different approach was adopted for the Vulindlela study. The following closed question was posed: Is there any particular time of the year when your family is more likely to get diarrhoea: Spring, Autumn, Winter, Summer, after rains, drought, do not know. Seventy-six percent of the respondents thought that diarrhoea was associated with seasons or weather and 22% were not sure. The results of this perception are shown in figure 5h.

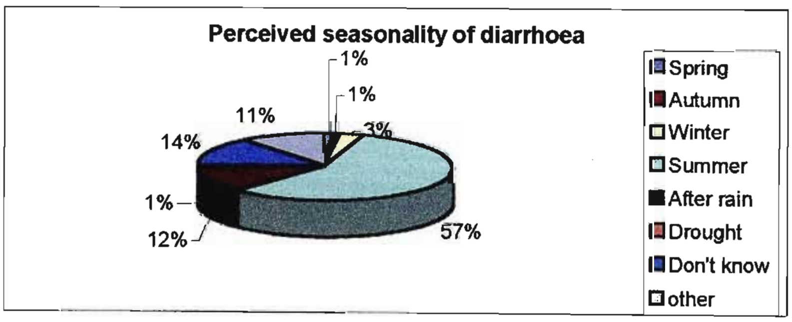


Figure 5h: Seasonality of Diarrhoea in Vulindlela

Most of KwaZulu-Natal falls into a sub-tropical belt with a summer rainfall. The study areas have similar climatic conditions and, as seen in figures 5g and 5h, in both scenarios, summer seems to be the worst period for diarrhoeal disease. This theory was echoed by the Public Health section in Umgeni Water based on reports from doctors in Pietermaritzburg who found that there was a peak in diarrhoeal disease cases after rain events in summer (Bailey, 1999b).

5.7 Deaths Due to Diarrhoea

As previously discussed, the most important reason for the international research in this area is that preventable diarrhoea is perceived to be the cause of many deaths worldwide. If the causes of the diarrhoea can be identified and addressed, thousands of lives, especially those of children, would be saved.

This issue was explored in both the Mpolweni and the Vulindlela studies. In Mpolweni, no definite cases of death due to diarrhoea were reported: 62.4% of the respondents indicated that nobody in their household died as a result of diarrhoea and 37.6% of the respondents were either unsure or did not provide any response. In the Vulindlela study, the respondents were asked if there were any deaths in the household over the previous year: 11% said that there were, 87% said that there were not and 2% did not respond. The reported reasons for death are recorded in table 5.4, of which one is attributed to diarrhoeal disease (age unknown).

Table 5.4: Reported causes of death in the study population in Vulindlela

Reason	Frequency
Aids	1
Asthma	1
Diarrhoea	1
Head/Stomach problem	1
High blood pressure	2
Malnutrition	1
Sharp pain	1
Shooting incident	1
TB	2

CHAPTER 6: RESULTS : PATHWAYS TO DIARRHOEA

6.1 Exposure Variable Analysis

The use of diarrhoea as an indicator to evaluate the health impact of an intervention has one serious drawback: there are many pathways that may lead to diarrhoea in a population. As described in chapter 2, the ecological pathways and potential confounding variables to diarrhoeal disease are complex and inter-related. In many studies, researchers have identified various pathways and risk factors that will cause diarrhoea (Molbak *et al*, 1997).

In both Mpolweni and Vulindlela, the baseline surveys allowed some of these potential risk factors to be explored. In Mpolweni, the study considered 80 exposure variables through the questionnaire and observation surveys. The study found an association between diarrhoeal disease and sixteen of these variables, p value of < 0.05, denoted by a tick in table 6.1. If these, two variables (age and being the cook in the home) showed a significant association, p value < 0.01, denoted by a double tick. One variable (gender) showed a very significant association, p value < 0.001, denoted by a triple tick. In Vulindlela, the study did not include a rigorous observation survey. Of the 55 exposure variables explored, eight showed an association, p value < 0.05, denoted by a tick in table 6.2. Of these, three variables (number of people living in a single house, age, and cooking as a water use activity) showed a significant association, p value < 0.01, denoted by a double tick. A variable (washing nappies as water use activity) showed a very significant association, p value < 0.001, denoted by a triple tick.

The areas that have been shaded in yellow denote those variables that were part of the observation survey, while the remaining areas form part of the question survey.

Table 6.1: Association between diarrhoea and potential risk factors in Mpolweni

Variables identified in Mpolweni survey	p-Value	Significance	
		Yes	No
SOCIO-DEMOGRAPHIC VARIABLES			
Household type	p> 0.05		✗
Crowdedness Index	p<0.05	✓	
Number of people in the house	p<0.05	✓	
Age of person (children <5)	p<0.005	✓✓	
Gender (female)	p< 0.001	✓✓✓	
Educational Standard	p> 0.05		✗
Problems with obtaining health care	p<0.05	✓	
Poor parent response to illness (> 3 days)	p<0.05	✓	
Awareness of Health Provision	p > 0.05		✗
Listen to the radio (86% Ozulu)	p> 0.05		✗
Attendance at community education program	p> 0.05		✗
WATER SOURCES			
Source of water River (<500m)	p> 0.05		✗
Source of Water River (500-1000m)	p< 0.05	✓	
Source of Water > 1000m	p> 0.05		✗
WATER USES			
Washing hands	p> 0.05		✗
Drinking water	p> 0.05		✗
Washing nappies	p> 0.05		✗
Washing clothes	p> 0.05		✗
Bathing	p> 0.05		✗
Presence of children playing in or near stream	**p> 0.05**		✗
WATER MANAGEMENT ACTIVITY			
Collecting water for the home	p> 0.05		✗
Plastic water collection/storage containers	p< 0.05	✓	
Knowledge about washing water containers	p> 0.05		✗
Substance used to clean water containers	p> 0.05		✗
Frequency of washing water containers	p> 0.05		✗
Knowledge about invisible water contaminants	p< 0.05	✓	
Knowledge about water disinfect ion	p> 0.05		✗
Procedure of disinfecting water	p> 0.05		✗
Failure to use boiled/ disinfected water because of poor taste	p < 0.05	✓	
Volume storage potential	**p> 0.05**		✗
Appearance of stored water	**p> 0.05**		✗
Location of water collection	**p> 0.05**		✗
Distance of water collection from house	**p> 0.05**		✗
SANITATION			
Presence of latrine	p> 0.05		✗
Communal use of latrines	p> 0.05		✗
Closeness of water for washing hands	p> 0.05		✗
Frequency of using soap for washing hands	p> 0.05		✗
Way babies feces are handled	p> 0.05		✗
Overflow of toilets in heavy rains	p> 0.05		✗
Distance between toilet and house	**p> 0.05**		✗
Distance between toilet and nearest water source	**p> 0.05**		✗
Material of toilet roof	**p> 0.05**		✗

Table 6.1 continued:

Variables identified in Mpolweni survey	p-Value	Significance	
		Yes	No
Material the walls the toilet is made of	p> 0.05		✗
Bowl construction inside toilet	p> 0.05		✗
Presence of ventilation pipes	p> 0.05		✗
Presence of feces in toilet or on property	p> 0.05		✗
Presence of anal cleansing material	p> 0.05		✗
Presence of disinfectant	p> 0.05		✗
Approximate depth of hole	p> 0.05		✗
Presence of children with nappies in household	p> 0.05		✗
Washing of hands after changing nappies	p> 0.05		✗
Children playing near toilet	p> 0.05		✗
Type of toilet	p< 0.05	✓	
Presence of bad smell from the toilet	p< 0.05	✓	
Presence of water and soap for washing hands at or near toilet	p< 0.05	✓	
Presence of waste-receptacle in the house	p> 0.05		✗
Presence of flies around waste site	p> 0.05		✗
Presence of smell from waste site	p> 0.05		✗
Accessibility of household rubbish site to children	p> 0.05		✗
Type of waste observed at house	p< 0.05	✓	
Presence of putrefying organic matter on property	p< 0.05	✓	
KITCHEN / COOKING ACTIVITIES			
Being the cook in the home	p < 0.005	✓✓	
Cooking / milk preparation	p> 0.05		✗
Presence of working fridge	p> 0.05		✗
Places used in food preparation	p> 0.05		✗
Type of energy used for cooking	p> 0.05		✗
Use of hot water for washing dishes	p> 0.05		✗
Use of detergents for washing dishes	p> 0.05		✗
Presence of houseflies in the kitchen	p> 0.05		✗
Method of waste disposal	p> 0.05		✗
Use of dung in house	p> 0.05		✗
Presence of working fridge	p> 0.05		✗
Appearance of food	p> 0.05		✗
Washing hands before food preparation	p> 0.05		✗
Cleanliness of dish washing container	p> 0.05		✗
Presence of dirty dishes	p> 0.05		✗
Presence of flies in food-storage area	p> 0.05		✗
Presence of detergent in kitchen	p> 0.05		✗
ANIMAL VECTOR VARIABLES			
Presence of flies	p> 0.05		✗
Animal types (dogs, cats, chickens, goats, other) and numbers	p> 0.05		✗

Key:

(yellow)	Observation Survey
(white)	Questionnaire survey

Table 6.2: Association between diarrhoea and potential risk factors in Vulindlela

Variables identified through questionnaire survey	P value	Significance	
		Yes	No
Crowdedness Index	0.32		✗
Number of people living in any single house	0.003	✓✓	
Age of person	0.004	✓✓	
Gender	>0.05		✗
Identification that AIDS is a problem for their community	0.82		✗
Identification that Bilharzia is a problem for their community	0.22		✗
Visiting traditional healers	0.22		✗
WATER SOURCES			
Water source as tap in garden	0.96		✗
Water source as communal tap	0.13		✗
Water source as river	0.15		✗
Water source as unprotected spring	0.88		✗
Water source as protected spring	0.64		✗
Water source as rain tank	0.42		✗
WATER MANAGEMENT			
The length of time taken to fetch water	0.75		✗
The times/day water collection takes place	0.10		✗
The volume of water collected	0.06		✗
The use of plastic containers for water storage	0.22		✗
Using the same container to collect and store water	0.28		✗
Using any cup to scoop water from storage container	0.02	✓	
Never cleaning water storage containers	0.43		✗
Use of some method to disinfect of stored water	0.035	✓	
SANITATION			
Communal use of latrine	0.30		✗
Overflowing toilets	0.10		✗
Method of handling babies feces	0.49		✗
Dumped rubbish	0.63		✗
Methods of waste disposal	0.79		✗
Waste water	0.22		✗
Animal waste	0.85		✗
WATER USE/ ACTIVITY			
Swimming in the river	0.39		✗
Cattle drinking on the property	0.75		✗
Washing nappies as a water use activity	0.001	✓✓✓	
Washing clothes as a water use activity	0.24		✗
Bathing as a water use activity	0.34		✗
FOOD RELATED ACTIVITY			
Shortage of food	0.03	✓	
Presence of fridge for storing food	0.81		✗
Types of energy used for cooking	All > 0.05		✗
Use of hot water for washing dishes	0.41		✗
Bottle feeding of infants	0.50		✗
Cooking as a water use activity	0.009	✓✓	

Table 6.2 continued.

Variables identified through questionnaire survey		P value	Significance	
			Yes	No
ANIMAL VECTOR RELATED VARIABLES				
Rats		0.05	✓	
Mosquitoes		0.17		✗
Ants		0.28		✗
Flies	All houses reported flies being a problem therefore there are no comparative analyses			
Cockroaches		0.71		✗

6.2 Diarrhoea and the Social Environment

Stanton *et al* (1992) suggest that nearly all methods to reduce diarrhoeal morbidity and mortality require behavioral change. While this may be true, the Mpolweni and Vulindlela studies identified certain non-behavioral factors that may predispose a person to diarrhoeal disease, such as: age, gender, and the number of people living in the home. The relationship between diarrhoea, gender and age was discussed earlier. In both study areas, socio-demographic variables are significantly associated with diarrhoeal disease, *p*-values being less than 0.05 (see table 6.3).

Table 6.3: Relationship between socio-demographic variables and the prevalence of diarrhoea.

Variable	p-Value	
	Vulindlela	Mpolweni
Crowdedness	0.32	p<0.05
Number of people living in a home (regardless of home size)	0.003	p<0.05
Age	0,004	p<0.005
Gender	>0.05	p< 0.001

The crowdedness factor in Vulindlela is an exception to this conclusion. Homes in Vulindlela are comparatively large with an average of 8 rooms in each household and the lack of crowdedness may contribute toward a healthier lifestyle. VanDerslice (1994) argues that socio-economic factors do not directly affect the risk of diarrhoea, but rather influence family behavior, which in turn affect a family member's exposure to pathogens and infection.

6.3 Diarrhoea and the Water Environment

One of the objectives of this study is to identify whether any of the risk factors to diarrhoeal disease can be associated with water. The factors considered included: the water source, the quality and quantity of water used, the habits regarding water transport, water storage and disinfection of stored water supplies, each of which is discussed below.

6.3.1 Water sources.

Water quality at source is dependent on many factors including whether the:

- Source is surface or ground water
- Catchment is sparsely or densely inhabited
- Source is protected from polluting influences.

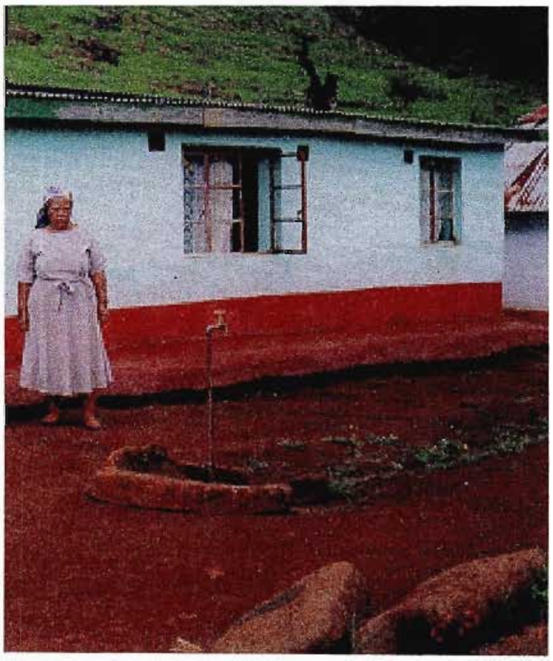


Fig 6a: Household in Vulindlela with tap prior to water supply scheme development.

This section explores the relationship between the water source and the prevalence of diarrhoea in Mpolweni and Vulindlela.

The two studies differ markedly in that, for Mpolweni, rivers are the source of water for 77.2% of the households whereas, in Vulindlela, a nearby stream or river was the source of water for only 3% of the population.

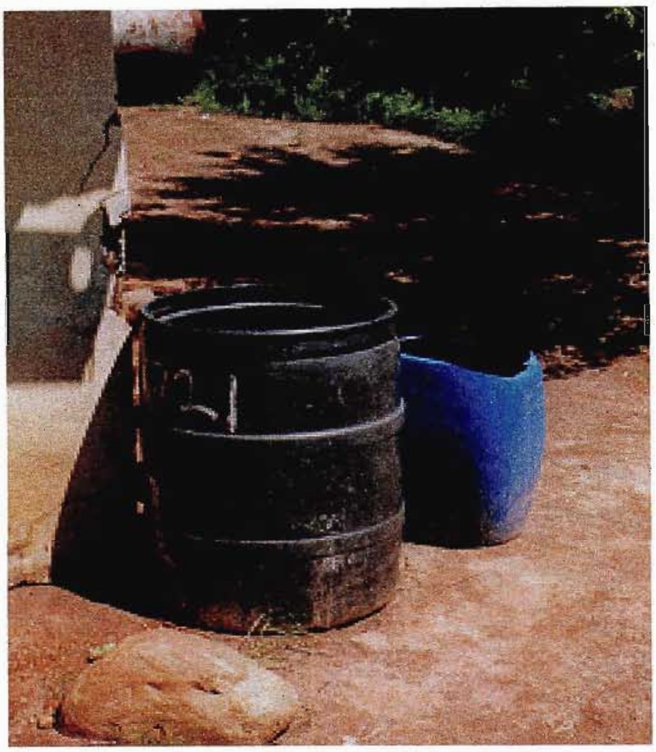


Fig 6b: Rain run-off receptacles at household in Vulindlela

In Mpolweni, there were no communal taps; in Vulindlela, 28% of the sample used a communal tap to supply their water. Vulindlela had also benefited from a spring protection program and reticulation from spring sources to households, developed between 1980 and 1994. As a result, 37% of the households surveyed had a tap supply water in their garden (see fig. 6a). However, at the time of the survey, only 54% of these taps delivered water when opened. This is an indication of the lack of reliability of the existing water reticulation supply. In regard to the source of this water, 53% identified a spring, 20% thought it was a borehole and 9% did not know. Both Mpolweni (70.7%) and Vulindlela (75%) made use of run-off from the roof into rain storage tanks during the rainy season (see fig. 6b). Neither community had access to dams or delivery by water tankers. In both instances, the distance from the water source was considered. For Mpolweni, the question was closed and the distance to the water source was identified in three categories: less than 500 meters, 500 meters to 1000meters, and greater than 1000 meters.

For Vulindlela, the question was open with regard to the time taken to fetch water and did not prescribe distance.

In Mpolweni, the probability analysis indicates that diarrhoea is independent of water collected less than 500 meters and more than 1000 meters from the river and from the roof or "other" sources. However, diarrhoea is associated with water sourced 500m to 1000m from the river. Households in this zone are predominantly overcrowded and it is postulated that overcrowdedness is the principal risk factor rather than the source of water.

In Vulindlela, the sources of water provided more insight into the potential impact of different sources of water on health. However, the study found no association between the prevalence of diarrhoea and the source of their water, as all the water source exposure variables had a p value > 0.05 (see table 6.2).

6.3.2 <u>Water volume</u>

The provision of an adequate supply of water has most influence on a group of diseases referred to as "water-washed" diseases. Lack of access to sufficient quantities of water supply restricts good hygiene practice, allowing diseases such as scabies, eye infections and skin infections to emerge (Feacham, 1984).

In a 1986 study on strategies to prevent diarrhoeal disease in developing countries, it was suggested that water quantity may have more impact on diarrhoea than water quality (Esrey and Habicht, 1986).

Fig. 6c: Water collection at spring in Vulindlela

It might be expected that larger households would require more water to be collected and this would result in more trips. In this study, the average family size in Mpolweni is 8 whereas in Vulindlela it is 6 people, yet the results show that water is collected more frequently in Vulindlela (four times a day) than in Mpolweni (three times a day).

In Vulindlela, water is collected from springs and communal taps, which can result in queues and lengthy waiting periods. In addition, water from these sources can frequently dry up toward the middle of the day. It appears that, in order to allow everyone to access the water source within a reasonable time period and to receive an adequate quota of water, the community has developed a norm of collecting smaller qualities of water more frequently. These restrictions are not experienced in Mpolweni where access to the river is freely available.

In regard to the total volume of water collected per household per day, Mpolweni households collect between 300 and 600 liters and Vulindlela households collect between 200 and 400 liters per day. The volume of water collected per capita from the two areas is similar: in Mpolweni, it is 56.25 liters and in Vulindlela it is 50 liters per person per day. Both the Vulindlela Water Supply Scheme and the Mpolweni Water Supply Scheme are designed to deliver 50 liters per person per day. The schemes will not therefore improve the supply, but they will improve the convenience of obtaining water.

In the Vulindlela study, there is no apparent correlation between the quantity of water collected and diarrhoea (p= 0,06).

Clearly too little water can place constraints on the amount of water available for good household and personal hygiene. Research shows that failure to use water for personal and domestic hygiene is associated with diarrhoeal disease (Maung et al, 1994).

The Vulindlela and Mpolweni studies therefore explored several water use variables in considering risk factors associated with water-use, as described below.

6.3.3 Water uses.

Water use in each area was explored to determine if any particular water use could be associated with diarrhoeal disease. In Mpolweni, there was strong evidence to suggest that diarrhoea is independent of any of the water uses that were surveyed though the questionnaire (p always > 0.05). The observation survey however identified that the availability of soap for hand washing at or near the toilet was associated with reduced diarrhoeal disease in those families. This indicates a possible bias introduced either by respondents to the questionnaire or by the person carrying out observations. Such an observation has been reported in many international studies on this subject.

Hand washing is a hygiene related behavior that has been frequently studied in hospital settings, where it has been demonstrated that enteric infections can be spread via contaminated hands and that hands can be decontaminated by washing with soap and water (Feachem, 1984). Several studies have shown that interrupting fecal-oral transmission by increased hand washing with soap and water, particularly after defecation, may be an effective measure in the control of diarrhoeal disease (Birmingham et al, 1997). In Mpolweni, although washing hands is not reported as a common behavior (see table 6.4), there was evidence of less diarrhoea in households where soap and water, or just water, were available for cleaning hands near the toilet facility, than in households where these was absent.

Table 6.4: Relationship between washing hands and diarrhoea in Mpolweni Households

		Households Reporting Diarrhoea (Number)		
		Yes	No	Total
Presence of Soap / Water	Soap and Water	4	4	8
	Water	1	9	10
	None	81	82	163
	Not reported	86	95	181

In Vulindlela, the presence of soap and water for washing hands was not observed. However, the questionnaire asked the respondent whether hand washing occurred daily, occasionally, or never. As 98% of the people claimed that they washed their hands daily, it was not valid to test the association between hand washing and diarrhoeal disease.

6.3.4 Water management

Ensuring that the rural and peri-urban family has a supply of water when needed is an arduous, time-consuming task carried out predominantly by women in the traditional household. Decisions about the management of this process need to be made daily. This study considered this process and these decisions as possible routes to diarrhoeal disease.

Types of Water Containers

In most rural communities in KwaZulu-Natal, water is collected from a stream, communal tap, spring or borehole, and it is then carried and stored at the home to ensure that water is available when needed.

Stored water can become contamination, resulting in diarrhoea. Collection and storage vessels can be made of plastic, pottery, metal or any number of compounds. For both Vulindlela and Mpolweni, the study explored this issue to see firstly which type of vessel is used and secondly whether the compound of the vessel itself poses a risk factor toward causing diarrhoea.

Fig 6d: Water storage in Vulindlela house

In Mpolweni, 51.1% of the containers used to collect/store drinking water were made of plastic, 32.1% were of the pottery type and 16.7% were made of metal. The statistical analysis suggests substantial evidence to support an association between diarrhoea and the type of water container ($p<0.05$). It was found that, in 43% of the homes where diarrhoea was experienced, plastic containers were being used.

In Vulindlela, the relationship between the type of water collection/ storage container could not be compared as 100% of the sample collected water using a plastic container and 99% stored water in a plastic container. The remaining 1% stored water in metal containers.

Cleanliness and Disinfection of Water

In a study of the strategies for waterborne disease prevention in Bolivia, Quick *et al* (1997) showed that the introduction of a simple point-of-use disinfection and storage system resulted in significantly lower median *E coli* colony counts and fewer number of diarrhoea cases per household.

In Mpolweni, while 64% of the respondents in Mpolweni believed that even clean "looking" water can make them sick ($p<0.05$), reflecting the understanding between bacterial contamination of water supplies and diarrhoea, only 52% of the sample practiced some form of disinfection of the water supply. It was also found that the prevalence of diarrhoea is independent of the practice of disinfection ($p>0.05$). However, in a subsequent question on the perceived like or dislike of the taste of boiled or disinfected water, the indication was that, in households where people were reported sick with diarrhoea, neither boiled nor disinfected water was used for drinking because of the poor taste: in 75% of the households where diarrhoea was reported, boiled water was considered to taste bad; in 66% of the households where diarrhoea was reported, disinfected water was considered to taste poor. The prevalence of diarrhoea was significantly associated with the taste perception ($p<0.05$). The sample did associate boiling with preparing food ($p< 0.05$), but little association was found between boiling water for drinking, washing hands, washing clothes or general cleaning.

In Vulindlela, only 24% of the sample practiced some form of disinfection (see table 6.5). The community was not asked why they did not use disinfection practices. However, the perception of the survey team was that the community believes that the water quality in springs is excellent most of the time and therefore disinfection is not necessary (pers comm. Xaba, 1999).

Table 6.5: Disinfection processes used in Vulindlela

Disinfection Process	% Using the process
Boil	3
JIK	20
Tablets	1
None	75

In Vulindlela, analysis of the base-line survey in Vulindlela found a relationship between the prevalence of diarrhoea and those households who do not use any method to disinfect their water supply (p-value =0,035). In addition, households were asked to explain how they scooped water from the containers when needed. Those households who used any available receptacle and did not put aside a specific cup for this purpose tended to have a greater prevalence of diarrhoea in their homes (p= 0,02). This may be due to the cup impacting negatively on the quality of water in the storage container, as discussed below.

6.3.5 Water Quality

Water quality samples were collected from the storage containers of 100 households in Vulindlela and 25 randomly selected households in Mpolweni. Analyses for Coliforms, *E Coli*, and *F Streptococci* were carried out at the Umgeni Water analytical laboratories. The summary statistics of these analyses are presented in Tables 6.6 and 6.7. Original water quality data can be found in appendix 3.

Table 6.6: Water Quality Results of Stored Water in Mpolweni

Variable	N	Mean	Median	St Dev	SEMean	Min	Max
Total Coliforms per 100 ml	25	5347	1700	9416	1883	0	47000
E coli per 100 ml	25	3150	940	8874	1775	0	45000
Fecal strep per 100 ml	25	172	56.0	357.7	71.5	0	1640

Table 6.7: Water Quality Results of Stored Water in Vulindlela

Variable	N	Mean	Median	St Dev	SE Mean	Min	Max
Total Coliforms Per 100 ml	96	6580	550	33870.4	3456.9	0	280000
E coli per 100 ml	97	2246	104	12994.0	1319.3	0	124000
Faecal strep Per 100 ml	67	142	14	12994.0	46.8	0	2480

In both Mpolweni and Vulindlela, the water quality of water stored for consumption in household containers would not comply with potable water guidelines in South Africa (Umgeni Water, 1998b). This is, however, to be expected because, in the absence of disinfection, the quality of water at household level is dependent on the quality of water at the source and the cleanliness of the household container.

Fig. 6e indicates the quality of water in the Mpolweni River, the source of most of the water in Mpolweni (Umgeni Water Analytical laboratory, weekly sampling program).

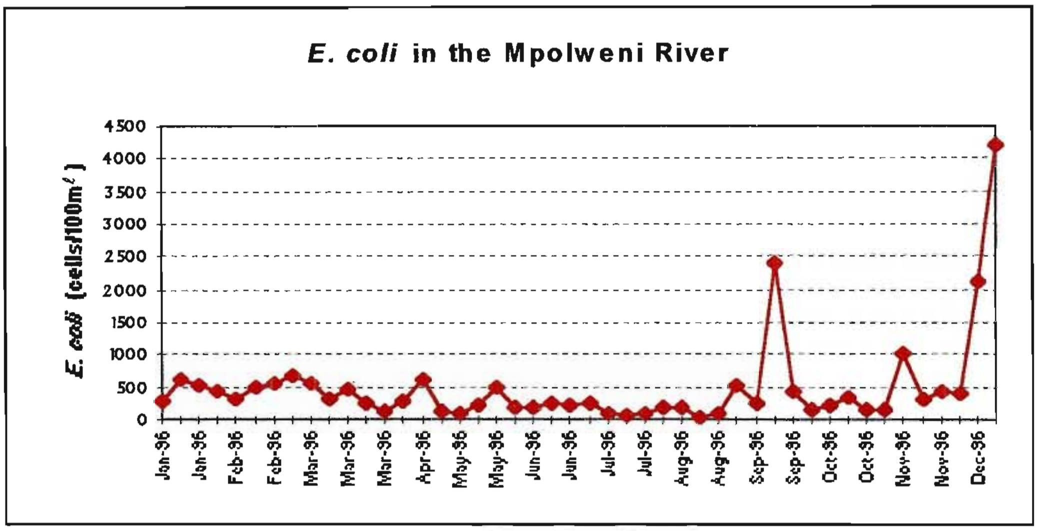


Fig 6e: E coli levels in the Mpolweni River during 1996

There are noticeable peaks in water quality results in September and December, when the level of *E coli* in the stream rises considerably. From a cursory examination of the results, there appears to be an association between increased levels of *E coli* in the Mpolweni River and increased diarrhoeal prevalence in the community. However, the statistical analysis of the results does not confirm this correlation.

Table 6.8: Average Quality of Water at source in Vulindlela

	Coliforms Per 100 mℓ.	E coli Per 100 mℓ.
Mean	659	117
Median	74	6
Standard Deviation	2438.1	268.4
Minimum	0	0
Maximum	21000	1480
Count	95	95
Confidence Level (95.0%)	496.7	54.7

In Vulindlela, the quality of water from the sources is on average much cleaner than that available in Mpolweni (see table 4.12). This is however to be expected, as the water supply in Vulindlela originates mostly from springs. Despite this improvement in quality, the water does not comply with potable standards (see table 6.8)

Table 6.9: Allowable compliance for Surface Water intended for Potable Use (European Economic Community, 1975) assuming some form of simple disinfection will take place.

Determinand	Unit	
Total coliform	count/100 mℓ	50
E coli	count/100 mℓ	20
F streptococci	count/100 mℓ	20

To test the significance of association between the water quality determinants and diarrhoea, four categories for each determinant were calculated. These were 1=0-100, 2=101-500, 3= 501-1000, 4=>1000. The chi-squared test was carried out to explore association between any of the water quality determinants and the prevalence of diarrhoea.

In Mpolweni, no significant association was found between the determinands and the prevalence of diarrhoea.

6.4 Diarrhoea and Sanitation

It is broadly acknowledged that sanitation is regarded as the 'stepchild' of water supply, with few communities demanding improved sanitation (Cairncross, 1992). South Africa is no exception. Most communities in rural KwaZulu-Natal use the 'long-drop', more technically known as the unimproved pit latrine. These latrines are covered with varying forms of superstructure ranging from well-constructed latrines, to bare holes in the ground with a few pieces of tin and wood for privacy (See figures 6f, 6g and 6h). The Mpolweni survey team often commented on the observed lack of pride in the toilet, whereas much effort was put into keeping the home in good repair (See figure 6f).

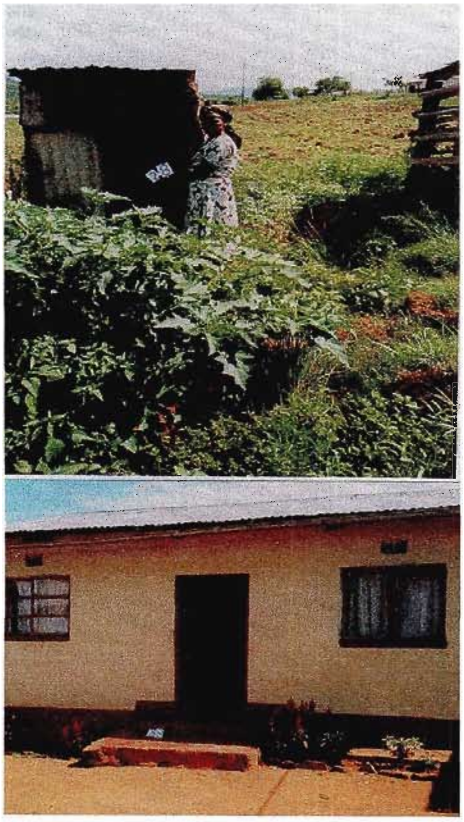


Fig 6f: Relationship between house-pride and lack of toilet pride in Mpolweni

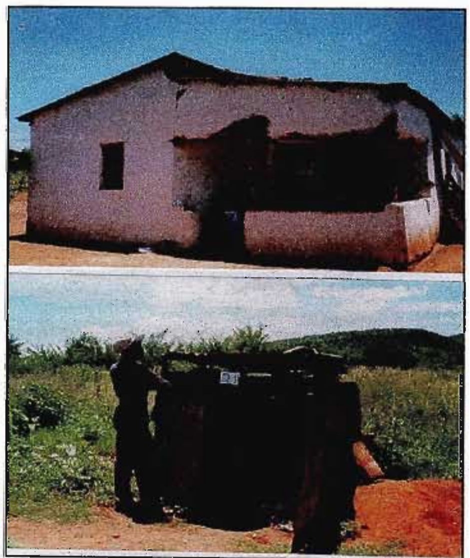


Fig 6g: Example of poorly maintained home and toilet in Mpolweni

While several studies have identified that an improvement in sanitation will result in a reduction in the prevalence of diarrhoea (Blum, 1983; Shuval, *et al* 1981; Esrey *et al* 1991), analysis of the Mpolweni study results failed to find an association between the prevalence of diarrhoea and the presence of a latrine in that household ($p > 0.05$). Of the households in Mpolweni, 89% had latrines, whereas 11 percent did not (see table 6.10).

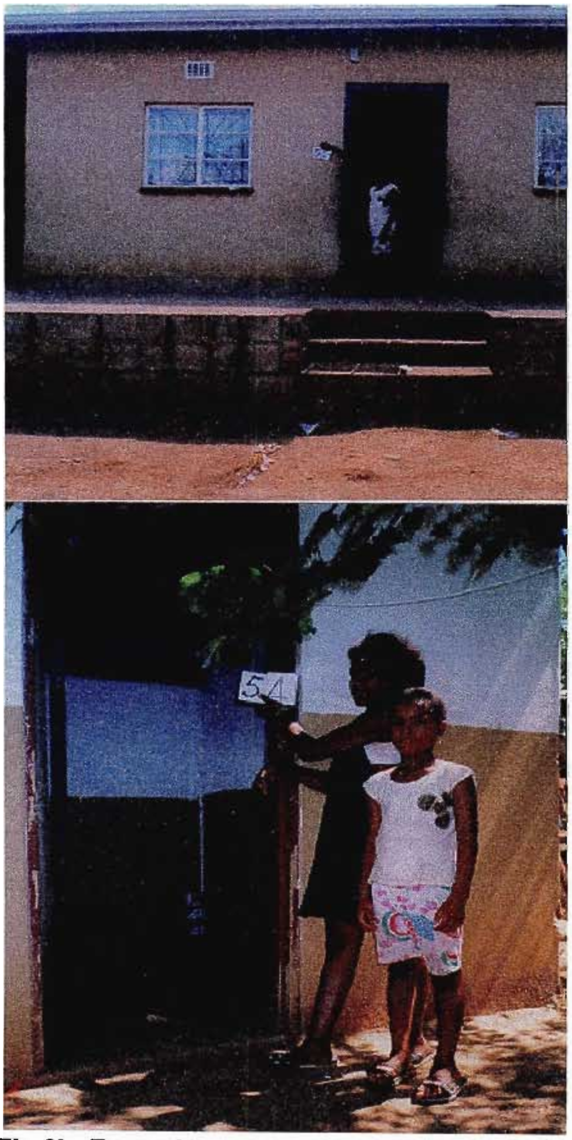


Fig 6h: Example of well maintained household and toilet in Mpolweni.

Of those who had latrines, 95% percent had pit latrines, 0.5 % had a hole in the ground with a flimsy super-structure, 1.1 % had a flush toilet where the water is manually added to the tank for flushing and the waste pipe enters the surrounding environment, 1.1 % had a pungalutu[7] and no data was obtained for the remaining 2.3 %. A large proportion of those who had diarrhoea are in homes with pit latrines. Latrine cleanliness, the presence of ventilation pipes, the presence of toilet paper, the approximate depth of the pit, and the distance from the house to the toilet were all examined. The study failed to find an association between the prevalence of diarrhoea and any of these factors (see table 6.1).

However, an association was found between particularly bad smelling toilets in Mpolweni and the incidence of diarrhoea in those households. In the absence of an association being found with a presence of flies, no explanation can be offered for this association at this time.

The latrine is not used by all members of the family. Places other than the latrine are used related to age and the weather. In many families, young children defecate near the latrine, as there is a fear that young children could fall in the latrine. In Vulindlela, 24% of the households indicated that places other than the latrine was used to relieve themselves and, of these, 22% used the yard of their household for this purpose and 2% used a nearby bush. Eight per cent of the sample did not respond as they found the question too embarrassing.

In Mpolweni, 21% of the homes where defecation was not carried out in the latrine reported cases of diarrhoea in their home. There is evidence therefore that diarrhoea is independent of human fecal contamination in the yard.

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[7] Pungalutu is a type of ventilated improved pit latrine that was designed in KwaZulu-Natal and is being constructed in rural areas using local material.

TABLE 6.10: Relationship between Latrines and Diarrhoea in Mpolweni

	DIARRHOEA		
PRESENCE OF TOILET	Yes	No	All
Yes	43.33	46.11	89.44
No	4.44	6.11	10.56
All	47.78	52.22	100

In Vulindlela, 100% of the sample population had a pit latrine or similar structure on their property and, therefore, the relationship between latrines and diarrhoea could not be tested. No association could be found with any of the toilet related variables (see table 6.2).

The Vulindlela study however picked up a significant relationship between washing nappies and the prevalence of diarrhoea (p-value = 0.001). The statistical analysis was taken further with the application of the trend test, which found that there is a negative (decreasing) trend of diarrhoea from those who washed nappies often (rank 1) to those who only occasionally (rank 3) used water for washing nappies.

There are two probable explanations for this association:

- Mothers of infants with diarrhoea are exposed and may be vulnerable to the pathogens in babies feces and
- The presence of nappies in a household is indicative of the presence of babies, the most vulnerable group with respect to the prevalence of diarrhoeal disease.

Considering that this is one of the few water uses to indicate a relationship to diarrhoeal incidence, it seems unlikely that water is the risk factor but rather the fecal material in the nappy. In fact, Cairncross (1992) advocates children's feces are more infectious than those of adults due to the large burden of worms, parasitic ova and pathogenic bacteria.

6.5 Diarrhoea and Food Management.

Environmental health officials suggest that the most prevalent cause of diarrhoeal disease in rural areas is due to the food eaten rather than a contaminated water supply (South African Institute for Environmental Health Conference Proceedings, 1997). Risk behaviors such as watering the vegetable garden with sewage polluted water, children defecating around the garden, failure to store leftover food properly because there is no refridgerator can all result in bacteria such as the genus *Salmonella* infecting the food supply.

In both the Mpolweni and the Vulindlela surveys, a relationship between cooking and diarrhoeal disease was identified. In Vulindlela, a relationship was found between the use of water in cooking food (p-value= 0.002) and, in Mpolweni, there was a relationship between being the cook in the family and the prevalence of diarrhoea ($p<0.005$).

Malnutrition as a risk factor has been investigated in several studies and, in some, it was identified as a risk factor (Baqui, 1993), while other studies failed to find an association. In Mpolweni, no association between food security and diarrhoea was reported but an association was found between families who reported that they had food shortage during the month and diarrhoeal disease.

6.6 Diarrhoea and Animal Vectors

Feachem *et al* (1983) identified that the control of zoonotic reservoirs (infections in domestic and farm animals and control of flies breeding near human and animal feces) may be one intervention that will reduce the burden of diarrhoeal disease.

Heeren and Ngoma (1997), in their study of causes of Shigella in the Eastern Cape, identified that flies were a significant factor for diarrhoea. People who were exposed to flies were three times more likely to develop disease compared to those who were not exposed to flies.

In the Mpolweni study, no association was found with either domestic animals or insect vectors.

In Vulindlela, the presence of rats in the houses was of slight significance for diarrhoeal disease (p-value = 0,05)

CHAPTER 7: LIMITATIONS AND IMPLICATIONS OF THE STUDIES.

Drawing on the results discussed in chapter 4 relating to the prevalence and pathways for diarrhoea, it is possible to draw conclusions on the limitations of the studies and the implications for using diarrhoea to evaluate the impact of water supply schemes on human health.

7.1 Complexity of Relationships

A review of health impact studies prior to 1990 showed greater impacts on morbidity, anthropometry and mortality from sanitation than from water (Esrey *et al,* 1996). The studies predicted a 36% reduction in diarrhoea from improved sanitation, 15% from improved water quality, and 20% from improved water quantity. One goal of this dissertation is to evaluate whether the baseline data would provide sufficient information to indicate whether, or if, there is an improvement in the prevalence of diarrhoea after the investment in a water supply scheme, such a change could be linked to the water supply intervention.

In both Vulindlela and Mpolweni, very few exposure variables can be directly linked to water supply or source as being a risk factor for diarrhoeal disease. From this, it follows that the introduction of a new water supply will have no bearing on diarrhoeal disease, if only direct relationships are examined.

However, many studies devoted to determining the source of diarrhoeal infection, have found that the transmission cycle is not a straight forward relationship, but can involve the complex interaction of the biological, environmental, social and behavioral determinants of diarrhoea (Lonergan and Vansickle, 1991). The Mpolweni and Vulindlela studies were not able to consider such complex interactions due to resource constraints.

An example of the complexity of such relationships is found in the work of Shuval (1981), who proposed that there is a threshold at which the effectiveness of water and sanitation investments is realized. At the lower end of the socio-economic spectrum, investments in water and sanitation do not show substantial benefits. Similarly, benefits are not realized at the higher end of the socio-economic scale. Therefore, it is suggested that a point of saturation is reached beyond which further significant health benefits cannot be reached.

The only water related risk factor commonly found in both the Mpolweni and the Vulindlela studies was the disinfection of water in storage. Although this is related to water supply, there is also clearly a behavioral implication. With the introduction of chlorinated water, the presence of residual chlorine in storage containers should contribute toward disinfection of the stored water. However, chlorine dissipates rapidly and, without additional disinfection, stored water can quickly reach levels of contamination that would cause diarrhoeal disease and the effects of the water supply intervention would be lost. In addition, the tendency for communities to continue to store water because of intermittent supplies will exacerbate the situation. The introduction of the water supply scheme therefore will not necessarily improve the quality of the water being consumed, if water is still stored.

While some studies have been able to demonstrate an improvement in diarrhoeal disease with the introduction of water, there is little understanding as to how and why the improvement occurred. Epidemiological studies are intended to demonstrate conclusively a relationship. In Mpolweni and Vulindlela, there are more non-water risk factors than water related risk factors related to diarrhoea. In addition, a person's health is affected by both the external environment and genetic factors. Resistance to disease was not considered in the present study.

Hence, for Mpolweni and Vulindlela, it is not possible to conclusively conclude a relationship between water factors and diarrhoea.

Cairncross (1999) concludes that existing literature on impact studies does indicate that improved water supply will result in improved hygiene, which may be reflected in increased water consumption. In the absence of this behavioral change, the benefits that may accrue from improved water quality alone are minor and may even negligible in many settings.

7.2 Methodological Problems

Both observational and experimental epidemiological studies are used to determine associations between water interventions and health outcomes. Black suggests that the promotion of experimental methods at the expense of observational methods (analytical case-control and cohort) has its limitations (Black, 1996).

Environmental interventions are difficult to evaluate. As discussed in Chapter 2, while randomized controlled trials are regarded as the best methodology to use, interventions such as the introduction of a water supply scheme are not always introduced on a random basis. Economic, political, environmental and even health considerations impact on the decision of where and when to build a water supply scheme.

The Mpolweni study was carried out in a discreet area, where a large proportion of the population had expressed an interest in being connected to the intended water supply scheme. The baseline, cross sectional study did approach sample selection on a random basis. The use of random selection was not possible in the Vulindlela study for two reasons: the "stepped-wedge-design" (see fig. 1c) required that the choice of sample be stratified by selection of households that would receive water connections within a specific time-frame; and, in addition, a relatively small proportion of Vulindlela households have signed up for water connection due possibly to the existence of a ready, free supply of spring water. This may have had the effect of biasing the study, as it can be assumed that only households who have disposable income to pay for water are included in the study. It has been demonstrated that socio-economic variables do have an impact on health (Stronks *et al*, 1997).

As discussed in Chapter 2, descriptive disease surveillance surveys, analytical cohort and cross-sectional studies have been criticized as producing meaningless results when used to try to evaluate the effectiveness of water supply interventions. The criticism is based on the lack of adequate control, one-to-one comparison, failure to record facility usage and failure to analyze by age. Case -control studies became the preferred methodology.

In the Mpolweni and Vulindlela studies, an attempt has been made to take into consideration as many confounding variables as possible. However, there are short-comings. In Mpolweni, the water quality sampling was not sufficiently exhaustive to provide sufficient data to make conclusive conclusions. In Vulindlela, while it was possible to take into consideration many confounding factors (such as age and gender), there was no observation of facility usage. So, while water quality has been rigorously analyzed, there is little proof that diarrhoea, or the absence thereof, has any relationship to the water quality of the storage container at the time. Even testing the quality at source is somewhat meaningless, because it is not possible to correlate the prevalence of diarrhoeal disease over a two-week period prior to the interview with the quality of water at source on the day of the interview.

One-to-one comparison is a common methodological error when trying to evaluate the impact of water supplies on health (Blum and Feachem, 1983). To minimize costs, a single village with the intervention is commonly compared with the village prior to the installation of water reticulation. Unless households within the village are independent and the implementation of reticulation can be shown to not be village-wide, several clusters of the intervention need to be compared with several clusters without the intervention.

It is for this reason that, in the Vulindlela study, a "stepped-wedge" multi-cluster study was introduced. Not only does this innovative study design allow for more clusters, but it also allows both cross-sectional and longitudinal analysis can be carried out. In addition, groundbreaking work is underway to provide a methodology to relate the cross-sectional and the longitudinal analyses.

Most interventions are, however, not delivered under 'trial' conditions that allow for epidemiologically accurate studies. It is therefore necessary to explore non-epidemiological methodologies, including Public Health Effectiveness Trials and prospective Health Impact Assessments, when considering the development of water supply schemes.

De Zoysa *et al* (1998) make a case for 'Public Health Effectiveness Trials' which measure the impact of an intervention delivered under normal program conditions. It is suggested that these designs, which are still required to control for confounding and other influences, can adopt a more pragmatic evaluation design than the randomized controlled trial. This form of evaluation also allows for a consideration of how the intervention is delivered and how the new facilities are used. In the case of a water supply scheme, problems such as breakage in the bulk-line associated with the deterioration in water quality and quantity, failure on the part of the household to utilize the water supply because of cost, reduced pressure due to under-design can blunt or obscure the intended health impact. This methodology makes allowances for such considerations.

In conclusion, the experience of the baseline studies in both Mpolweni and Vulindlela, and the follow-up studies that are taking place in Vulindlela, indicate that the epidemiological approach is fraught with difficulties, which make it impossible to draw firm conclusions.

In the studies, no allowance has been made for factors such as burst pipes, illegal connections and subsequent contaminated lines, poorly located taps, failure on the part of the household to use the water supply, the use of two water supplies for different household purposes and the inability of the study to distinguish between water supplies.

In many water supply schemes, performance indicators have been introduced as a system of evaluation (Stephen and Still, 1999). Among these indicators are those that measure service performance, financial performance and accountability. In place of epidemiological studies, well-considered health indicators could be added to this process, with a consequent saving of resources which have and continue to be used to produce questionable results.

CHAPTER 8: CONCLUSIONS

The Mpolweni and Vulindlela schemes were developed to supply water to previously disadvantaged communities and with the intent of improving the health status of the population, through a reduction in the incidence of waterborne disease in general, and the prevalence of diarrhoeal disease, in particular. The underlying assumption was that the development of the water supply schemes would improve the quality of water supply to the community, which would reduce the exposure of the community to contaminated water supplies, and substantially reduce waterborne disease.

To evaluate this hypothesis, a situational analysis was carried out, and the burden of diarrhoeal morbidity as a measurable disease outcome was established for both study areas. The prevalence and possible pathways to diarrhoea were identified.

The first objective of this dissertation was to describe the socio-economic and environmental situation in the communities prior to the installation of the water supply schemes. This was accomplished. The study explored the water supply and sanitation resources. Mpolweni depends heavily on the Mpolweni and Mgeni rivers as a primary source for water in winter and a secondary source complimenting rain harvesting as a source in summer. Vulindlela benefits from a spring protection program, with up to 37% of the households having a supply of water tapped to their property and only 3% using surface water from a nearby stream. The remaining study population utilizes a communal tap or a nearby protected or unprotected spring. Sanitation infrastructure is similar in both areas with the majority of people using unimproved pit latrines.

The second objective of the study was to establish the prevalence of diarrhoea in the study areas prior to the installation of the water supply scheme. This objective was also accomplished. The household prevalence of diarrhoea in Vulindlela and Mpolweni is 40.4% and 49% respectively. It was found that children under the age of 5 years were the most vulnerable, with 20.1% of children in Mpolweni and 21.3% of children in Vulindlela reporting incidences diarrhoea in the period prior to the survey.

The third objective was to examine the risk factors and possible pathways associated with diarrhoeal disease in each of the study areas. The Mpolweni study considered eighty exposure variables through the questionnaire and observation surveys. The study found an association between diarrhoeal disease and sixteen of these variables (p value < 0.05), of which the strongest associations were found between diarrhoea and children less than five years old, female gender and being the cook in the home. Others associations include: crowdedness index, number of people in the house, plastic containers used in water collection, failure to disinfect water, type of toilet, presence of soap and/or water near toilet for washing hands and the presence of putrefying organic matter on the property.

The Vulindlela study did not include a rigorous observation survey and considered 55 exposure variables of which eight had a p value < 0.05 (number of people living in the home, age, water disinfection, washing nappies, food shortage, being the cook and rodent presence) and are considered significant.

However, no association could be found between the prevalence of diarrhoea and the source of water in either Mpolweni or Vulindlela.

In both studies, water use was also considered. Using water to wash nappies was associated with diarrhoeal disease in Vulindlela. However it is posited that it is the fecal contamination in the nappy rather than the water that is problematic. No association between water use and diarrhoea was established in Mpolweni.

In both studies, water management and particularly the disinfection of stored water supplies was found to be associated with diarrhoeal disease. In addition, the use of plastic storage containers to store water at the household provided additional risk in Mpolweni.

The fourth objective of the study was to evaluate the appropriateness of the baseline studies for considering the health impact of the water supply scheme interventions, with respect to diarrhoeal disease as an indicator of health. This objective was also achieved, but the result was not positive. As described above, many of the risk factors associated with diarrhoeal disease in both Vulindlela and Mpolweni were not associated with water source, supply or usage; hence, it is unlikely that these risk actors will be directly ameliorated by the introduction of the water scheme. It is therefore posited that any improvement or deterioration in the prevalence of diarrhoeal disease after the introduction of the water supply scheme cannot be directly related to the change in water supply.

The study has provided many lessons regarding study design and the efficiency of using epidemiological studies as a health impact assessment tool in the water sector. Although double-blinded randomized trials are considered the gold standard for evaluation, it is very difficult to conduct a truly randomized trial for environmental interventions, such as a water supply. There is no placebo for water and, in many communities, a cluster effect is experienced because the whole community benefits from the water supply.

This was not the case in Vulindlela. The Steeped Wedge Design provides some innovative features, which overcome some of the problems. However, new problems emerge when only a few households in the community can afford the intervention. Illegal connections and long standing times for water in reservoirs result in deteriorated supplies of treated water.

Given the difficulties experienced with epidemiological studies and in regard to future work, it is possible to make two recommendations:

- A generalized Health Impact Assessment be developed and evaluated for use in assessing health factors in a water supply scheme. Some water companies, such as Umgeni Water, are already using a series of key performance indicators to evaluate and monitor rural supply schemes. Current indicators include service performance, financial performance and accountability indicators. Health related indicators would be a valuable addition to such a protocol.

- Patterns of hygiene behaviour be evaluated for adding to the list of key performance indicators. The WHO Minimum Evaluation Procedure suggests that health improvements are the culmination of a long chain of events from the original construction, through operation and use which in turn permit changes in hygiene behavior and possible prevent ion of disease. Patterns of hygiene behavior may prove more reliable than measuring disease rates.

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APPENDICES

Appendix 1: Mpolweni Observation Survey

Appendix 2: Mpolweni Questionnaire Survey

Appendix 3: Vulindlela Questionnaire Survey

Appendix 4: Vulindlela Water Quality Results

APPENDIX 1

Mpolweni Observation Survey

OBSERVATION GUIDELINES

HOUSE:

- Description, construction materials, sketch, gradient, proximity to river/stream and GPS fix of house:

Photo:

TOILET:

- Description. Sketch, proximity to river/ stream and gradient in vicinity of toilet

Photo:

Distance and gradient of slope of toilet to house	
Distance and gradient of slope of toilet to nearest	

stream	
What is the toilet roof made of?	
What type of toilet is it?	
Describe bowl construction inside toilet?	
Is there any smell?	
Are there ventilation pipes?	
Presence of flies?	
Presence of faeces in toilet/bush/near house or stream?	
Presence of anal cleansing material e.g. Toilet paper, newspaper	
Presence of water and or soap for cleaning of hands when leaving toilet?	
Observe a family member going to the toilet and note any cross contamination afterwards (hand to mouth contact with another person)	
Presence of disinfectant/ cleaning materials for toilet e.g. Soap	
Approx depth of hole	

CHILDREN AND MOTHERS	
Any children in nappies playing near the toilet, in or around the house?	
Any mothers changing nappies near the toilet, in or around the house?	
Does mother wash hands after changing nappies i.e. any cross-contamination afterwards?	
Are there any children playing near the waste source?	
Are there any children playing near the river/ stream?	
ANIMALS	
What kind of animals are near the house (50m radius) and how many?	
Are there any animal faeces around, if so, what type?	
How close are the animal faeces to the house and veg. Garden	
Any flies from these faeces?	
Is the house floor made from cow dung?	
Where do the cattle drink and how far is it from the house?	
What is the contact between humans and cows/ dogs/ goats etc?	
WATER USE	
What type of container is used for storage and what type of neck does it have?	
How many containers are in use (volumes)?	
Comment about water status e.g. old/ dirty?	
Where do they collect water?	
How far is it from the house?	

Can you observe any water contact activities e.g. Bathing, laundry, watering plants etc?	
FOOD PREPARATION	
Are there any working fridges?	
What is the appearance of the food?	
Is there any one washing hands before preparing food?	
Are washing up tubs clean?	
Any dirty dishes?	
Any flies around kitchen area where food is prepared or stored?	
Any washing-up soap/ detergents	
WASTE DISPOSAL	
What is used for waste disposal in the house?	
What type of waste disposal do they have outside e.g. Pit, bin? Any flies around? Any smell? Putrefaction of organic matter?	

APPENDIX 2

Mpolweni Questionnaire Survey

General Questionnaire

HOUSE NUMBER
GPS READING: X:
Y:

1ST SURVEY IDENTIFICATION POINT:

1 per sample unit.
Sample unit = 1 fenced lot.

Date.. Interviewer..

The purpose of this study is to try to understand how many people in Mpolweni are getting diarrhoea and also to understand how they are getting it.

1.GRID REFERENCE POINT:

2. Type of dwelling(s)?

House	
Shack	
Other	

3. How many people live in this dwelling?

4. How many bedrooms or sleeping huts are there in this dwelling?

5. Did your family live in this dwelling last year?

Yes	No

(If yes)

6. Were you part of the Umgeni questionnaire in January 1996 ?

Y ES	NO

7. Can you remember if you reported that any of your family members were sick with diarrhoea last January?

YES	NO

8. Description of people living in this dwelling.

NOTE: Codes:
1.age A= Adult (>16)
B= Adult (>12)
C= Child (<12)
D= Child (<5)
E= Baby (<1)

2. Employment status S= Skilled

U= Unskilled

3. Place of work Z= Home
X= Local Town (Commuting)
Y= LT (Resident)
W= Outside

4. Wages/salary R0 - 25
R26 - 50
R51 - 100
>R101

House member	1	2	3	4	5	6	7	8	9	10	11	12
Age												
Sex / Gender												
Relation to head of home.												
Formal education received (highest std)												
Employment status												
Place of work last year												
School last year												
Does this person collects water for this house ?												
Does this person cook often?												

Objective: Health

(In each case use the following code for answers: Yes =1. No = 2 Not sure = 3)

13. Which of the following symptoms have people in your home experienced in the last six (6) months:

Member	1	2	3	4	5	6	7	8	9	10
Age										
Stomach pain										
Bloody diarrhoea										
Water diarrhoea										
Vomiting										
Itching										
Experience Weakness										
Cough										
Abdominal cramps										
Headache										
Dehydration										

14. Details of children under or equal to five years suffering from diseases during the past 6 months.

Illness	Yes	No	Not sure	Verification		
				Name and age of child.	Clinic Card	Nil
Diarrhoea						
Worms						
Stomach problems						
Eye infection						
Other						

16. If your child becomes sick, how sick and for how long must it be until you will get medical help? Describe

17. How often do you think the clinic visits your area?

1X per week	1X per month	Never

18. Do you have any problems taking your child to the clinic or hospital?

Yes	No

19. How much does it cost you?

20. Do you feel that you can stop your child from getting diarrhoea?
Discuss...

21. Dis your child respond well to treatment at the clinic?

Objective: Environmental and Water Use

22. Where do you get your water from? Use the last column to rank the source you use most often.

Most often = 1; less often = 2 ; etc.

River	< 500 m		
	500 - 1000 m		
	> 1 km		
Roof Source			
Other			

23. How many times a day do you collect water? __________ times a day

24. At which point do you collect your water? ....

Codes: NOTE: A ---P
ALSO if springs or boreholes are being used?

25. Is there any other area / point where you get your water?............................

26. How much water do you collect at one time?

27. Which of the following water uses are more common in your household

	ALOT	SOME	LITTLE
Washing hands			
Drinking / In artificial juices			
Cooking/ Preparation of milk for babies			
Washing nappies			
Washing clothes			
Bathing			

Other (Please ask them if there is anything that specifically uses a lot of water)

....

28.How many containers do you use per day?

29. What containers do you use to collect/store drinking water for the home? (Ask to see all containers and complete one column for each type of container currently in use.)

Container	A	B	C	D	E	F	G	H
What is the approximate volume in litres?								
What is it made of? (Plastic, metal, pottery, or other)								
How wide is the opening of the mouth?								

30. Is it easy to see that your container needs to be washed?

31. What do you clean the containers with?

32. How often do you clean them?

33. Which container do you always use when you drink water?

34. How many glasses of water do you drink per day?

35. Can water that looks clean make anyone in your family sick with diarrhoea ?

yes	no	unsure

36. Do you find it easy to put disinfectant into your water to kill disease?

yes	no	unsure

37. Which procedure do you use to make the water fit for drinking?

Boil	Jik	Alum	None

38. Which of the following do you consider neccessary for water to be boiled?

EATING / FOOD (Water added to food that is to be cooked)

YES	NO

A GLASS OF WATER TO DRINK

YES	NO

DRINKING WATER

YES	NO

WASHING HANDS / BODY

YES	NO

WASHING CLOTHES

YES	NO

CLEANING

YES	NO

39. Does boiled water have a good taste?

YES	NO

40. Does water that has been disinfected have a good taste?

YES	NO

41. Which do you prefer?

39	40

.Does anyone use the river for washing clothes?

YES	NO

Who does this ?..................................

Does anyone use the river for swimming in ?

YES	NO

Who does this?

Does your family water any plants in the yard?

What water do they use for watering plants?

From where do the catttle drink?

Who looks after them?

42. Do you have a latrine in this dwelling?

43. Do other families use this same latrine at any time?

Yes	No	Unsure

44. Is any place besides the latrine used for defecation?

Yes	No	Unsure

45. If yes.....complete the following . Can you tell us about these places. Do not give options.

Place	Rank
In the yard of the dwelling	
**Use a bush nearby	
On the bank of the river	

** How close to the river is the bush?

46. Under which conditions will this habit change?

47. Do you have any problems getting toilet paper?

Yes	No

48. Is water close enough for you to easily wash your hands after going to the toilet?

Yes	
No	
Sometimes	

49. How often do you use soap to wash your hands?

Always	
Sometimes	
Never	

50. How do you handle baby faeces?

child goes without a nappy, so don't know.	Pit	Toilet	Other

51. During heavy rains, does your latrine ever overflow with water?

Yes	No	Unsure

Objective: Procedure in food preparation:

(If possible ask to speak to the person who prepares the food.)

52. Does this dwelling have a working fridge?

Yes	No

53. Where do you do most food preparation?

Sink	Table	Other

54. Where do you cook the food?

Gas stove	Electric stove	Fire	Other

55. Do you use hot/cold water when you need to wash dishes?

Yes	No	Sometimes	Always

56. What kind of soap is used to clean the dishes with. (Ask if they would mind showing it to you)

57. Do you have a problem with houseflies entering your toilet and kitchen?

58. What do you do with your rubbish /waste?

Nil	Pit	Other

59. How long is it left there?

60. Do you use dung in the house?

OBJECTIVE: ACCESS TO INFORMATION ON HEALTH , WATER AND SANITATION ISSUES.

61. Do you often watch TV ?

Yes	No

62. Do you listen to the radio ?

Often	Sometimes	Never

Which station do you listen to?

63. Have you attended any community education programme about water and health in the last year?

Yes	No	Not sure

64. Have you heard about Oral Rehydration Solution?

Yes	No	Not sure

65. What are the quantities used in ORS? (Tick those that are responded to)

Water	Sugar	Salt	Other

Lastly

66. What are the three most important problems that you think the children <5 in this community have?

....
....
....
....

That is all the questions I have. Thank you for your time.

APPENDIX 3

Vulindlela Questionnaire Survey

GENERAL QUESTIONNAIRE

An Evaluation of the Impact of RDP levels of Water Supply on Community and Environmental Health.

Ucwaningo ngohlelo lokufakwa kwamanzi yiRDP ezimpilweni zabantu.

Questionnaire No:
Inombolo :
Area/Location :
Indawo :
Reservoir Zone # :
Date :
Usuku :
Interviewer :
Umcwaningi :
HOUSE NUMBER:
INOMBOLO YENDLU :

1 per sample unit.
Sample unit = 1 fenced lot.

The purpose of this study is :
Inhloso yocwaningo :

- to establish the incidence of illness amongst children under 5 that may be related to water in Vulindlela (Diarrhoea Scabies, Bilharzia, Dysentery and Hepatitis).
- *ukubhekela ukudlanga kwesifo sohudo, isichenene kanye nezinye izifo ezingadalwa amanzi ezinganeni ezineminyaka engaphansi kwemihlanu zasemphakathini waseVulindlela.*
- to explore the possible risk factors associated with water borne diseases
- *ukuthola izinto ezinobungozi obuhambelana nezifo ezidalwa amanzi*
- to evaluate the impact of the Vulindlela Water Supply Scheme on the Health of the community.
- *ukubhekisisa umthelela wamanzi ezimpilweni zabantu baseVulindlela.*
- to contribute toward the definition of criteria for future Umgeni Water Health Impact Assessment
- *ukufaka isandla ohlelweni lwaseMgeni oluzobhekela umthelela wamanzi ezimpilweni zomphakathini esikhathin esizayo.*

Definition
Diarrhoea: Three or more loose/ liquid/ watery stools or any number of loose stools containing blood in a 24-hour perio (Baqui AH *et al*; 1991).
Isifo sohudo: *Uhudo olunamanzi noma igazi olwenzeka izikhathi ezingaphezulu kwezintathu ngosuku olulodwa.*

1. Name of respondent:..
   Igama lophendulayo: ....
2. Number of children aged 0-5yrs living in the house:...
   Inani lezingane ezineminyaka emihlanu nengaphansi ezihlala kulelikhaya: ....
3. Relationship of respondent to head of household:..
   Ubuhlobo nenhloko yekhaya: ....

OBJECTIVE: HOMESTEAD DESCRIPTIONS
INHLOSO: INCAZELO NGEKHAYA

4. Number of rooms in the homestead:
Inani lamakamelo:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

5. Number of people living in this dwelling for four consecutive days per week?
Inani labantu abahlala kulelikhaya okungenani izinsuku ezine esontweni?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

6. Did any of your family members suffer from diarrhoea during the last **2 weeks**?
Ingabe likhona yini ilunga lomndeni elike laphathwa isifo sohudo ***emasontweni amabili edlule*** *?*

yes / *yebo*	no /*cha*

7. Description of people living in this dwelling.
Incazelo ngabantu abahlala kulelikhaya.

Sex: Male = M; Female = F
Ubulili: *Abesilisa = M; Abesifazane = F*

Relation to head of house: Self = 1; Spouse = 2; Child = 3; Sibling = 4; Parent = 5; Grandchild = 6; Grandparent = 7; Other = 8

Ubuhlobo nenhloko yekhaya: *Umninimuzi=1; Unkosikazi=2; Ingane=3; Isihlobo=4; Umzali=5; Umzukulu=6; Ugogo/Umkhulu = 7; Okunye = 8*

Employment status: Housewife = 1; Preschool = 2; School/Tertiary = 3; Pensioner = 4; Permanent Employed = 5; Casual Employed = 6; Self-employed formal = 7; Self employed hawking = 8; Unemployed = 9

Isimo ngokomsebenzi: *Umgcini wekhaya = 1; Inkulisa=2; Isikole=3; Uhola impesheni=4; Usebenza ngokugcwele=5; Usebenza itoho = 6; Uyazisebenza ngokugcwele = 7; Uyazisebenza ngokudayisa = 8; Akasebenzi = 9.*

Place of work: Home = 1; Vulindlela = 2; outside Vulindlela = 3
Indawo Yokusebenza : *Ekhaya=1; Vulindlela=2; ngaphandle kwaseVulindlela*

Place of school: Local community = 1; Vulindlela = 2; Other = 3
Ufundaphi : *Eduze kwasekhaya=1; Vulindlela=2; Other=3*

Name of household nember *gama lelunga lomndeni*									
Age ***minyaka yobudala***									
;ex / Gender *Jbulili*									
Relation to head of home. *Jbuhlobo nomninimuzi*									
)oes your child attend a reche? Name? *ngabe ingane iyaya nkulisa? Igama?*									
'ormal education (highest td passed) *banga eliphezulu liphasiwe*									
:mployment status *simo ngokomsebenzi*									
)ccupation *Jmsebenzi owenzayo*									
'lace of work *ndawo yomsebenzi*									
inancial household ontribution in last month *nali ekhishwe amalulnga mndeni ngenyanga edlule*									
[ad diarrhoea in the last **2 'eeks** *Jbe nesifo sohudo nasontweni **amabili dlule***									
'oes this person collect 'ater for this house :gularly ? *ngabe uwe ovamise kukha amanzi ?*									

8. How often does the migrant laborer come home?
Ubuya kangaki ekhaya ?

Migrant	1x week *kanye esontweni*	1x every 2 weeks *kanye emasontweni amabili*	1x month *kanye ngenyanga*	1x every 3 months *kanye ezinyangeni ezintathu*	1x every 6 months *kanye ezinyangeni eziyisithupha*	1x year *kanye onyakeni*
a						
b						
c						
d						
e						

9. Is this household ever short of food?
Ingabe lomndeni uke ukuswele ukudla ?

yes / *yebo*	no / *cha*

10. When is this household short of food?
Ukuswela nini ukudla lomndeni ?

1x week *kanye ngesonto*	month end *ekupheleni kwenyanga*	winter *ebusika*	summer *ehlobo*	middle month *phakathi nenyanga*

OBJECTIVE: HEALTH
INHLOSO : EZEMPILO

11. What are the common health problems in your community?
Iziphi izifo eziyizinkinga ezejwayelekile emphakathini ?

Bilharzia *Isichenene*	TB *Isifuba*	Malnutrition *Indlala*	High blood pressure *Isifo sikashukela*	Stress *Ukukhathazeka emoyeni*
Diarrhoea *Isifo sohudo*	Colds & flu *Umkhuhlane*	Misuse of alcohol *Ukuphuza ngokweqile*	Drug abuse *Izidakwamizwa*	Worms *Izikelemu*
skin infections *Izifo zesikhumba*	eye infections *Amehlo Abuhlungu*	Aids *Ingculaza*		

12. Which of the following symptoms have people in your home experienced in the last **2** weeks?
Yiziphi izimpawu kulezi ezilandelayo umndeni osuke wahlangabezana nazo emasontweni ama **2** *adlule ?*

a. Adults (≥ 6yrs) suffered from any of the diseases
a. Abadala (abaneminyaka eyisithupha nangaphezulu) abanalesisifo

Symptom / *Izimpawu*	No persons suffering *Inani labantu abanalesisifo*	No clinic visits *Uye kangaki emtholampilo*
stomach pain *isisu esibuhlungu*		
bloody diarrhoea *uhudo olunegazi*		
watery diarrhoea *uhudo olungamanzi*		
bloody urine *umchamo onegazi*		
itching hair/body. *ukuluma komzimba / nezinwele*		
back pain *ubuhlungu beqolo*		
fever *umkhuhlane*		
eye infection *amehlo abuhlungu*		
scabies *utwayi*		

b. Children (0 - 5 yrs) suffered from any of the diseases
b. Izingane (0-5 iminyaka) ezinalesisifo

Symptom / *Izimpawu*	No persons suffering *Inani labantu abanalesisifo*	No clinic visits *Uye kangaki emtholampilo*
stomach pain *isisu esibuhlungu*		
bloody diarrhoea *uhudo olunegazi*		
watery diarrhoea *uhudo olungamanzi*		
bloody urine *umchamo onegazi*		
itching hair/body. *ukuluma komzimba / nezinwele*		
back pain *ubuhlungu beqolo*		
fever *umkhuhlane*		
eye infection *amehlo abuhlungu*		
scabies *utwayi*		

13. What is the method of feeding for children under 5 in this homestead?
Iyiphi indlela esetshenziswayo yokupha izingane ezineminyaka engaphansi kwemi5 ukudla ?

Child	Breast only *Ibele lodwa*	breast & bottle *Ibele nebhodlela*	bottle only *Ibhodlela lodwa*	solids *Ukudla okuqinile*	breast & solids *Ibele nokudla okuqinile*	breast & bottle and solids *Ibele nebhodlela nokudla okuqinile*	bottle & solids *Ibhodlela nokudla okuqinile*
a							
b							
c							
d							
e							

14a. Where there any deaths in your family last year
Kuke kwashonwa emndenini ngonyaka odlule ?

yes *yebo*	no *cha*

14b. Complete details
Gcwalisa imininingwane

Age *Iminyaka*	Sex *Ubulili*	reason *Isizathu*

15. When any members of your family are sick do they visit a
Uma kukhona owomndeni ogulayo kungabe bayaya e

clinic *emtholampilo*	mobile unit *kumahamba nendlwana*	GP *kudokotela*	hospital *esibhedlela*	traditional healer *enyangeni/ sangoma*

16. What is the mobile unit/clinics name?
Yini igama lomtholampilo/ umahamba nendlwana?

17. Do you give your child a sugar/salt solution when it has diarrhoea?
Uma ingane inohudo kungabe niyayinika inhlanganisela kashukela nosawoti ?

YES *YEBO*	NO *CHA*

18. What are the quantities of sugar (teaspoons) and salt (teaspoons) when making up a 1L sugar/salt solution?
Ufaka isikali esingakanani sikashukela nosawoti uma wenza elitheni eyodwa yamanzi?

Sugar *Ushukela*	Salt *Usawoti*

19. Is there any particular time of the year when your family is more likely to get diarrhoea?
Ingabe sikhona isikhathi esithile onyakeni lapho umndeni uphathwa isifo sohudo?

Spring *Intwasahlobo*	autumn *Intwasabusika*	winter *ebusika*	summer *ehlobo*	after the rains *emuva kwezimvula*	draught *ngesomiso*	Do not know *Angazi*

OBJECTIVE: WATER SUPPLY AND STORAGE
INHLOSO: UKUTHOLWA KWAMANZI NOKUWALONDOLOZA

20. Where do you get your water from? Use the last column to rank the source you use most often.
Niwathathaphi amanzi ? Sebenzisa isikhala esisekugcineni ukusho lapho enijwayele ukukha khona amanzi.

Source of water ***Imvelaphi yamanzi***	**Yes** ***Yebo***	**No** ***Cha***	**Rank** ***Izinga***
Tap in house *Umpompi endlini*			
Tap in garden *Umpompi engadini*			
*Communal Tap *Umpompi womphakathi*			
*River *Umufula*			
Rain Tank *Ethangini lamanzi emvula*			
*Unprotected spring *Umthombo/ Isiphethu esingavikelwe*			
*Protected spring *Umthombo/ Isiphethu esivikelwe*			
*Bore-hole *Ipitsi*			
*Dam *Idamu*			
Tanker *Ithangi*			

Daily = 1; occasionally = 2; Never = 3
Nsukuzonke = 1; kuqabukela =2; akukaze = 3

21. Where does the water that comes out of your tap come from?
Ingabe lamanzi asempompini asukaphi?

River *Umfula*	Spring *Umthombo/ Isiphethu*	Bore-hole *Ipitshi*	Rain tank *Ithangi lemvula*	Tanker *Ithangi*	Umgeni

22. How long does one trip take you to collect water? ....
Kuthatha isikhathi esingakanani ukuya kanye uyokha amanzi ? ....

23. How many times a day is water collected for the household ? ___________
Amanzi akhiwa kangaki ngosuku ekhaya ?

1 time *kanye*	2 times *kabili*	3 times *kathathu*	4 times *kane*	5 times *kahlanu*

24. How much water do you collect at one time?
Ukha amanzi angakanani ngesikhathi ?

<25L	25 L	50L	50-100L	> 100L

25. Which of the following water uses are more common in your household?
Ikuphi kulokhu okulandelayo okuvamise ukusetshenziselwa amanzi ekhaya ?

Activity ***Ukusetshenziswa kwamanzi***	**Rank** ***Izinga***
Washing hands *Ukuwasha izandla*	
Drinking *Ukuphuza*	
Preparing juices *Ukwenza iziphuzo*	
Preparation of milk formulaes for babies *Ukwenza ubisi lwezingane*	
Washing nappies *Ukuwasha amanabukeni*	
Washing clothes *Ukuwasha izingubo*	
Stock Watering *Ukunika imfuyo*	
Bathing *Ukugeza*	
Watering garden *Ukuchelela ingadi*	

Daily = 1; occasionally = 2; Never = 3
Nsukuzonke = 1; kuqabukela=2; akukaze=3

26. What type of container is used to collect and carry water in?
Iluphi uhlobo lwesitsha olusetshenziswayo ekukheni amanzi?

Plastic *Ipulasitiki*	Metal *Insimbi*	clay pot *Isitsha sobumba*	other *Okunye*

27. What type of container is water stored in ?
Iluphi uhlobo lwesitsha olusetshenziswa ekulondolozeni amanzi ?

Plastic *Ipulasitiki*	Metal *Insimbi*	clay pot *Isitsha sobumba*	other *Okunye*

28. Is the storage container the same as the collection container ?
Kungabe isitsha sokukha amanzi siyefana nesokulondoloza amanzi ?

YES *YEBO*	NO *CHA*

29. How is water removed from the storage container?
Amanzi akhiwa kanjani esitsheni sokuwalondoloza ?

Designated cup *Ngenkomishi ebekelwe ukukha amanzi kuphela*	any cup *noma ngayiphi inkomishi*	other *Okunye*

30. How is the container cleaned?
Sihlanzwa kanjani isitsha samanzi ?

Rinsed out with water *Sihlanjululwa ngamanzi*	scrubbed with soap and a cloth *sihlanzwa ngensipho nendwangu*	scrubbed with sack and soap *sihlanzwa ngesaka nensipho*	scrubbed with steel wool & soap *sihlanzwa ngesteel wool nesipho*
scrubbed with steel wool *sihlanzwa nge steel wool*	scrubbed with handy andy *sihlanzwa nge handy andy*	scrubbed with liquid soap *sihlanzwa ngensipho engamanzi*	scrubbed with steel wool, handy andy and liquid soap *sihlanzwa ngesteel wool, handy and nensipho engamanzi*

31. How often do the water containers get cleaned?
Zihlanzwa kangaki izitsha zamanzi ?

Daily *Nsukuzonke*	Weekly *Masonto onke*	Monthly *Nyanga zonke*	Never *azikaze zihlanzwe*

OBJECTIVE: GENERAL SANITATION
INHLOSO: UKUHLANZEKA KWEKHAYA

32. Do you have a toilet on this property?
Ikhona indlu yangasese kulelikhaya ?

Yes *yebo*	no *cha*

33. Do you share a toilet with other households?
Kungabe indlu yangasese niyisebenzisa kanye nomakhelwane na ?

Yes *yebo*	no *cha*

34. Does anyone in your household use places other than the toilet to relieve themselves?
Ukhona osebenzisa enye indawo ngaphandle kwendlu yangasese uma efuna ukuzikhulula ?

Yard of dwelling *Ibala lomuzi*	nearby bush *ehlathini eliseduze*	river bank *umsebe womfula*

35. Where is the childs' (≤2) faeces disposed of?
Amakaka ezingane ezineminyaka engaphansi kweminyaka emibili atshtingwa kuphi ?

Child goes without a nappy, so don't know. *Ingane ayiligqoki inabukeni, angazi*	Pit *umgodi*	Toilet *endlini yangasese*	Outside yard *ngaphandle komuzi*	Other *Okunye*

36. Where does your household dispose of its refuge?
Utshingwa kuphi udoti kulelikhaya ?

Own Pit *Emgodini wekhaya*	Communal pit *Emgodini womphakathi*	No specific place *Ayikho indawo ecacile lapho utshingwa khona*	River banks *Emsebeni womfula*	Burn it *Uyashiswa*

37. How does your family purify its water for drinking?
Niwahlanza kanjani amanzi okuphuza?

Boil *Bilisa*	JIK *Ujikhi*	Tablets *Amaphilisi*	None *Lutho*	Other *Okunye*

38. What activities do your household members conduct in the river?
Yiziphi izinto enizenza emfuleni?

Washing clothes *Ukuhlanza izingubo*	fishing *ukudoba*	swimming *ukubhukuda*	religious ceremonies *ukubhabhadisa*	bathing *ukugeza*	washing car *ukuhlanza imoto*	other *okunye*

39. Who swims in the river?
Obani ababhukuda emfuleni?

Children males *Izingane zabafana*	children female *Izingane zamantombazane*	adult male *Abesilisa*	adult female *Abesifazane*

40. Rank in order from 1to 4 the most common use of spare time by school children after school finishes each day:
Sebenzisa izinombolo kusukela ku 1 kuya ku 4 ukuhlela indlela izingane zesikole ezisebenzisa ngayo isikhathi emuva kwesikole:

Activity ***Umsebenzi***	**Rank** ***Izinga/ Inombolo yohlelo***
Doing their homework *Zenza umsebenzi wesikole*	
Watching television *Zibukela umabonakude*	
Fetching water from the river, communal tap, spring *Ziyokha amanzi emfuleni, empompini womphakathi, esiphethwini*	
Visiting friends *Zivakashela abangani*	

41. Do the cattle drink water on your property?
Ingabe izinkomo ziyawaphuza amanzi emzini wakho?

Sometimes *Kwesinye isikhathi*	Always *Njalo*	Never *Azikaze*

42. Where do they drink from?
Ziwaphuzaphi amanzi ?

Tap *empompini*	water container *esitsheni samanzi*	water puddles *Izincibi zamanzi*	rainwater tank *ethankini lamanzi emvula*	container specific for animal *isitsha sokuphuzela izilwane*

43. When it rains, does your toilet overflow?
Uma lina i-toilet liyachichima ?

Yes *yebo*	No *cha*

OBJECTIVE : ENVIRONMENTAL CONSIDERATIONS
INHLOSO: OKUPHATHELENE NENDAWO

44. Do you have any of the following problems in or around the house?
Unazo yini lezinkinga endlini nangaphandle ?

Rats *Amagundane*	Mosquito *ominyane*	ants *izintuthwane*	flies *izimpukane*	cockroaches *amaphela*	Dumping rubbish *ukuchithwa kukadoti noma ikuphi*	Waste water *amanzi angcolile*	Animal waste *ukungcola kwezilwane*	Other *okunye*

OBJECTIVE: PROCEDURE IN FOOD PREPERATION
INHLOSO : INDLELA YOKULUNGISA UKUDLA

45. Where is cooked food stored?
Kubekwaphi ukudla okuphekiwe ?

On a plate *epuletini*	in a pot *ebhodweni*	in a fridge *efrijini*	on a table *etafuleni*

46. Where is raw food stored?
Kubekwaphi ukudla okungakaphekwa ?

In a cupboard *ekhabethweni*	in a vegetable rack *esitsheni semifino*	in a fridge *efrijini*	in another room *kwenye indlu*	in the dishes *ezitsheni*	in buckets *emabhakedeni*	in the trunk *ethilankini*

47. What is used to cook food?
Nisebenzisani ukupheka ukudla ?

fire -dung *ubulongo*	Fire - wood *izinkuni*	gas stove *isitofu segesi*	electric stove *isitofu sikagesi*	paraffin stove *isitofu sikaphalafini*	other *okunye*

48. If fire, how available is the fuel?
Uma kuyizinkuni, zitholakala kanjani?

Scarce *Ziyindlala*	moderate *Zikhonyana*	highly *Ziningi*

49. Do you use hot water to wash your dishes?
Niyawasebenzisa amanzi ashisayo ukuwasha izitsha ?

Yes *Yebo*	No *Cha*	Sometimes *Kwesinye isikhathi*	Always *Njalo*

50. List **3** advantages of having tap water within 200m of your homestead?
Yisho izinto ezi 3 ezinhle ngokuba namanzi ompompi ebangeni elinga 200m nekhaya lakho.

----

51. List **3** disadvantages of having tap water within 200m of your homestead?
Yisho izinto ezi 3 ezimbi ngokuba namanzi ompompi ebangeni elinga 200m nekhaya lakho.

----

52. What does your community need to improve its health of all its members?
Yini umphakathi oyidingayo ekwenzeni ngcono izinpilo zawo ?

----

53. What are the **3** worst problems facing your community?
Yiziphi izinkinga ezinzima ezintathu ezibhekekene nomphakathi ?

APPENDIX 4

Vulindlela Water Quality Results

Water Quality Codes

HC	Household water container
S	Water Source
OA	Overall assessement as per DWAF/DOH Guidelines
HD	Household diarrhoea present
AS	Alternate source (pre 1997-2000 water supply infrastructure development)
ns	No sample collected

Colour classification system as per DWAF/DOH Guidelines for drinking water

ideal water quality - no health effects

good water quality - suitable for lifetime use

marginal water quality - problematic for sensitive groups

poor water quality - chronic health risk

unacceptable water quality - severe acute health effects

Figure : Shange II. Water Quality Results - Survey 1.

Shange	S*	Temp	pH	Tot. Coli-forms	*E. coli*	F. strep	Turb.	Cond.	THR	Ca	Mg	Fe	Mn	NO_3	Cl	F	SO_4	Cu	Zn	Cd	As	OA*	HD*
Units		°C	mg/l	per 100ml	per 100ml	per 100ml	NTU	mS/m	mg/lcaco3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Std				0	0	0	0.5	70	22-300	150	70	0.2	0.05	10	250	1	200	0.5	1	0.01	0.01		
Jan-99																							
29236S	AS			36	6	26	0.59	5.93	17.8	3.3	2.3	0.05	<0.01	0.89	4.64	<0.1	0.53	<0.05	<0.03	<0.001	<0.002		
29236HC				840	770	240																	
33414S	AS			1260	510	22	5.68	9.8	26.1	4.1	3.8	0.44	0.04	3.43	9.18	<0.1	1.36	<0.05	<0.03	<0.001	<0.002		
33414HC				3600	960	42																	
29067S	AS			14	4	0	0.4	7.36	26.8	5.4	3.2	0.34	<0.01	0.28	4.61	<0.1	0.18	<0.05	<0.03	<0.001	<0.002		
29067HC				1380	410	42																	
29202S	AS			930	4	16	2.53	7.14	12.2	2.2	1.6	0.19	0.02	2.5	9.76	<0.1	0.4	<0.05	<0.03	<0.001	<0.002		
29202HC				700	480	0																	√
29156S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		
29156HC				4	4	2																	
29217S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		
29217HC				1400	1170	160																	√
29215S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		
29215HC				2200	1970	88																	√
29216S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		
29216HC				4200	4200	36																	
2137S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		
2137HC				2400	1400	184																	
29036S	AS			36	4	0	0.34	6.75	11.2	1.8	1.6	0.13	<0.01	3.79	8.14	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
29036HC				710	70	0																	
2081S	AS			0	0	0	0.18	8.38	29	5.6	3.6	0.15	<0.01	0.93	4.52	<0.1	1.81	<0.05	<0.03	<0.001	<0.002		
2081HC				520	258	370																	√
29120S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		
29120HC				1070	820	328																	
29161S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		
29161HC				2200	1800	254																	
29004S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		
29004HC				420	380	144																	√
29005S	AS			310	214	72	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		

Figure cont. : Shange II. Water Quality Results - Survey 1.

Shange	S*	Temp	pH	Tot. Coli-forms	*E. coli*	F. strep	Turb.	Cond.	THR	Ca	Mg	Fe	Mn	NO_3	Cl	F	SO_4	Cu	Zn	Cd	As	OA*	HD*
Units		°C	mg/l	per 100ml	per 100ml	per 100ml	NTU	mS/m	mg/ lcaco$_3$	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l		
Standard				0	0	0	0.5	70		0.01	70	0.2	0.05	10	250	1	200	0.5	1	0.005	0.05		
29005HC				4200	1180	388																	
2083S	AS			14	4	0	0.4	7.36	26.8	5.4	3.2	0.34	<0.01	0.28	4.61	<0.1	0.18	<0.05	<0.03	<0.001	<0.002		
2083HC				1270	880	12																	
29023S	AS	no sample																				ns	√
29023HC		no sample																				ns	
29086S	AS			42	2	0	0.53	9.2	28.3	5.3	3.6	<0.02	<0.01	0.52	4.73	<0.1	3.22	<0.05	<0.03	<0.001	<0.002		
29086HC				84	36	0																	
39095S	AS			0	0	0	0.18	8.38	29	5.6	3.6	0.15	<0.01	0.93	4.52	<0.1	1.81	<0.05	<0.03	<0.001	<0.002		
39095HC				1320	970	0																	
29063S	AS			12	0	16	2058	13.4	48.2	9.6	5.8	0.08	<0.01	3.29	11.7	<0.1	1.39	<0.05	<0.03	<0.001	<0.002		
29063HC				1800	1400	356																	
33329S	AS	25.2	6.44	12	0	16	2058	13.4	48.2	9.6	5.8	0.08	<0.01	3.29	11.7	<0.1	1.39	<0.05	<0.03	<0.001	<0.002		
33329HC				220	64	2																	
2073S	AS			190	2	2	2.53	7.14	12.2	2.2	1.6	0.19	0.02	2.5	9.76	<0.1	0.4	<0.05	<0.03	<0.001	<0.002		√
2073HC				670	30	0																	
2122S	AS			190	2	2	2.53	7.14	12.2	2.2	1.6	0.19	0.02	2.5	9.76	<0.1	0.4	<0.05	<0.03	<0.001	<0.002		√
2122HC				950	760	2																	
2051S	AS			8000	1100	102	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		√
2051HC				260	260																		
29134S	AS			8000	1100	102	4.83	5.31	9.16	1.5	1.3	0.21	0.02	2.12	6.12	<0.1	0.31	<0.05	<0.03	<0.001	<0.002		√
29134HC				620	450	344																	

Figure : Mafakatini. Water Quality Results - Survey 1.

Mafakatini	S*	Temp	pH	Tot. Coli-forms	*E. coli*	F. strep	Turb.	Cond.	THR	Ca	Mg	Fe	Mn	NO_3	Cl	F	SO_4	Cu	Zn	Cd	As	OA*	HD*
Units		°C	mg/l	per 100ml	per 100ml	per 100ml	NTU	mS/m	mg/lcaco$_3$	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Standard				0	0	0	0.5	70	22-300	150	70	0.2	0.05	10	250	1	200	0.5	1	0.01	0.01		
Jan-99																							
36988S	AS	18.6	6.84	3400	1480	112	64.2	4.63	17.08	3.5	2	2.03	0.18	0.16	3.36	<0.1		<0.05	0.07	<0.001	<0.002		
36988HC				1480	210	300																	
42626S	AS			90	18	500	64.2	4.63	17.08	3.5	2	2.03	0.18	0.16	3.36	<0.1		<0.05	0.07	<0.001	<0.002		
42626HC				12	2	114																	
36908S	AS			36	18	80	64.2	4.63	17.08	3.5	2	2.03	0.18	0.16	3.36	<0.1		<0.05	0.07	<0.001	<0.002		
36908HC				84	42	1900																	√
36978S	AS			2400	1270	58	2.53	4.44	17.08	3.5	2	2.03	0.18	0.15	3.52	<0.1		<0.05	0.07	<0.001	<0.002		
36978HC				110	60	330																	√
42525S	AS			110	80	140	64.2	4.63	17.08	3.5	2	2.03	0.18	0.16	3.36		<100	<0.05	0.07	<0.001	<0.002		
42525HC				5100	130	340																	√
42709S	AS	17.5	5.66	930	68	20	4.79	6.51	12.92	2	1.9	0.07	0.01	3.07	9.14	<0.1		<0.05	<0.03	<0.001	<0.002		
42709HC				890	700	104																	√
36984S	AS			930	68	20	4.79	6.51	12.92	2	1.9	0.07	0.01	3.07	9.14	<0.1		<0.05	<0.03	<0.001	<0.002		
36984HC				720	100																		√
36963S	AS	24.7	6.58	104	48	8	0.4	10.8	31.25	7	3.3			2.23	4.68	0.14	1.94						
36963HC				180	24	26																	√
42614S	AS			104	48	8	0.4	10.8	31.25	7	3.3			2.23	4.68	0.14	1.94						
42614HC				270	0	32																	√
4578S	AS	21.5	5.82	68	30	4	0.32	6.88	16.67	2.5	2.5	<0.02	<0.01	3.73	4.71	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
4578HC				310	68	60																	
42718S	AS	23.7	6.03	2	2	0	0.37	4.54	10.42	2	1.3	0.11	<0.01	1.36	3.14	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
42718HC				2200	840	6																	
36970S	AS			2	2	0	0.37	4.54	10.42	2	1.3	0.11	<0.01	1.36	3.14	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
36970HC				14	14	0																	√
26298Stk				0	0	30	0.94	2.66	<6.67	<1.0	<1.0	0.09	0.02	0.58	0.58	<0.1	1.77	<0.05	0.03	<0.001	<0.002		
26298S	AS	20.6	6.49	18	10	144	64.2	4.63	17.08	3.5	2	2.03	0.18	0.16	3.36	<0.1		<0.05	0.07	<0.001	<0.002		
26298HC				22	20	68																	√
7253S	AS	28.6	6.24	0	0	0	0.3	8.84	30.90	4.2	2.5	0.02	<0.01	4.93	6.08	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
7253HC				320	0	12																	
25776S	AS			20	5	0	0.05	<0.01	<6.67	<1.0	<1.0	0.05	<0.01	0.73	2.6	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		

HD*: Household Diarrhoea Present
OA: Overall assesssment as per DWAF/DOH Guidelines
S: Source
AS: Alternate source

Figure cont. : Mafakatini. Water Quality Results. Survey 1.

Mafakatini	S*	Temp	pH	Tot. Coli-forms	*E. coli*	F. strep	Turb.	Cond.	THR	Ca	Mg	Fe	Mn	NO_3	Cl	F	SO_4	Cu	Zn	Cd	As	OA*	HD*
Units		°C	mg/l	per 100ml	per 100ml	per 100ml	NTU	mS/m	mg/lcaco3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Standard				0	0	0	0.5	70	22-300	150	70	0.2	0.05	10	250	1	200	0.5	1	0.01	0.01		
25776HC				820	250	26																	
24706S	AS	21.3	6.21	50	0	4	0.17	5.38	16.50	3.1	2.1	0.05	<0.01	2.07	2.85	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
24706HC				50	0	4																	
25765S	AS	27.9	6.38	20	0	0	0.05	<0.01	<6.67	<1.0	<1.0	0.05	<0.01	0.73	2.6	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
25765HC				290	140	0																	√
42021S	AS			20	0	0	0.05	<0.01	<6.67	<1.0	<1.0	0.05	<0.01	0.73	2.6	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
42021HC				714	498	2480																	
42023S	AS			20	0	0	0.05	<0.01	<6.67	<1.0	<1.0	0.05	<0.01	0.73	2.6	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
42023HC				296	184	0																	√
42022S	AS			20	0	0	0.05	<0.01	<6.67	<1.0	<1.0	0.05	<0.01	0.73	2.6	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
42022HC				0	0	78																	√
25722S	AS			20	0	0	0.05	<0.01	<6.67	<1.0	<1.0	0.05	<0.01	0.73	2.6	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
25722HC				118	2	10																	√
25797S	AS	20.1	6.64	48	26	26	1.26	4	13.42	3.7	1	0.12	<0.01	0.4	1.69	<0.1	0.36	<0.05	<0.03	<0.001			
25797HC				384	64	124																	
7395S	AS			20	0	0	0.05	<0.01	<6.67	<1.0	<1.0	0.05	<0.01	0.73	2.6	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
7395HC				354	318	140																	
25769S	AS			0	0	0	0.3	8.84	20.92	4.2	2.5	0.02	<0.01	4.93	6.08	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
25769HC				6	2	0																	
4553S	AS			0	0	0	0.3	8.84	20.92	4.2	2.5	0.02	<0.01	4.93	6.08	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		
4553HC					1000	110																	√

Figure : Lower Khobongwane Water Quality Results - Survey 1

L. Kob	S*	Temp	pH	Tot. Coli-forms	*E. coli*	F. strep	Turb.	Cond.	THR	Ca	Mg	Fe	Mn	NO_3	Cl	F	SO_4	Cu	Zn	Cd	As	OA*	HD*
Units		°C	mg/l	per 100ml	per 100ml	per 100ml	NTU	mS/m	mg/lcaco3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Std				0	0	0	0.5	70	22-300	150	70	0.2	0.05	10	250	1	200	0.5	1	0.01	0.01		
Jan-99																							
29425S	AS	26.6	6.91	520	72	390	6	22.5	76.30	15	9.3	0.17	0.01	7.29	15.3	<0.1	5.17	<0.05	<0.03	<0.001	<0.002		
29425HC				2200	2200																		1
29393S	AS			520	72	390	6	22.5	76.30	15	9.3	0.17	0.01	7.29	15.3	<0.1	5.17	<0.05	<0.03	<0.001	<0.002		
29393HC				64	28																		
29373S	AS	26.6	6.91	58	36	80	0.32	2.78	6.92	1.1	<1	0.02	<0.01	0.44	4.03	<0.1	0.33	<0.05	0.03	<0.001	<0.002		
29373HC				56	54																		
29375S	AS	23.6	6.86	74	20	54	0.68	2.82	7.58	1.2	1.1	0.05	<0.01	0.33	3.69	<0.1	0.28	<0.05	<0.03	<0.001	<0.002		
29375HC				370	64																		1
29377S	AS	25.2	7.26	26	4	40	0.68	6.95	24.90	5.3	2.8	0.1	<0.01	0.21	4.6	<0.1	0.72	0.12	0.08	<0.001			
29377HC				32	0																		
29378S	AS			26	4	40	0.68	6.95	24.90	5.3	2.8	0.1	<0.01	0.21	4.6	<0.1	0.72	0.12	0.08	<0.001			
29378HC				62	16																		
29406S	AS			58	36	80	0.32	2.78	6.92	1.1	<1	0.02	<0.01	0.44	4.03	<0.1	0.33	<0.05	0.03	<0.001	<0.002		
29406HC				190	28																		1
29370S	AS			8	2		0.68	6.95	24.90	5.3	2.8	0.1	<0.01	0.21	4.6	<0.1	0.72	0.12	0.08	<0.001			
29370HC				140	24																		1
29382S	AS			290	2		0.52	2.72	6.92	1	<1	0.03	<0.01	0.4	4.04	<0.1	0.3	<0.05	<0.03	<0.001	<0.002		
29382HC																						ns	
29374S	AS			290	2		0.52	2.72	6.92	1	<1	0.03	<0.01	0.4	4.04	<0.1	0.3	<0.05	<0.03	<0.001	<0.002		
29374HC				320	20																		
29430S	AS			290	2		0.52	2.72	6.92	1	<1	0.03	<0.01	0.4	4.04	<0.1	0.3	<0.05	<0.03	<0.001	<0.002		
29430HC				820	370																		
29414S	AS			210	64		0.52	2.72	6.92	1	<1	0.03	<0.01	0.4	4.04	<0.1	0.3	<0.05	<0.03	<0.001	<0.002		
29414HC				280000	124000																		1
29379S	AS			30	22		0.52	2.72	6.92	1	<1	0.03	<0.01	0.4	4.04	<0.1	0.3	<0.05	<0.03	<0.001	<0.002		
29379HC				340	20																		
29388S	AS	26.5	6.95	18	18		0.52	2.72	6.92	1	<1	0.03	<0.01	0.4	4.04	<0.1	0.3	<0.05	<0.03	<0.001	<0.002		
29388HC				340	104																		
29469S	AS	24.6	6.88	280	6		0.41	2.05	6.92	1.1	<1	0.02	<0.01	0.27	2.99	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002		

HD: Household diarrhoea Present
OA: Overall Assessment as per DWAF/DOH Guidelines
S: Source
AS: Alternate Source

Figure cont. : Lower Khobongwane Water Quality Results - Survey 1.

Site	S*	Temp	pH	Tot. Coli-forms	*E. coli*	F. strep	Turb.	Cond.	THR	Ca	Mg	Fe	Mn	NO_3	Cl	F	SO_4	Cu	Zn	Cd	As	OA*
Units		°C	mg/l	per 100ml	per 100ml	per 100ml	NTU	mS/m	mg/lcaco3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Std				0	0	0	0.5	70	22-300	150	70	0.2	0.05	10	250	1	200	0.5	1	0.01	0.01	
29469HC				2070	1390																	
29476S	AS	no sample																				ns
29476HC				720	430																	
29471S	AS	no sample																				ns
29471HC																						ns
29368S	AS			280	6		0.41	2.05	6.91667	1.1	<1	0.02	<0.01	0.27	2.99	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002	
29368HC				180000	33000																	
29470S	AS			280	6		0.41	2.05	6.91667	1.1	<1	0.02	<0.01	0.27	2.99	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002	
29470HC				740	74																	
29472S	AS			280	6		0.41	2.05	6.91667	1.1	<1	0.02	<0.01	0.27	2.99	<0.1	<0.16	<0.05	<0.03	<0.001	<0.002	
29472HC				29000	11000																	
29396S	AS	25	6.87	320	12		0.35	2.9	<6.67	<1	<1	0.08	<0.01	0.37	4.01	<0.1	0.3	<0.05	<0.03	<0.001	<0.002	
29396HC				88	22																	
29418S	AS			240	14		0.35	2.9	<6.67	<1	<1	0.08	<0.01	0.37	4.01	<0.1	0.3	<0.05	<0.03	<0.001	<0.002	
29418HC				68	68																	
29386S	AS	20.7	6.77	84	8		0.28	2.81	<6.67	<1	<1	0.04	<0.01	0.31	3.57	<0.1	0.22	<0.05	<0.03	<0.001	<0.002	
29386HC				580	2																	
29381S	AS			630	30		0.75	2.95	6.91667	1	<1	0.04	<0.01	0.3	3.58	<0.1	0.28	<0.05	<0.03	<0.001	<0.002	
29381HC				420	58																	
294080S	AS	no sample																				ns
294080HC				5600	4200																	

Figure : Mthoqotho. Water Quality Results - Survey 1.

Mthoqoto	S*	Temp	pH	Tot. Coli-forms	*E. coli*	F. strep	Turb.	Cond.	THR	Ca	Mg	Fe	Mn	NO_3	Cl	F	SO_4	Cu	Zn	Cd	As	OA*	HD*
Units		°C	mg/l	per 100ml	per 100ml	per 100ml	NTU	mS/m	mg/ $Icaco_3$	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Std				0	0	0	0.5	70	22-300	150	70	0.2	0.05	10	250	1	200	0.5	1	0.010	0.01		
Jan-99																							
24098S1	AS			90	40	8	2.72	6.35	21.92	3.6	3.1	0.1	0.01	1.04	4.95	<0.1		<0.05	<0.03	<0.001	<0.002		
24098HC				1340	290	14													0.12	<0.001			√
24098S	AS			11	0	3	0.15	5.62	12.00	1.8	1.8	0.06	0.02	3.61	5.76	<0.1		<0.05	0.4	<0.001			
24098HC				1340	290	14																	√
23726S	AS			1170	288	>1000	4.18	5.62	13.80	2	2.1	0.08	0.02	3.58	5.68	<0.1		0.07	<0.03	<0.001			
23726HC				980	194	7																	
24070S	AS			1170	288	>1000	4.18	5.62	13.80	2	2.1	0.08	0.02	3.58	5.68	<0.1		0.07	<0.03	<0.001			
24070HC				48	12	2																	
24006S	AS			18	5	3	0.5	5.51	12.40	1.8	1.9	0.02	0.02	3.76	5.69	<0.1		<0.05	0.07	<0.001	<0.002		
24006HC				64	15	13																	
24134S	AS			90	40	8	2.72	6.35	21.90	3.6	3.1	0.1	0.01	1.04	4.95	<0.1		<0.05	<0.03	<0.001	<0.002		
24134HC				1260	4	12																	
23705S	AS	20.7	5.55	20	4	0	1.28	6.06	14.80	1.2	2.1	0.04	0.09	3.87	5.74	<0.1	0.9	0.08	0.04	<0.001			
23705HC				670	150	0																	
32053S	AS	23	6.53	42	18	10	0.47	4.52	12.30	1.9	1.8	0.02	<0.01	0.49	4.75	<0.1	0.28	0.05	<0.03	<0.001			
32053HC				34	2	24																	√
24464S	AS	22.5	5.82	36	6	14	0.5	5.51	12.40	1.8	1.9	0.02	0.02	3.76	5.69	<0.1		<0.05	0.07	<0.001	<0.002		
24464HC				14000	3100	0																	
24099S	AS	21.2	5.92	6	6	0	0.24	5.61	12.60	1.9	1.9	0.03	0.02	3.66	5.24	<0.1	0.29	0.1	<0.03	<0.001			
24099HC				24	6	2																	√
32055S	AS			6	6	0	0.24	5.61	12.60	1.9	1.9	0.03	0.02	3.66	5.24	<0.1	0.29	0.1	<0.03	<0.001			
32055HC				90	50	16																	
24146S	AS			18	5	3	0.5	5.51	12.40	1.8	1.9	0.02	0.02	3.76	5.69	<0.1		<0.05	0.07	<0.001	<0.002		
24146HC				380	130	2																	
24143S	AS			1170	288	>1000	4.18	5.62	13.80	2	2.1	0.08	0.02	3.58	5.68	<0.1		0.07	<0.03	<0.001			
24143HC				28000	1500	40																	√
24001S	AS			1170	288	>1000	4.18	5.62	13.80	2	2.1	0.08	0.02	3.58	5.68	<0.1		0.07	<0.03	<0.001			
24001HC				2	2	0																	√
24135S	AS			18	5	3	0.5	5.51	12.40	1.8	1.9	0.02	0.02	3.76	5.69	<0.1		<0.05	0.07	<0.001	<0.002		

Figure cont. : Mthoqotho. Water Quality Results - Survey 1.

Mthoqoto	S*	Temp	pH	Tot. Coli-forms	*E. coli*	F. strep	Turb.	Cond.	THR	Ca	Mg	Fe	Mn	NO_3	Cl	F	SO_4	Cu	Zn	Cd	As	OA*	HD*
Units		°C	mg/l	per 100ml	per 100ml	per 100ml	NTU	mS/m	mg/lcaco$_3$	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Std				0	0	0	0.5	70	22-300	150	70	0.2	0.05	10	250	1	200	0.5	1	0.010	0.01		
24135HC				840	470	114																	
24010S	AS			18	5	3	0.5	5.51	12.40	1.8	1.9	0.02	0.02	3.76	5.69	<0.1		<0.05	0.07	<0.001	<0.002		
24010HC				1100	48	8																	
24015S	AS	24.7		21000	700	2	0.27	5.4	12.33	1.6	2	0.02	0.02	3.72	7.55	<0.1		<0.05	<0.03	<0.001	<0.002		
24015HC				40	0	0																	
24121S	AS	26.2	6.27	740	510	130	3.4		7.17	1.2	<1.0	0.1	0.04					<0.05	0.34	0.002			
24121HC				17000	900	4																	
24133S	AS	25.4	5.81	0	0	2	0.34	5.42	12.33	1.6	2	0.04	0.02	3.67	7.5	<0.1		<0.05	0.03	<0.1	<0.002		
24133HC				16	2	2																	
23741S	AS	30.6	6.5	10	2	0	2.95	4.26	9.92	2.3	<1.0	0.2	0.01	0.28	8.45	<0.1		<0.05	0.47	<0.001	<0.002		
23741HC				5800	2400	2																	
24020S	AS			18	5	3	0.5	5.51	12.40	1.8	1.9	0.02	0.02	3.76	5.69	<0.1		<0.05	0.07	<0.001	<0.002		
24020HC				26	12	4																	
32059S	AS			4	4		0.34	5.42	12.33	1.6	2	0.04	0.02	3.67	7.5	<0.1		<0.05	0.03	<0.1	<0.002		
32059HC				630	64																		
24053S	AS			4	4		0.34	5.42	12.33	1.6	2	0.04	0.02	3.67	7.5	<0.1		<0.05	0.03	<0.1	<0.002		
24053HC				1070	520																		√
23735S	AS	23.9	7.14	220	156		16.5	2.14	23.00	3.2	3.6	0.19	0.01	0.62	7.14	<0.1	2.76	<0.05	0.53	<0.001	<0.002		
23735HC				74	10																		√
32052S	AS	22.4	6.62	820	148		7.58	7.31	20.50	3.7	2.7	0.16	0.01	0.99	6.83	<0.1	3.25	<0.05	<0.03	<0.001	<0.002		
32052HC				5400	5400																		
33507S	AS	no sample																				ns	
33507HC				360	24																		√