THE EFFECT OF WATER SUPPLY, HANDLING AND USAGE ON WATER QUALITY IN RELATION TO HEALTH INDICES IN DEVELOPING COMMUNITIES

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EXECUTIVE SUMMARY

Background and motivation:

A large number of South Africans do not have access to adequate water and sanitation. Population growth and urbanisation has placed increased pressure on the need for sanitation and safe water supplies, but due to financial and human resource constraints it is unlikely that high grade facilities will be provided in the immediate future. In developing communities in South Africa many households are making use of 'serviced sites' which include outside or communal taps and outside flush toilets or bucket latrines. As an increasing number of such sites are being developed it is essential that the impact of these services on health be assessed.

Little information relating the quality of water supplied to the quality of water used/consumed and its impact on health is available. Assumptions are often made, not based on scientific data, that the supply of clean water will have a positive impact on the health status of a population, but studies conducted in numerous countries indicate that the benefits of water supply improvements are variable. Although high levels of faecal contamination are generally assumed to be associated with diarrhoeal disease, a direct relationship has rarely been found. High levels of food and water contamination have been found in the home environment even when clean water was supplied. Improvements in water quality alone seem to have little effect on water handling practices and the subsequent contamination of stored water.

Aims and objectives as specified in contract

This study aimed to investigate the quality of water supplied compared to the quality of water consumed in relation to health indices in a developing community. Various categories of services were included in the study, namely no formal water supply, communal taps used by > 100 people per tap, outdoor taps on individual plots and in-house taps.

The objectives as stated in the proposal for the duration of the 3 year study were as follows:

a) determination of the quality of water at the point of collection and the quality of water after transport and storage.

b) examination of patterns of water usage, including water used for drinking, washing and hygiene purposes, quantity of water used and identification of the treatment of water by the end-user prior to use and

c) correlation of the water quality with the health indicators of the study population.

The study was designed to assist in providing policy guidelines for the provision of water in developing communities.

Study design

The study was conducted making use of the case-control methodology recommended by a working group for "*measuring the health impact of water supply and sanitation*" as the epidemiological assessment technique. The case-control study was undertaken to estimate the risk of diarrhoea associated with the quality of water at the source and end user point. More than 300 households were included, of which half were cases and half controls. Cases were preschool children with severe diarrhoea visiting a health facility. Hygiene and sanitation factors, education and socio-economic factors were explored by means of personal interviews and observational studies. Controls of similar age and with a similar type of water supply were selected from the same neighbourhoods as the cases. Water samples from both cases and controls were taken from source supplies (taps) and points of use (in-house), and analysed to assess the microbiological quality. A cross-sectional study recording all preschool children who were brought to all health facilities in the study area was conducted to examine the relationship between different types of water and sanitation facilities and diarrhoea among preschool children.

Brief summary of results and conclusions

Water provided to the study population was of good microbiological quality and complied with SABS guidelines. However, water was significantly more contaminated after handling and storage than at source. Cases and controls were found to have equally poor water quality after collection and storage, with higher levels of *E. coli* counts observed in control in-house samples. Even though no statistically significant association between poor in-house water quality and diarrhoea was observed, analysis of questionnaire and observational data of the case-control study identified some risk factors for severe diarrhoea among pre-school children. A strong association was found between the child's attendance at a day care centre or crèche and diarrhoea. An increased risk of diarrhoea was associated with poor knowledge regarding food handling and hygiene; as well as a lower level of knowledge regarding the causes and prevention of diarrhoea; and poor kitchen hygiene.

In the case-control study, poorer water quality was observed where communal taps are used. In the cross-sectional study, a comparatively larger proportion of diarrhoea cases was recorded from areas where communal taps are the type of water supply used, compared to areas where a tap is available on site. This indicates that a private outdoor tap appears to minimise the risk associated with water-related disease. Many other factors such as whether children attend a day care centre or are cared for by a non-family member; hygiene practices; and knowledge of causes and prevention of diarrhoea, were shown as important factors impacting on the health of the population in a developing community.

With regards to providing policy guidelines for the provision of water in developing communities, it appears that the provision of private outdoor taps (as opposed to shared facilities) will contribute to the reduction of the risk associated with diarrhoea.

Extent to which objectives were reached and actions to be taken as a result of the findings

The objectives of the study, as specified in the proposal, were achieved as follows:

a) Water quality at point of collection and after storage was adequately assessed. Seasonal variations could not be determined due to a change in the supply source. A new pipeline was installed with accompanying high free chlorine concentrations, which influenced the water quality significantly. The variations that were observed can therefore not be attributed to a seasonal variation.

b) The patterns of water usage, quantity of water used and treatment of water by the end-user was determined. The average quantity of water used was calculated as 50ℓ/week, which was based on the participants' response to a question enquiring how often their water containers were filled per week. This amount does not reflect the amount of water actually used, but rather the amount that was stored within the household, and was the closest possible estimate.

c) No direct relationship between water quality and diarrhoea was found, even though a high level of water contamination was found after collection and storage. However, poorer water quality was observed (after handling and storage) where communal taps are available. Furthermore, a comparatively larger proportion of diarrhoea cases was recorded in the cross-sectional study, from areas where communal taps are the type of water supply used, compared to areas where a tap is available on site.

Recommendations for further research and technology transfer.

Investigations into the activities leading to the contamination of water occurring at communal taps are recommended. In addition, the development of technology (engineering approaches) to reduce contamination of water during collection from communal taps should be explored.

The suitability of indicator organisms presently used for assessing drinking water quality and associated health risks is tenuous. At present there is no absolute indicator organism which complies with the criteria specified for the ideal indicator organism. Indicator organisms have limitations in that certain viruses and parasites are known to be more resistant to disinfection than the indicator organism, *E. coli* and the absence of the latter will not necessarily indicate absence of the former. A search for more suitable indicator organisms is needed and recommended. There would be merit in investigating the association between bacterial pathogens and indicator organisms.

Further research should focus on appropriate holistic health promotion programmes to address the range of practices around water usage, storage and environmental hygiene. An in-depth holistic intervention programme, aimed at a national level, is recommended. The situation with respect to hygiene practices and water quality at day care centres should be investigated to establish minimum requirements and a management system for such facilities, as well as differentiating between problems related to formal and informal day care facilities.

It is recommended that the final results of this study be distributed to various authorities involved in policy decisions for water and sanitation supply and health policies, such as the Department of Water Affairs and Forestry; Departments of Health (local, regional and national); and local and metropolitan councils. Feedback to the community involved in this study should be provided, possibly through local radio. In addition, a short summary is being distributed to clinic staff and environmental health officers, with the possibility of providing a more formal presentation to the health workers.

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1. INTRODUCTION

A large number of South Africans do not have access to adequate water and sanitation. Population growth and urbanisation has placed increased pressure on the need for sanitation and safe water supplies, but due to financial and human resource constraints it is unlikely that high grade facilities will be provided in the immediate future. In developing communities in South Africa many households are making use of 'serviced sites' which include outside or communal taps and outside flush toilets or bucket latrines. As an increasing number of such sites are being developed it is essential that the impact of these services on health be assessed.

Little information relating the quality of water supplied to the quality of water used/consumed and its impact on health is available. Assumptions are often made, not based on scientific data, that the supply of clean water will have a positive impact on the health status of a population, but studies conducted in numerous countries indicate that the benefits of water supply improvements are variable. Although high levels of faecal contamination are generally assumed to be associated with diarrhoeal disease, a direct relationship has rarely been found. High levels of food and water contamination have been found in the home environment even when clean water was supplied. Improvements in water quality alone seem to have little effect on water handling practices and the subsequent contamination of stored water.

In the climate of scarce water resources the need to understand the health impacts of water supply and sanitation are important. The scarcer the resource, the greater is the need to know how and why water supply may influence infection and disease in the community; and to influence the hygiene behaviour of the population as regards the health implications of polluted water.

This study aimed to investigate the quality of water supplied compared to the quality of water consumed in relation to health indices in a developing community. Various categories of services were included in the study, namely no formal water supply, communal taps used by >100 people per tap, outdoor taps on individual plots and in-house taps. The study was conducted making use of the case-control methodology recommended by a working group for "*measuring the health impact of water supply and sanitation*" as the epidemiological assessment technique. The working group was organised by the International Centre for Diarrhoeal Disease Research and the London School of Hygiene and Tropical Medicine with support from UNICEF, the International Development Research Centre and the World Health Organisation (WHO). The case-control methodology was reported to be less time consuming and expensive than the conventional methods. A case-control study is more efficient in that it has greater statistical power with smaller sample sizes, has a greater control of biases and allows for investigation of multiple causes. No follow up is required as with the longitudinal study design which would result in the loss of many study participants, especially in a developing community. In addition to the case-control study, a cross sectional study was conducted to examine the incidence of diarrhoea of preschool children presenting at clinics in the study site during specific periods. This provided additional information regarding the incidence of diarrhoea for different levels of water provision.

1.1 Objectives

The objectives as stated in the proposal for the duration of the 3 year study were as follows:

a) determination of the quality of water at the point of collection and the quality of water after transport and storage. The microbial and physico-chemical water quality data of water used for drinking and household purposes was collected at intervals over a three year period to indicate any seasonal variation that occurs.

b) examination of patterns of water usage, including water used for drinking, washing and hygiene purposes, quantity of water used and identification of the treatment of water by the end-user prior to use and

c) correlation of the water quality with the health indicators of the study population.

The study was designed to assist in providing policy guidelines for the provision of water in developing communities.

1.2 Brief overview of study design:

A study site that contains the various levels of water supply described above was chosen. Diarrhoea was used as an indicator of health status as it is the major water-related disease shown to be related to water and sanitation provision. Khayelitsha was chosen as the study site as it contains different levels of water and sanitation provision and it has a relatively high incidence of diarrhoea in children. An incidence based case-control study was undertaken to estimate the risk of diarrhoea associated with the quality of water at the source and at end user point. More than three hundred households were included in the study. Cases were defined as preschool children who presented at selected clinics with severe diarrhoea. Hygiene and sanitation factors as well as education and socio-economic status were explored. Controls were matched for age and type of water supply from the immediate neighbourhood of the case. Water samples from both cases and controls were taken from source supplies(taps) and from points of use(in-house).

In addition to the case-control method a cross sectional study was conducted to examine the relationship between different types of water and sanitation facilities in peri-urban communities and diarrhoea among preschool children.

To provide an indication of water quality, the microbiological quality of the water samples was assessed using the standard bacterial indicator organisms for drinking water *ie.* heterotrophic plate counts, total coliforms, and faecal coliforms. In addition, *E. coli* and coliphage concentrations were determined. Ten percent of the samples were analysed for

Giardia, Cryptosporidium and enteric viruses. The SABS specifications recommend that drinking water quality be assessed using the heterotrophic plate count, total and faecal coliforms counts. *E. coli* is more specific as an indicator of faecal pollution, and was therefore included in the study. Coliphages are also indicators of faecal pollution and provide an indication of virus survival in water. Determining whether *Giardia, Cryptosporidium* and enteric viruses were present provided an indication of the occurrence of pathogens.

2. LITERATURE REVIEW

2.1 INTRODUCTION

In South Africa, as in most developing countries, rapid urbanisation has outstripped investments of municipal governments in infrastructure and services, especially in residential areas with a predominance of poorer households. The result has been an increase in people living in overcrowded and informal settlements. People in these settlements live in substandard housing with often inadequate water supply, sanitation and other basic necessities (WHO, 1988; Hadoy & Satterthwaite, 1989; Seager, 1995). Enteric infections, particularly due to bacterial pathogens, are readily transmitted under these circumstances (Levine & Levine, 1994). Population growth creates water shortages not only by adding to the numbers of consumers but also by increasing population density beyond the level that nearby water supplies can serve. Also, population growth worsens global warming, which could change rainfall patterns (Population Reports, 1992). Thus, the goal of the Decade for the International Drinking Water Supply to improve coverage of safe water provision by 90 per cent (WHO, 1981) seem to be failing as efforts are being overwhelmed in the urban population by rapid urban growth (Lloyd, *et al.*, 1989).

The national and international agencies investing in water supply and other sanitation programmes are working on the generally accepted assumption that the provision of an adequate quantity of safe water and proper facilities for the sanitary handling and disposal of human body wastes are basic necessities for the maintenance of good health and productivity. However, despite this premise being widely accepted it has been validated quantitatively only in a limited number of well controlled studies in urban areas and to a varying degree for rural situations (Shuval, *et al.*, 1981). In fact, Yacoob (1994), points out that over 50 000 people still die each day from diseases relating to water and sanitation, while others struggle through their daily lives weakened by repeated bouts of diarrhoea and other water-related diseases. In this discussion a review of water and sanitation supply was conducted, examining the associated health impacts as well as water-related diseases, in particular diarrhoea, with particular emphasis on the South African situation. The various epidemiological methodologies for measuring health impacts of water and sanitation provision were considered and evaluated, and the importance of health education for improved hygienic practices was considered.

2.2 WATER AND SANITATION SUPPLY AND ASSOCIATED HEALTH EFFECTS

In 1975, it was estimated that only 74 per cent of the urban population in the developing countries had access to a safe water supply. In 1985, half way through the International Drinking Water Supply and Sanitation Decade, the number of people served had increased by more than 300 million, an increase of over 70 per cent. While considerable progress was made during this period, according to the WHO Statistical Quarterly (1991), these figures seem to understate the number of people who lack adequate water supply, and that local specialists in most developing countries find it hard to reconcile the official figures with reality in the urban centres in which they work. There are several reasons for the assumption that people are adequately served with safe water. Firstly, the statistics on coverage are frequently based on the assumption that all those with water are adequately served, but frequently communal water taps are so few that people have to queue for a long time for water. This has the effect of reducing water consumption below the level required for good health. Secondly, the criteria used to define an adequate water supply[1] are open to question. For example, the availability of a water tap within 100 meters of a house is often considered adequate, yet, this is not necessarily adequate for maximizing health. Finally, the water in piped systems is often of doubtful quality and many households and settlements judged to be adequately served may have to resort to other sources such as using water from streams and other surface sources, which in urban areas are often little more than open sewers, or to purchase from insanitary vendors (Hardoy, *et al.*, 1990; Saunders and Warford, 1990; Tulchin, 1986).

Water from such sources (rivers, ponds and canals) is often used for a variety of purposes - ablutions, washing clothes, the disposal of human excreta - so it becomes highly polluted and therefore an important vehicle for the domestic transmission of infections and infestations (Tulchin, 1986). It has been estimated that about 200 million more people drink unsafe water now than in 1975 (Lloyd *et al.*, 1989). This is a major area of concern as there seems to be less progress made on the safeguarding of the quality of the water provided. Biological and microbiological pollution of water courses and drinking-water supplies remain widely prevalent. Communicable water-related diseases, with diarrhoea in the first place are still the most widespread health problems. Appropriate measures to protect the quality of potable water, not only from microbiological contamination, but also from chemicals are still needed in developing countries. Lack of human and financial resources severely hamper the public works authorities to discharge their responsibilities with regard to drinking-water surveillance and control. National drinking-water quality standards, where they exist, are often not supported by the necessary laboratory services to monitor compliance or stimulate improvements in the safety of the water supplied (Kreisel, 1991).

In South Africa it is estimated that more than 12 million people do not have access to an adequate supply of potable water and nearly 21 million lack basic sanitation. The provision of these basic services is planned as a part of a coherent development strategy (DWA&F, 1994).

Improved water supply and sanitation may improve the quality of life, they may facilitate other development activity, they may save the time spent in carrying water over long distances; but the foremost benefit anticipated is **improved health** (Dangefield, 1983; Shuval, *et al.*, 1981). A clean water supply is believed to be among the cornerstones of those environment and social changes which produced the dramatic decline in infectious diseases in Europe and North America over the last 130 years. Although infectious mortality can be reduced by curative services alone, morbidity can only be significantly reduced by preventive measures and improved water and sanitation are central to the concepts of preventive medicine and public health (Lloyd, *et al.*, 1989; Saunders & Warford, 1976; Feachem, *et al.*, 1985). In the last three decades, an increasing amount of evidence has accumulated for

[1]According to the WHO (1984) definitions, 'water supply' encompasses everything from a relatively sophisticated pumping, storage, treatment and distribution system to a simple protected spring or well with no storage or extensive distribution system. 'Reasonable access to water' in an urban area includes apart from household connections, a public fountain or standpost located not farther than 200 metres from a house. A 'safe water supply' simply refers to uncontaminated water.

the importance of access to safe water as a means of improving health (Bradley, 1974; Feachem, 1978; 1983).

However, it is known that the great majority of people in developing countries will not receive in the foreseeable future, adequate and safe water supply (Huttly, 1990; Hardoy, *et al.*, 1990; Kalbermatten, *et al.*, 1980; Mendis, 1978). It is this climate of scarce resources to meet an enormous need that makes understanding of the health aspects of water supply and sanitation important. The scarcer the resource, the greater is the need to know exactly how and why water supply may influence infection and disease in the community; and to influence hygiene behaviour of the population concerning health implications of polluted water. In the discussion below, the health impacts of water supply, as well as water-related diseases, in particular diarrhoea, are reviewed. Although there are a wide range of water-related diseases, as will be shown below, the emphasis on diarrhoea in this review stems from the fact that it constitutes a major public health burden in developing countries, and, that it is often the focus of health impact assessments of water and sanitation interventions.

2.3 WATER-RELATED DISEASES

The infections related to water supply and sanitation are numerous and the relationships are often complex. However, a conceptual system for understanding disease related to water was developed over the past three decades and is now fairly widely used (Bradley & Emurwon, 1968; Bradley, 1974; Feachem, 1978; 1983). To consider the problem of water-related diseases and its prevention in a world-wide context, an understanding of Bradley's (1968) classification, later modified by Feachem (1975) has been found useful as it is based upon epidemiologic considerations and permit generalizations about the likely effect of environmental changes and other actions on their incidence.

A water-related disease is one which is in some gross way related to water in the environment or to impurities within water. Water-related diseases may be divided into those which are caused by a biological agent of disease (a pathogen), or those that are caused by some chemical substance in water. The water-related infections are so described because their transmission, or the prevention of their transmission depends in part upon water (Craun, 1986). There are four categories of water-related diseases, and these include water-borne, water-washed, water-based and water-vectored diseases. Below is a brief discussion of these diseases.

2.3.1 Water-borne Diseases: These are diseases transmitted through the ingestion of contaminated water, and water acts as the passive carrier of the infectious or chemical agent. Potentially water-borne diseases include the classical infections, notably cholera and typhoid, but also include a wide range of other diseases such as infectious hepatitis and some diarrhoea and dysenteries. Although the effects of an acute epidemic are dramatic, it is the continuing occurrence of endemic cases which is more devastating in the long run. Thus, the acute diarrhoeal diseases with their continuing high prevalence and mortality rates, centred mainly on young children, present one of the greatest health problems of the developing world.

2.3.2 Water-washed Diseases: These diseases fall into two main groups: those affecting gastrointestinal tract, often leading to diarrhoea, and diseases of the skin and body surface.

These may be significantly reduced following improvements in domestic and personal hygiene. These improvements in hygiene often depend upon increased availability of water and the use for hygienic purposes of increased volume of water. A water-washed disease may be formally defined as one whose transmission will be reduced following an increase in the volume of water used for hygienic purposes, irrespective of the quality of that water.

2.3.3 Water-based Diseases: These are diseases in which the pathogen spends an essential part of its life in a water snail or other aquatic animal. Water quality and cultural social behaviour play roles in the transmission of these diseases.

2.3.4 Water-vectored Diseases: These diseases are transmitted by insects which either breed in water (malaria-carrying mosquitos) or insects which bite near water (riverine tsetse fly). As these diseases are controlled through means other than water supply considerations, they are not considered important for discussion here.

2.4 DIARRHOEAL DISEASES

Diarrhoeal diseases remain the leading infectious cause of infant and child morbidity and mortality in developing countries (Huttly, 1990; Lonergan, 1991). Diarrhoeal diseases have been found to account for more than one-third of paediatric deaths in most parts of the developing countries (WHO, 1979). More recently, incidence estimates based on 7 350 cross-sectional surveys in 70 countries have yielded a global median incidence rate of 3,4 episodes per child per year. Diarrhoea was estimated to account for 35.8% of all deaths in the under-5's in the period 1981 - 1986. Huttly (1990) estimates that young children in developing countries experience 1 500 million episodes of diarrhoea per year and 4 million diarrhoea-associated deaths (12.0 per 1 000 population under 5). The morbidity/mortality burden is high in all regions although there is considerable variation, with children in Africa generally suffering the most (Huttly, 1990) A recent review of diarrhoeal diseases for sub-Saharan Africa concluded that the median attack rate is 4.9 episodes per child per year and child mortality rates 11 per 1 000 (Feachem & Jamison, 1990). Using the available mortality data as well as internationally comparable information on the risks of contracting disease among the children, it is possible to estimate that there are around 1.5 million cases of diarrhoea in children under age of five years per annum in South Africa (Yach, *et al.*, 1989).

The infectious dose (ID)[2] of a diarrhoea-causing pathogen varies according to the particular pathogen and various host factors (Kreisel, 1991). Esrey, *et al.* (1985) suggested that water and sanitation improvements would be more likely to have an impact on diarrhoea caused by high-ID pathogens than on those caused by low-ID pathogens. This hypothesis was confirmed in their etiology-specific impact studies. According to the WHO (1984), water disinfected at 0.5 mg/l of free residual chlorine for 30 minutes at 1 NTU would constitute minimal health risk. A large number of outbreaks of viral and parasitic disease of waterborne have since resulted in a review of the safety of current water quality (Hayes, *et al.*, 1989; Environmental Protection Agency, 1976). Thus increasingly, the more recent analytic methods have permitted the detection of viruses (Payment and Armon, 1989) and parasites

[2]The number of ingested organisms required to cause diarrhoea.

(Smith and Rose, 1990) in water quality standards.

2.5 MICROBIOLOGICAL METHODS FOR ASSESSING WATER QUALITY

The most common and widespread health risk associated with drinking water is contamination by human or animal faeces and with the microorganisms contained in faeces. Pathogenic organisms of concern include bacteria, viruses and protozoan parasites. The diseases they cause vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis cholera or typhoid fever, to name but a few.

To ensure that a drinking water supply is safe and does not contain any pathogenic microorganisms it should be examined for indicators of pollution. Routinely it is impossible to test the water supply for all pathogens related to water-borne diseases because of the complexity of the testing and the time and cost related to it. It is preferable to use indicator systems which are able to index the presence of pathogens and related health risks in water. Ideally the indicator system should fulfil a number of criteria, namely,

-it should be present when the pathogen is present and should be absent in unpolluted water
-it should be present in numbers greater than the pathogen it indicates
-its survival in the environment and resistance to treatment processes should be comparable to that of pathogens
-it should not be harmful to human health
-it should be easy to identify and isolate (Berg, 1978).

At present, there is no absolute indicator which complies with all of the above criteria, but the traditional indicators of drinking water quality include the coliform group (including the faecal or thermotolerant coliforms, and more specifically, *E. coli*) and the standard or heterotrophic plate count. As microbial drinking water quality guidelines aim at ensuring both the protection of human health and the evaluation of the treatment efficacy more than one indicator organism is often needed. Some of the indicators specifically address treatment efficacy with no, or very little, emphasis on human health.

The coliform group of bacteria has been used much more than any other indicator group for monitoring drinking water because it addresses both health and treatment efficacy objectives. To date, the coliform group is still the most reliable indicator for drinking water. Although the total coliform group can only remotely indicate human health risk, the group includes *E. coli*, which usually originates from faecal matter. The major deficiencies of the coliform group are their natural survival pattern which differs greatly from known bacterial pathogens. Deficiencies include differences in response to conventional water treatment processes compared to that of enteric pathogens and the suppression of growth due to high populations of other microorganisms. Many countries continue using coliforms as indicators of drinking water quality to allow for comparison with historical data.

In the late 1940's the total coliform group was split to include a subgroup, namely the faecal coliform group. This group is more representative of faecal pollution and therefor may be more indicative of possible health implications. It should be recognized that the faecal coliform determination does not distinguish between human and animal faecal contamination.

Generally no faecal coliforms should be present in drinking water. Most recent standards. guidelines and criteria include this indicator subgroup of faecal coliforms, however only in some of these guidelines is a direct analysis of the subgroup specified. The faecal coliform group includes other species of bacteria including *E. coli* but not all are of faecal origin.

The total number of bacteria can be used to assess the quality of water by making use of alternative methods (heterotrophic plate count - HPC, or standard plate count - SPC). Both the SPC and HPC are not able to indicate faecal pollution, but are useful in assessing the efficiency of water treatment processes and in the interpretation of coliform counts.

When indicators provide evidence of faecal pollution in drinking water supplies, this is *prima facie* evidence of a health hazard, but whether the hazard will manifest in overt cases of disease will depend on whether pathogens are actually present, the immunity of the community served, and how the water is used (Australian Drinking Water Guidelines, 1994). Some enteric pathogens may be present in water with few, if any, indicator organisms. For example, organisms such as enteric viruses and protozoan parasites (*Cryptosporidium* oocysts and *Giardia* cysts) are resistant to disinfection and may survive where indicators have been eliminated. Bacteriophages are sometimes recommended as alternative indicators of water quality because of their similarity to enteric viruses, they are present in numbers greater than or equal to enteric viruses, are more resistant to disinfection, persist in water longer and are detected using simple and rapid techniques. However, bacteriophages are not absolute indicators of enteric viruses, with viruses having been detected in water where phages were absent.

Because the potential presence of pathogens in water cannot be predicted solely by faecal indicators it may be necessary to under certain circumstances monitor for the presence of pathogens in addition to routine indicators provided that the facilities are available. The WHO (1984) have recommended that under certain circumstances (such as during epidemics and the evaluation of a new water source) it is necessary to monitor for *Salmonella spp., Shigella spp., Vibrio cholera, Yersinia enterocolitica, Campylobacter fetus,* enteropathogenic *E. coli and* enteric viruses, whereas in Australia it has been recommended to monitor for *Salmonella sp., Vibrio cholerae, Shigella spp., Yersinia, Leptospira, Legionella, Giardia, Naegleria fowleri,* enteric viruses, nematodes, cestodes and trematodes (Australian Draft Guidelines, 1994; Mc Neill, 1985). The EEC Directive (1980) specifies that water intended for human consumption should not contain pathogens and if it is intended to supplement the microbiological analysis of water intended for human consumption, the samples should be examined for pathogens including *Salmonella*, pathogenic staphylococci, enteroviruses and faecal bacteriophages.

2.6 IMPACT OF WATER SUPPLY : REVIEW OF PREVIOUS STUDIES

Data from several studies, in various geographical areas and involving different intervention strategies have produced varied results. Because most studies on the impact of water-supply improvements have reported the impact on children under five years, the review of these studies will be restricted to this age group. The major pitfalls in measuring the impact of water supply and sanitation investments by the use of epidemiological data on diarrhoeal diseases have been summarised by Blum & Feachem (1983). In their review of 50 studies they concluded that while most studies claimed to show improvement in one or more health indicators, a critical review of the studies raised serious doubts as to the validity of their conclusions. Most of the studies reviewed were either longitudinal or cross-sectional and none were case-control studies. These methods were also condemned by the expert panel convened by the World Bank and other international research bodies in the 70's (Cairncross, 1990).

At an International Conference on 'measuring the health impact of water and sanitation programmes' in 1983, the case-control method was given credibility by UNICEF, WHO, and the International Development Centre as a "new technique" to be used to measure impact on diarrhoeal disease in less time and at a lower cost than with the conventional methods (Cairncross, 1990; Baltazar, 1988). A case-control study is an observational, analytical type of epidemiological study in which a group of people with a particular disease (the cases) are compared with a group of people without the disease (the controls). The purpose of the comparison is to determine whether, in the past, the cases have been exposed (more or less) often to a specific factor than the controls, and thus gives clues to the factors which might elevate (or reduce) the RISK of the disease under investigation. Results from case-control studies can only provide estimates of relative risk. They cannot measure either incidence or prevalence.

The findings of a study conducted in the Philippines, confirmed that the case-control studies of the effect of improved environmental sanitation on diarrhoeal disease can be carried out rapidly, at modest cost and can produce valid estimates of effect (Baltazar, *et al.*, 1988). Stanton & Clemens (1987) maintain that the generalizability of the case-control method lies more in its method than its results. It provides a feasible means of arriving at a "community diagnosis" for water-sanitation practices that correlate with childhood diarrhoea. They see the method as being able to preserve the family as the unit of analysis, which seems intuitively logical for an analytic strategy intended to detect behaviours that can be altered through family based interventions.

Two years later, a review of data from 67 studies in 28 countries was done by Esrey, *et al.* (1985). Their findings showed that improvements in morbidity and mortality rates could be expected from investments in water supply and sanitation facilities; and that investments which improve both water quality and availability were especially effective. They later identified eight studies of the impact of such variables on early childhood mortality from all causes. In these studies the mortality of children with improved water supply and sanitation facilities was reported to be 0 to 81% lower than that of children without such facilities. Other recent findings have also confirmed this correlation (Esrey & Habicht, 1986; Victora, *et al.*, 1988; Pickering, *et al.*, 1986). In an urban area in Brazil, Victora, *et al.* (1988) found that the infants whose homes had piped water had a diarrhoea mortality rate that was 80% lower than those from homes with no easy access to water. In addition, they found that infants receiving untreated water were not at significantly higher risk than those receiving treated water. These findings seem to suggest that the beneficial effects of piped water may relate to the easy availability of water than to its quality. This finding is in agreement with other research on child mortality due to water-related causes (Esrey, 1985; Esrey & Habicht, 1986).

Results from health impact evaluation studies adopting a health-facility based case-control design have yielded more reliable data. In Malawi and the Philippines, children from homes using safe potable water and good sanitation facilities yielded 20% less diarrhoea (Young & Briscoe, 1988; Baltazar, 1988). In a study conducted in Sri Lanka (Mertens, *et al* also found association between improved water supplies and diarrhoea. In a rural area in Bangladesh, findings of a longitudinal study conducted to evaluate integrated water, sanitation and hygiene education programmes showed that diarrhoeal morbidity rates in under 5's, similar prior to the intervention project became 25% lower in the intervention area than in the control area (Huttly, 1990). A similar study conducted in a rural area of Nigeria, diarrhoea morbidity showed only in a limited subgroups of the population (Aziz, *et al.*, 1990). A study conducted in rural Malaysia demonstrated the efficacy of the case-control study in the empirical development of an intervention programme (Knight, *et al.*, 1992).

As stated earlier, there are several routes for faecal-oral transmission of diarrhoea causing pathogens. The mechanisms whereby the provision of improved water-supply and sanitation facilities reduce the transmission are complex and are not easy to measure. While evaluation of water quality by microbiological indicators provides a useful method of comparing different types of water sources and of assessing the risk of contamination, more recent findings seem to suggest that it is difficult to detect a health impact even where there are substantial improvements to drinking water quality (Esrey, *et al.*, 1990; Payment, *et al.*, 1991; Pinfold, *et al.*, 1993). In a study conducted in the Philippines, Moe, *et al.* (1993) demonstrated that there is only a significant relationship between incidence of diarrhoea and drinking water quality when that water is grossly contaminated (> 1000 E. coli per 100 ml). Although high levels of faecal contamination are generally assumed to be associated with diarrhoeal diseases, a direct relationship has rarely been found (Huttly, 1990; Black, *et al.*, 1982; Henry, *et al.*, 1990). Perhaps, this is due to the difficulties inherent in doing so. Even so, several studies have reported high levels of food and water contamination in the home environment, even when clean water was supplied (Black, *et al.*, 1982; Blum, *et al.*, 1990; Feachem, *et al.*, 1978). Other studies have shown that even when safe water is supplied, high degrees of contamination occur between the source and the use in the home (Daniels, *et al.*, 1990; Blum, *et al.*, 1990; Feachem, *et al.*, 1978). This data seem to support the growing evidence that improvements in water quantity and sanitation facilities are of greater importance than water quality in the reduction of diarrhoeal diseases (Esrey & Habicht, 1986; Cairncross, 1987).

2.7 OTHER EPIDEMIOLOGICAL METHODS: A BRIEF REVIEW

Epidemiological studies can be divided into two main types: intervention studies and observational studies (Rothman, 1986). Intervention studies are studies in which the investigators do have control over who is and who is not exposed to the factor under investigation. These studies can be subdivided into two types: clinical trials and preventative trials. Clinical trials are studies of the effect of a specific treatment on patients who already have a particular disease while preventative trials study the effect of a possible preventative measure on people who do not yet have a particular disease.

Observational studies, on the other hand are studies which describe the distribution of disease in human population and investigate possible aetiological factors to explain that distribution. The investigators have no control over who and who is not exposed to the factor under study.

In addition to the case-control study, observational studies can be divided into the following:

- Cohort or follow-up studies: these are studies in which people are identified and grouped with respect to whether or not they have been exposed to a specific factor. The groups are followed up over time to determine whether the incidence of a particular disease is any greater (or less) in the exposed group than in the non-exposed group. These studies can be either retrospective or prospective. The latter implies that exposures and outcomes have occurred prior to investigation taking place; whilst the latter implies that exposure and outcomes occur after investigation begins.

- Cross-sectional or prevalence studies: studies in which a defined population is surveyed and their disease and exposure status determined at one point in time or over a short period of time. Prevalence rates of disease in the whole population and in those with and without the exposure under investigation can be determined. Cross-sectional studies are often used as a basis for public health planning, and to provide information for the formulation of aetiologic hypotheses. The most important advantage of these studies is that they are relatively quick and inexpensive to carry out as compared to case-control and cohort studies. Its two major disadvantages are that they are not suitable for a disease which is rare and cannot test aetiological hypotheses.

- Ecological studies: in these studies information on the characteristics and/or exposures of individual members of the population groups are generally not obtained. Existing statistics are used to compare the mortality or morbidity experience of one or more populations with some overall index of exposure.

2.8. HEALTH EDUCATION PROGRAMMES

It has been suggested that health benefits from improved water supply only occur concurrently with improved sanitation, whereas the benefits of improved sanitation may occur in the absence of improved water supply. An additional factor which should be taken into account is health education. It has been argued that hygiene education is as important in improving health as better sanitation (Editor: WQI, 1994). The role for appropriate hygiene education is being acknowledged, with programmes being developed which brace a multi-disciplinary approach. Although there is scarce resource on the effectiveness of hygiene-education programmes, in a review of three studies, Feachem (1984) reported reductions in diarrhoea incidence rate of 14 - 48%. An educational intervention in urban Bangladesh was based on three hygienic practices which were associated with high rates of diarrhoea. In the six months following the intervention, the incidence of diarrhoea was 20% lower than in the control communities (Feachem, 1984). In both the intervention and control areas, diarrhoea incidence rates were inversely related to the number of improved hygienic practices that were reported by the respondents. An integrated water, sanitation and hygiene intervention programme in Bangladesh examined diarrhoea incidence in relation to household hygienic practices (Alam, *et al.*, 1989). Another fairly recent community-based hygiene education study conducted in Zaire showed a reduction in diarrhoeal rates (Haggerty, 1994).

These studies seem to suggest that improvements on water quality alone would have little effect on water handling practices and the subsequent contamination of other stored water.

Domestic activities related to the storage and use of water, as well preparation and consumption of food may have a more important bearing on faecal-oral disease transmission. The mere material improvement of water supplies and sanitation facilities would doubtless prove to be less effective than if the people were advised by means of health education of the sources of their particular disease problems and how to avoid them. It is, therefore essential that an intensive education programme should form an integral part of any sanitation or water supply project.

2.9 MEASUREMENT OF HYGIENE BEHAVIOUR

Hygiene[3] practice may be promoted by better access to water and sanitation or by hygiene education, and improvements in hygiene education, and improvements in hygiene may be reflected in increased water consumption. A review of studies in this area shows that the most significant impacts on disease incidence stem from the behavioural changes which constitute hygiene improvements, and which interventions in the water sector seek to bring about (Feachem, 1984; Alam, *et al.*, 1989; Clemens & Stanton, 1987). If no such change in behaviour results from improved water supply or sanitation, the only health benefits which are likely to occur are those stemming from improved water quality, however there is evidence that in many settings these are relatively minor or even negligible (Cairncross, 1990; Feachem, 1984). Unless more information is made available about the conditions which bring about behavioural changes, it is not possible to know how a health benefit can be expected. Unfortunately all the health impact studies reviewed above had difficulty in measuring behavioural factors. In some studies these factors were neglected because of an emphasis on water quality. In others where an effort was made to study them but the researchers lacked the necessary expertise or resources. In a large number of these studies, only a simple questionnaire was used, and the findings showed too many discrepancies for detailed analysis to be considered worthwhile.

In an attempt to find ways to address some of these pitfalls, a workshop on 'Measurement of Hygiene Behaviour' was arranged by the London School of Hygiene and Tropical Medicine in Zimbabwe in April 1991. A large number of papers at this conference identified hygiene practice as the most neglected aspect of water and sanitation projects. As Quarry (1991) pointed hygiene education is often an "add on" or afterthought in these projects, and is convinced that for any water and sanitation project to be to be successful, people who are to benefit from such projects should be involved from the planning stage.

There are possible reasons that have been advanced for the measurement of hygiene behaviours. Firstly, specific hygiene behaviours may be measured in order to more precisely establish the links between specific behaviours and health outcomes. Secondly, hygiene behaviour may be measured in order to evaluate hygiene education interventions Hubley (1991) points out that evaluating hygiene behaviour involves more than just measuring hygiene behaviour or showing a change in behaviour. Although the classical experimental design is a useful method, often problems are encountered in matching the control and the

[3]Hygiene in this context refers to practices such as the washing of hands, the handling of food and utensils, and/or the disposal of children's stools.

test groups and in interpreting results. He emphasizes that any health education input should be regarded as a complex process involving a mix of variables relating to source, message, channel and receiver, and proposes that the following checklist be used to rate the advice presented in educational programmes:

- is it epidemiologically correct?
- how much does it cost to put it into practice?
- how much time and effort does it take up?
- is it culturally acceptable?
- does it meet a felt need of the intended audience?
- what, if any, new skills are required to perform the behaviour?
- how easy is it to understand the language and concepts presented in the advice?

Measurement of hygiene behaviour must be supplemented with a detailed description of the variables used in the hygiene education and some assessment of their contribution to overall effectiveness. Effectiveness refers to whether the programme achieved its stated objectives, which is change in a particular hygiene behaviour. Efficiency refers to the amount of effort including time, money and resources involved in achieving those objectives.

However, health education in the traditional sense is often disappointing both in design and results (Chauhan, 1983; Donaldson, 1982; Isley, 1984). First, there is a tendency to lecture to the public about good hygiene, repeating textbook prescriptions without considering how the ideas apply in the listeners' particular circumstances. This rather patronizing habit not only neglects the many strengths in existing knowledge and practice but it is also ineffectual. It fails to reveal the users' viewpoint and the genuine problems that technical innovations or medical implications pose for them (The World Bank, 1981). This approach assumes that "we know something that they don't and that all we have to do is develop the proper message and they will do what we think is best for them" (Quarry, 1991).

More and more health planners are beginning to understand that methodologies must be found to assist individuals to acquire the decision-making skills to enable them to understand and take control of the factors that effect their health and the welfare of their communities. In hygiene education, this approach utilizes the techniques of group formation, participatory training and group discussion to help community members to take responsibility for their own health. However it is important to realise that the common routine of hygiene educationalists does not often lead to empowerment (Quarry, 1991; Hubley, 1991). What then is an effective hygiene education?

2.10 EFFECTIVE HYGIENE EDUCATION

An effective hygiene education is one which stresses orientation toward the consumer, and one which assumes that the people will ultimately assume responsibility for their own health. This means an extreme departure from the usual time-honoured style of health education (Rohde, 1983). It means that the people are involved right from the outset in identifying needs, choosing the sequence of improvements to be made and deciding how these improvements are to be made, and deciding how these improvements will be implemented. For it is mainly in this way that projects will come to effectively incorporate local traditions, customs and beliefs that often play a key role in determining whether behaviour change will occur or not (Donaldson, 1982). The major pitfall of most hygiene education programmes lies in their 'top-down' approach which emphasizes specific outcomes such as behaviour change without taking into account the existing knowledge and practices of the communities, as well as the potential of the people for taking responsibility for their own health (Wallerstein & Bernstein, 1994; Oakley & Marsden, 1984). Although there is no concrete evidence supporting the effectiveness of community participation in improving the health of the people, there is general agreement that it is desirable, and that many countries are finding it a useful approach. In keeping with these trends, community participation was adopted as one of the key strategies of the International Drinking Water Supply and Sanitation Decade (1981-90).

Much contemporary scholarly effort has been lavished on the theory and practice of community participation. Today, this is perhaps the single most documented issue in the field of development. Inevitably, community participation has also become a bandwagon. It now seems that programmes must include at least a few references to community participation to appear credible. It has become common for planners and researchers to theorise about community participation without really appreciating what it means to implement this in a village or informal settlement (Chauhan, 1983; Shisana & Versfeld, 1993). The rationale for and strategies of community participation have been documented by Wallerstein and Bernstein (1994). In summary, health education involves more than conveying simple facts or messages, it aims at getting people to think about their situation, challenge assumptions and work for change. Emphasis is placed on development of community participation and processes of problem-solving, decision-making and empowerment. These are seen as pre-conditions for communities taking steps to change hygiene behaviours and improve their health.

Particularly crucial in this participation are recognition and utilisation of the key role women play as acceptors, users, managers and educators in matters of water supply and sanitation (WHO Chronicle, 1984; Elmendorf, 1982; Isley, 1984; Hubley, 1991). Women influence directly the volume consumed, the quality of the water delivered to the house and the hygiene of the eating utensils. In addition, it is women who form a constant link in the chain of contamination from faeces to fingers to food and who can break the chain by latrine use, hand-washing and protection of left-over food, and, therefore, are partly responsible for the prevention of and/or recovery of children from diarrhoea.

Developing problem-solving skills, decision-making and empowerment usually involves face-to-face communication using participatory learning methods with individuals, small groups and communities. A successful implementation of this approach is based on two important considerations. Firstly, a multidisciplinary approach involving professional people who have experience in community animation and who are trained in anthropology, sociology, communications and adult education should be embraced. Secondly, in order to prepare the project team for a more participatory approach it is useful to develop quicker appraisal methods to assist planners and researchers in identifying what Quarry (1991) refers to as a more subtle understanding of user's own perceptions of a given situation, and not the perceptions of planners or researchers. Although they have limitations, such methods have been successfully used. The value of these methods lies in their ability to strengthen the primary health care principles of equity, participation and multisectorial cooperation (WHO, 1988). Green (1990) calls this stage the diagnostic phase, and emphasizes that the community should be involved at this early stage of programme development.

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3. METHODOLOGY

3.1 STUDY SITE

3.1.1 Study site selection

Surveys were conducted in the Western Cape to establish the levels of services available in different areas. The following criteria were used in the selection of the study site:

- current status of water supply
- location *i.e.* logistically accessible for the research team
- access to health services
- availability of supporting data (*eg*. public health research and clinic data)

Khayelitsha was chosen as the study site as it has a mixture of the different levels of water and sanitation provision. There was also an established relationship between members of the project team and health service staff in the area and extensive background health information was available.

3.1.2 Study site description

Khayelitsha is situated on the eastern outskirts of Cape Town on the Cape Flats, bordering on the northern shore of False Bay (see map below). Three main natural phenomena which affect the population have been identified as winter flooding, localized cold winter temperatures, and wind erosion accompanied by sand blasting during summer months (Harrison, 1992).

Khayelitsha was originally 'planned' in 1983 to accommodate squatters residing in the Cape metropolitan area, comprising approximately 220 000 people in family dwellings and a further 30 000 labourers in hostels. Due to political and economical events, the plans altered and in 1984 'site and service' plots were made available and continue to be made available to provide the most basic service to residents. Some areas are provided with communal taps and bucket systems for sanitation. Despite the development of 'serviced sites', informal 'squatters' remain in areas of Khayelitsha with no formal water or sanitation provision, where residents make use of either neighbouring facilities, or the surrounding bush for ablutions.

According to the Lingelethu West City Council (1993), the number of dwellings and type of water and sanitation supply can be summarised as follows:

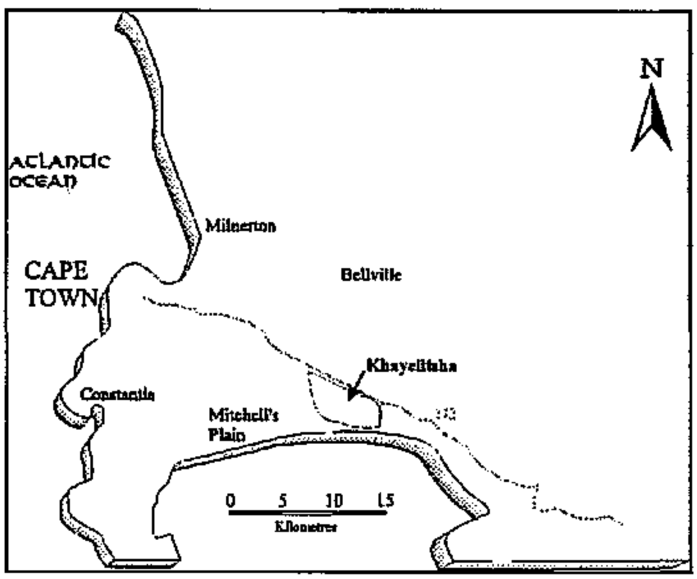
formal housing	10 557 (16%)
'site and services'	39 050 (60%)
communal taps with bucket latrines	11 200 (17%)
no official services	4 460 (7%)
TOTAL	**65 267**

Assuming an average of five people per dwelling, the Lingelethu West City Council estimated the population as 326 335 in 1993, which conforms to the general consensus which placed the population between 300 000 and 350 000 in 1992, of which approximately 20% were less than 5 years of age (Harrison *et al.*, 1992). With the population growth and influx of new residents it is assumed that in 1995 the population exceeds 400 000. (For a more detailed breakdown of sites and population densities estimated by the Lingelethu West City Council, 1993, see Appendix 1).

As in most developing communities, unemployment and its associated poverty are the predominant determinants of the health status of the population in Khayelitsha. Only 55% of women were employed in either the formal or informal sector (Cooper *et al.*, 1991). Earlier data estimated the general level of employment at 50% (Le Roux *et al.*, 1991). Eight percent of adults in Khayelitsha had no formal education, with 50% having had no secondary education (Harrison *et al.*, 1992). In the shack areas 90% of the people were unskilled, whereas in the formal areas at least one third had some kind of training.

Of the water-related diseases, diarrhoea appears to be the most prominent of childhood illnesses. It is estimated that the three most important causes of child and infant mortality in Khayelitsha, according to the 1991 register, are diarrhoeal disease, acute respiratory infections (ARI) and perinatal factors. Diarrhoea is responsible for 24,4% of infant deaths from known causes and 11,4% of all deaths, followed by ARI and perinatal factors respectively. The estimated under-five mortality rate for Khayelitsha for 1991 was 41,8 per 1000 live births (Harrison *et al.*, 1992). Mortality data for this type of settlement is not particularly accurate and morbidity data is even less so, but diarrhoea is certainly one of the most common illnesses affecting young children. Data for South Africa is only available reporting mortality. For South Africa as a whole, the reported mortality for under fives from diarrhoea according to 1990 statistics is approximately 17% of all deaths, and for the Western Cape it is 13% of all deaths (Bourne and Coetzee, 1995).

Health services for the residents in Khayelitsha comprise 2 day hospitals and 5 clinics. The Khayelitsha Site B oral rehydration unit operates 24 hours per day.



3.2 Case-control Study

3.2.1 Study design and study population

Study design

The study sample consisted of pre-school children in Khayelitsha. Information from the corresponding households was collected. An incidence based case-control study was undertaken to estimate the risk of diarrhoea associated with the water quality at the source and at the end user point, facilities provided, hygiene habits, knowledge of causes and prevention of diarrhoea, environmental factors and socio-economic status. The study population was stratified into four categories with different levels of water supply namely;

no formal water supply
stand pipes/communal taps (> 100 people per tap)
taps on individual plots (< 100 people per tap)
in-house taps.

Case definition

The health outcome under investigation was diarrhoea. Because of the logistical difficulty in identifying all diarrhoea cases in the community, a sample was drawn from pre-school children who were brought to the day hospitals with diarrhoea. The World Health Organisation's definition of diarrhoea, namely three or more loose or watery stools in a period of 24 hours was used (WHO, 1993b).

The selection of cases from the day hospitals allows for the inclusion of severe cases, *i.e.* diarrhoeal episodes of public health concern. The assumption is that most severe cases of diarrhoea (as opposed to mild forms which are very common) end up at a health facility unless the child dies before a health facility can be reached. Such diarrhoea is also more likely to be related to water contamination than mild forms of diarrhoea which may be caused by other organisms such as rotavirus, or associated with other illness such as throat and ear infections. Mortality data shows that relatively few deaths due to diarrhoea occur at home. Thus severe cases recruited at the clinics represent almost all severe diarrhoea cases that occur in the community. Using clinic confirmed cases also has the advantage that children who presented with diarrhoea related to other diseases were excluded as cases.

Definition of controls

Controls were selected according to age (±6 months) and type of water supply from the immediate neighbourhood of the case. Children who suffered from diarrhoea during the preceding 14 days at the time of the visit were excluded as controls. Controls were matched for the time of occurrence of the case as well as the dates for interviews and observational studies. Choosing controls from the neighbourhood allows for the control of factors such as access to health centres and other unknown risk factors which may be associated with the neighbourhood.

Comprehensive household based interviews and spot check observations by the fieldworkers were undertaken at the homes of the cases and controls. Interviews with the caretaker of the child were held and observations focused on hygienic practices of interest within the household.

Sample size for the case-control study

In case-control studies the sample size depends on first, the desired level of statistical significance of the results, second the desired power of the study, third the odds ratio that the study should detect, and fourth the proportion of the population exposed to the risk factors. This study aimed at detecting an odds ratio of at least 3 with a power of 80% at the 95% significance level. Assuming that the proportion of the population exposed to the risk factors of interest was at least 50%, at least 65 cases and 65 controls needed to be recruited (as calculated using Epi Info, version 5). In this study >150 cases and >150 controls were selected: thus a total of >300 households were studied. The increased sample size allowed for multivariate models or analyses to be used. The selection of cases and controls was spread over two three-month periods to include both wet and dry seasons.

Data collection methods

Mothers or caretakers of the children who were selected for the study were interviewed at the child's home. The questionnaire (translated into Xhosa and verified by back translation) sought information on the household's demographic characteristics, socio-economic factors, environmental data, behavioural and hygienic practices and morbidity data (see Appendix 2). Water samples were collected at the same time as the interview.

The following factors were explored in the study;

Household-related/demographic factors

- child's demographic characteristics
- parental age, education and occupation
- household's socio-economic status
- household size

Environmental factors

- access to water and sanitation facilities
- type of water and sanitation facilities
- domestic waste disposal
- type of housing

Behavioural and hygiene factors

- hand-washing before handling food and after defecation
- type of water collection containers

- water storage patterns and cleaning of storage containers
- water usage patterns and amount used
- storage and preparation of food
- child feeding practices
- defecation behaviour and disposal of stools
- disposal of garbage and waste water
- use of soap

After each interview a spot check observation was conducted to assess the cleanliness of the child under study, the home, main cooking room, the toilet and other hygiene indicators.

Controlling for bias

Interviewers were recruited from the community in Khayelitsha. Interviewers underwent intensive training on administering the questionnaire and performing observational assessments in order to minimise interviewer variation and bias. The questionnaire was translated into Xhosa, the main local language which is used in Khayelitsha in order to minimise variation due to the data collection instrument. Because it was not possible to blind the interviewer to the disease status of the child under study the questionnaire used specific questions to reduce interviewer bias due to their knowledge of the child's status. In addition validation interviews were conducted randomly on 10% of cases and controls.

Pilot study

A pilot study was undertaken within the study area to test the logistics of implementing the study and tested the content and relevance of the questionnaires. It was also used as part of the training process for the interviewers.

Ethical considerations

This proposal was approved by the Medical Research Council's Ethics Committee. Permission to implement the study in the health centres concerned was obtained from the responsible local authority, *ie.* Western Cape Regional Services Council (Cape Town Metropolitan Council), and authorities from the health centres. Relevant community representatives (Western Cape Regional Services Council; Khayelitsha Site B clinic and Health Inspectors; Khayelitsha Health Committee; SACLA; Lingelethu West City Council; Progressive Primary Health Care Network) were informed about the study as interviews and observational studies were conducted at the child's home.

The study was explained in general terms to caretakers of children who were included in the project. Project participants were informed about the recruitment process, what participation in the study entailed and how long their co-operation was required. Potential benefits of the study were described in lay terms. All participants were assured that their participation in the project was voluntary, that they were free to withdraw from the study at any time, and that their information would be treated as strictly confidential. A consent form was read to and signed by all the subjects who agreed to participate in the study (Appendix 2). Interviews conducted at the child's home were scheduled so that they did not interfere with the child's routine or treatment. During the identification of controls in the community, all the children identified as having an ailment were referred to the health centre. The collection of water samples was one of the reasons given for visiting the home.

3.2.2 Water quality measurements

Interviewers collected two water samples from each household included in the case-control study, one from the household's principal water source and another from the child's home, that is at the point of use.

Each water sample (>600 water samples) was analysed for the presence of the following indicator organisms using standard methods (Standard methods, 1989);

- heterotrophic plate count
- total coliforms
- faecal coliforms
- *E. coli*
- coliphages.

In addition 10% of the samples were analysed for the following organisms;

- *Giardia* cysts
- *Cryptosporidium* oocysts (Kfir *et al.*, 1993)
- enteric viruses (Nupen *et al.*, 1981).

Heterotrophic plate counts, total coliforms and faecal coliforms are tests specified in SABS and international guidelines for assessing drinking water quality. *E. coli* are more specific indicators of faecal pollution. Coliphages were included because they are useful indicators of faecal pollution and they are viruses, which are similar in resistance to disinfection practices, and therefore useful indicators of enteric virus survival in water. *Giardia* cysts and *Cryptosporidium* oocysts are known to cause diarrhoea, thus tests for some of the actual pathogens and not only indicator organisms in water were included.

3.2.3. Statistical and mathematical analyses

Statistical analyses of questionnaire data was conducted using the Statistical Analysis Software (SAS) and Epi Info (version 5) computer programmes. Chi square tests were performed to test for associations between variables. Where expected cell frequencies were less than 5, the Fisher's exact test was performed. The strength of the association between the exposure variables and diarrhoea was estimated using the odds ratio (OR). Logistic regression using the backward elimination procedure was used to investigate multivariate associations and to adjust for possible confounders.

Matched statistical analyses were conducted on selected variables of statistical significance. Odds ratios, 95% confidence intervals and p-values were calculated for these variables, as unmatched analysis may lead to under-estimations of odds ratios.

Statistical analyses of microbiological data were performed using Statgraphics (STSC version 6) and SAS. Analysis of variance and nonparametric comparison of two samples was used to compare water quality between cases and controls, in-house and tap waters. Nonparametric comparison of two samples using the pairs test (Mann-Whitney) was used to compare water quality of the two phases of the study.

A water quality 'index' was calculated for each water sample to provide an indication of the overall water quality. The index was calculated using the water quality guideline values; if the water satisfied the criteria for all the parameters it was scored as 100; if it did not comply with the guideline values the score varied between 95 and 0, depending on whether more than one parameter exceeded guideline values and the level of contamination. The 'index' was calculated by adding 'scores' for each microbial parameter rated as either 20, 15, 10 or 0, (with 20 representing the 'best' score and zero the 'worst' score)based on the three-tiered Department of National Health and Population Development criteria (Aucamp and Vivier, 1990) as follows:

score- for each parameter	20	15	10	0
SPC/mℓ	<100	101-1000	1001-10000	>10000
total coliforms/100mℓ	0	1-5	6-100	101+
faecal coliforms/100mℓ	0	1	2-10	10+
E. coli/100mℓ	0	1	2-10	10+
Phages/10mℓ	0	1-10	11-100	101+

If a water complied with guidelines for all parameters tested, its score would be 100.

3.3 Cross-sectional studies

Cross-sectional studies were undertaken to create a broad picture of the incidence of diarrhoea among preschool children in the study area *i.e.* Khayelitsha. Data collected in the cross-sectional study was used to facilitate the interpretation of and to complement results obtained from the case-control study. The cross-sectional study aimed to describe the preschool children who were brought to all the health facilities in Khayelitsha in terms of the type of water and sanitation supply and a number of socio-demographic variables.

Data was collected over a 1 week period during both the wet and dry seasons. Trained interviewers collected data from 7 local public facilities (5 clinics and 2 day hospitals). The parents/caretakers of the children brought to the health facility with diarrhoea were interviewed. Information on the child and water and sanitation facilities at home was recorded by means of a short questionnaire (Appendix 4). During the second round of data collection a series of questions were added to establish the position of the child within the family, *i.e.* eldest or youngest child, *etc.*.

4. RESULTS

4.1. Study site description

Illustrations of water and sanitation services are provided below.

4.2. Case-control study

4.2.1 Questionnaire and observational data

Profile of cases and controls

Data from questionnaires of a total of 169 cases and 166 controls were included in the study. The age distribution of both cases and controls was positively skewed, with less than 25% of the children over 3 years old. The median age of controls (18 months) was significantly higher than that of cases (12 months) ($p=0.0002$). On average, the controls were 6 months older than the cases. The proportion of children who were breast-feeding was similar between the cases and controls. Table 1 summarises some characteristics of cases and controls.

Demographic profile of study households

The average (median) household size for both cases and controls was 5 people. The age and gender breakdown of case and control households was also similar (see Table 1). Mothers of cases were significantly younger than mothers of controls ($p=0.0006$). On average, mothers of controls were 3 years older than those of the cases. There was no correlation between the age of cases and their mothers' age ($r=0.28$), and the age of controls and their mothers' age ($r=0.10$).

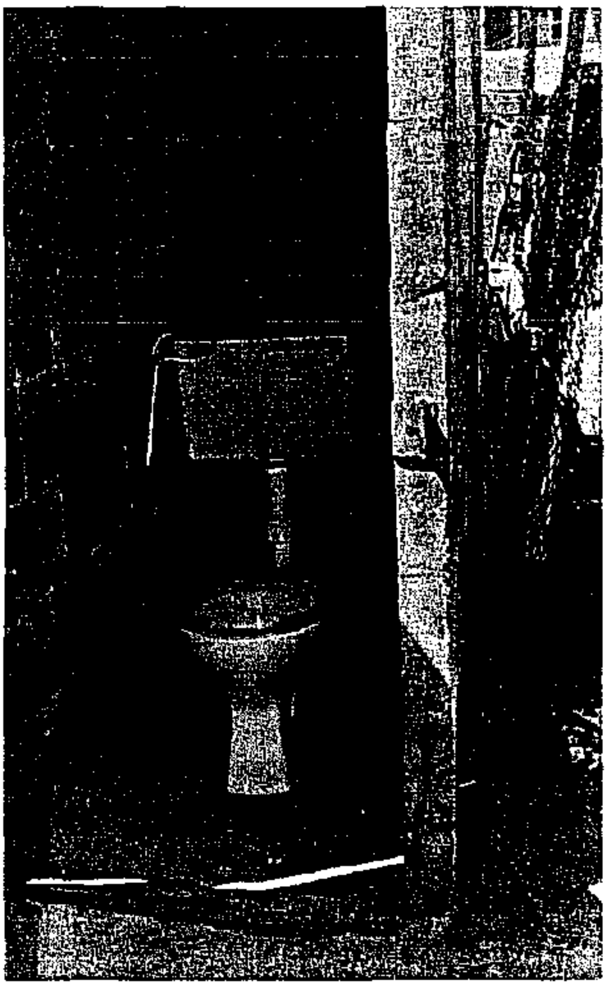
Socio-economic status of study households

Table 2 summarises the socio-economic status of study households. Type of housing, education and occupation of the child's mother, father's occupation and some household assets were used as indicators of socio-economic status. Most of the study subjects were generally of low socio-economic status and were living in shacks (81%). The majority of households owned a radio (69%), 41% owned a television and 30% owned an electric stove. Case and control households were of similar socio-economic status. However, there were relatively more working or student mothers among the cases than among the controls. The median of the maximum number of people sleeping in one room was 4 for the cases and 3 for the controls, however these figures were not significantly different ($p=0.72$).

Access to water and sanitation facilities

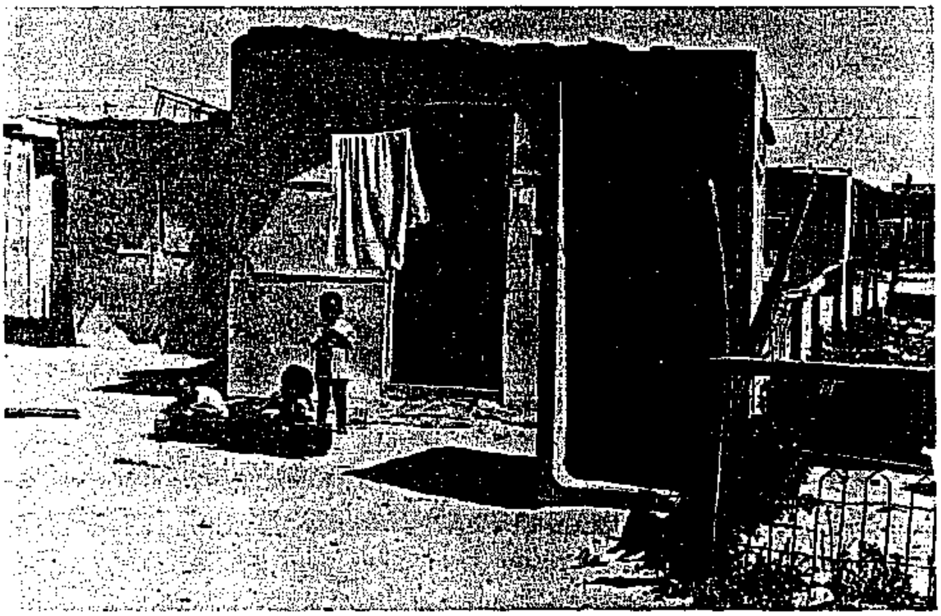
Cases and controls were similar with respect to type of water facilities provided and residence because they were from the same neighbourhood. The majority of households had access to communal taps (41%) or outdoor private taps (31%), and 12% had in-house tap water. Only 16% of households did not have any form of water provision. Illustrations of these services are provide below. Almost all the households

Formal Housing: in-house taps and toilets

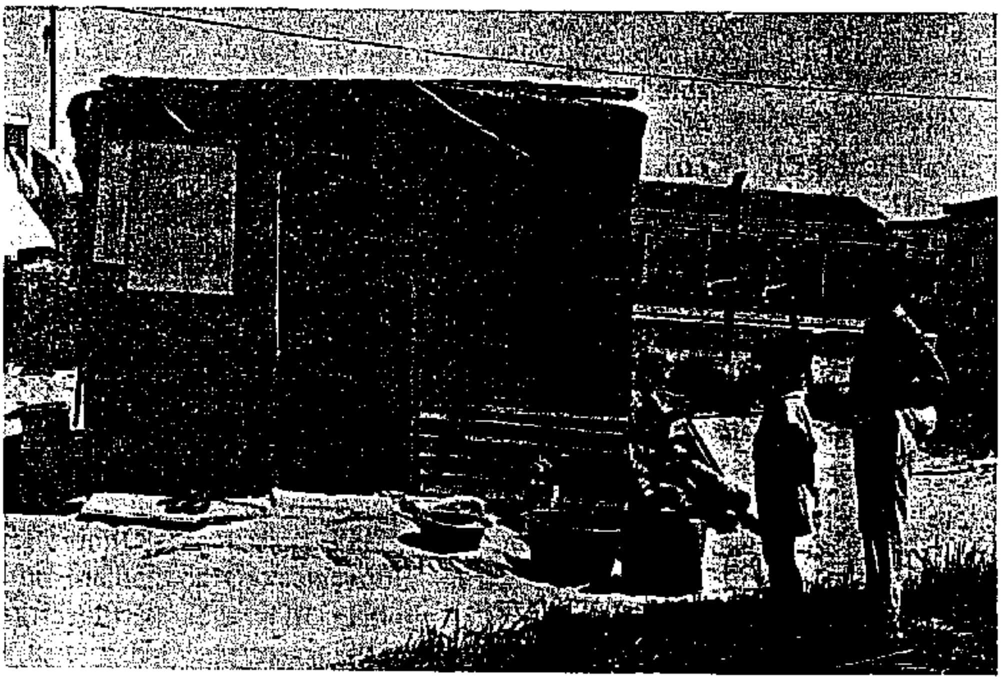


'Site and service': private outdoor tap and toilet

Communal taps



Bucket toilet



No formal services

(98.5%) said they do not pay for their water. Table 3 provides a breakdown of water and sanitation facilities for case and control households.

A majority of households had outdoor flush toilets (63%), 15% had bucket toilets, 10% had in-house flush toilets and 12% did not have any toilet. There were no differences in toilet provision between case and control households (see Table 3).

Risk factors for diarrhoea
Attending a day care centre was found to be a significant risk factor for diarrhoea (OR=3.8 p=0.002)(see Table 4, and Appendix 1 for illustrations). Children who were looked after by a non-relative during the day were also at higher risk of having diarrhoea (OR=2.2 p=0.03). Attending a day care centre persisted as a strong risk factor even after controlling for age and other possible confounders in the logistic regression (OR=5.1 p=0.0007). The presence of unwashed pots, plates and utensils in the kitchen or cooking room during the spot check observations was also a significant risk factor (OR=1.6 p=0.05). None of the other behavioural or hygienic risk factors that were measured was found to be a significant risk factor for diarrhoea.

Water storage and use
Of the more than 300 households that stored water, 97% used plastic containers (Appendix 1). Only 33% of these water containers were covered. Most households (67%) stored their in-house water in open containers. There were no differences in the storage of water between case and control households (p=0.33). The average (median) quantity of water stored per person per week (as calculated from responses to questions on how often the container was filled per week) was 50 litres in case households and 47 litres in control households. There was no significant difference in the quantity of water stored between case and control households (p=0.323).

Knowledge of the causes, management and prevention of diarrhoea
Caretakers of cases consistently demonstrated better knowledge of the symptoms of diarrhoea than caretakers of controls (see Table 5). Though not statistically significant, caretakers of cases were twice as likely as controls to say they did not know what the causes of diarrhoea were (OR=1.8). Caretakers of cases were half as likely as those of the controls to mention hygienic food handling, poor sanitary conditions and poor nutrition as potential causes of diarrhoea. The caretaker's recognition that hygienic handling of food is protective against diarrhoea was the only significant and strong association (OR=0.47 p=0.02). Caretakers of cases were more likely to say that teething was a cause of diarrhoea. Regarding ways of preventing diarrhoea, caretakers of controls were more likely to mention good personal hygiene, hygienic handling of food and clean water and sanitation as preventive measures. Cases' caretakers were more likely to say that diarrhoea could be treated by using the oral rehydration solution or by going to the clinic. Caretakers of cases were significantly more likely to report hand-washing before meals and after using the toilet or handling faeces.

Table 1. Characteristics of cases and controls

	Cases (n = 169)	Controls (n = 166)	*P*-value
Gender			
male	83(49.4)*	87(52.7)	*0.54*
female	85(50.6)	78(47.3)	
missing frequency=2			
Age (in months)			
median	12	18	*0.0002*
range	0.2 - 67.2	0.2 - 66.8	
% breast feeding	43.2%	40.4%	*0.60*
Household size and structure			
median	5	5	*0.35*
range	2-16	2-15	
mean no. males < 6y	0.7	0.8	*0.12*
mean no. females <6y	1.0	0.8	*0.09*
mean no. males between 6-14y	0.4	0.5	*0.45*
mean no. females between 6-14y	0.5	0.4	*0.57*
mean no. males >15	1.2	1.1	*0.39*
mean no. females >15	1.8	1.6	*0.08*
Age of mother (in years)			
median	26	29	*0.0006*
range	15-53	17-47	

* Figures in parentheses are column percentages

Table 2. Socio-economic status of case and control households

	Cases	Controls	*P*-value
Type of house			*0.50*
brick and tile	32 (18.9)*	24 (14.6)	
shack	134 (79.3)	139 (84.2)	
other	3 (1.8)	2 (1.2)	
missing frequency=2			
Number of rooms			*0.82*
median	4	3	
range	1 - 7	1 - 12	
Education of mother			*0.35*
no schooling	5 (3.0)	6 (3.6)	
Sub A to Std 3	18 (10.7)	24 (14.5)	
Std 4-6	58 (34.3)	60 (36.1)	
Std 7-10	86 (50.9)	71 (42.8)	
Other	2 (1.1)	5 (3.0)	
Occupation of mother			*0.45*
unemployed/housewife	126 (75.4)	135 (81.3)	
domestic worker	24 (14.4)	15 (9.0)	
student	10 (6.0)	4 (2.4)	
other	7(4.2)	12 (7.3)	
missing frequency=2			
Occupation of father			*0.24*
unemployed	57 (34.3)	60 (36.4)	
general work	94 (56.6)	84 (50.9)	
student	5 (3.0)	2 (1.2)	
other	3 (1.8)	9 (5.4)	
don't know	7 (4.2)	10 (6.1)	
missing frequency=4			
Household assets			
% with television	41.4	41.0	*0.93*
% with radio	71.0	66.3	*0.35*
% with refrigerator	7.1	9.0	*0.52*
% with electric stove	28.4	31.3	*0.53*
% with oven	4.7	7.8	*0.24*

* Figures in parentheses are column percentages

Table 3. Water and sanitation facilities of households

	Cases (n=169)	Controls (n=166)	*P*-value
Residence			
Site B	63	63	
Site C	42	39	
Town 2 Khayelitsha	15	15	
Khayelitsha	14	13	
Macassar	23	24	
Harare/Greenpoint	9	10	
Water supply			*0.97*
in-house tap	20 (11.8)*	20 (12.1)	
outdoor private tap	54 (32.0)	50 (30.1)	
communal tap < 100 people	39 (23.1)	36 (21.7)	
communal tap > 100 people	31 (18.3)	31 (18.7)	
no formal water	25 (14.8)	29 (17.5)	
Sanitation			*0.99*
in-house flush toilet	17 (10.1)	17 (10.2)	
outdoor flush toilet	107(63.3)	103(62.0)	
bucket toilet	25 (14.8)	25 (15.1)	
no toilet	19 (11.2)	20 (12.1)	
other	1 (0.6)	1 (0.6)	

* Figures in parentheses are column percentages

Table 4. Association between diarrhoea and potential risk factors

Risk factor	Odds Ratio	95% CI	*P*-value
irregular cleaning of water containers	1.2	(0.58-2.34)	*0.638*
uncovered water containers	0.8	(0.50-1.39)	*0.465*
plastic water containers	1.0	(0.18-5.40)	*0.985*
metal water containers	0.7	(0.26-2.01)	*0.496*
unwashed pots in kitchen	**1.6**	**(1.01-2.52)**	***0.052#***
uncovered food	1.1	(0.57-1.99)	*0.822*
flies in the kitchen	1.1	(0.43-2.95)	*0.799*
flies in the toilet	0.7	(0.35-1.45)	*0.318*
faeces on toilet floor	1.2	(0.31-4.52)	*0.803*
presence of chamber pot	1.0	(0.52-2.07)	*0.916*
chamber stored in-house	1.3	(0.78-2.12)	*0.290*
domestic animals	1.4	(0.71-2.71)	*0.301*
food from vendors	0.9	(0.47-1.82)	*0.822*
open disposal of stools	1.0	(0.53-1.88)	*0.995*
uncovered waste containers	1.3	(0.60-2.92)	*0.461*
absence of soap	0.8	(0.49-1.28)	*0.312*
non-relative day carer	**2.2**	**(0.99-5.06)**	***0.034****
creche/day care centre	**3.8**	**(1.51-10.6)**	***0.002*****

* Significant at the 95% level; ** significant at the 99% level; # approaching significance

Table 5. Association between caretaker knowledge and diarrhoeal disease

Knowledge item	Odds Ratio	95% CI	*P*-value
Symptoms of diarrhoea			
frequent passing of watery stool	**1.8**	**(1.12-2.86)**	***0.010****
vomiting	1.8	(0.77-4.54)	*0.130*
sunken eyes	1.2	(0.74-1.92)	*0.452*
Causes of diarrhoea			
do not know	1.8	(0.91-3.62)	*0.069*
polluted water	1.8	(0.53-6.99)	*0.296*
poor sanitation	0.6	(0.17-1.78)	*0.281*
unhygienic handling of food	**0.5**	**(0.23-0.93)**	***0.020****
malnutrition	0.5	(0.04-3.42)	*0.392*
teething	1.2	(0.72-1.88)	*0.526*
Prevention of diarrhoea			
good personal hygiene	0.6	(0.15-2.13)	*0.370*
clean water and sanitation	0.5	(0.10-1.82)	*0.222*
hygienic handling of food	0.5	(0.19-1.55)	*0.215*
go to clinic/see doctor	1.4	(0.86-2.18)	*0.167*
oral rehydration solution	1.1	(0.51-2.17)	*0.878*
Reported hand-washing with soap			
before food preparation	0.8	(0.40-1.46)	*0.384*
before eating	**1.6**	**(0.99-2.71)**	***0.043****
after using toilet	1.3	(0.83-2.09)	*0.218*
after cleaning	1.7	(0.67-4.33)	*0.226*
Hand-washing without soap			
before food preparation	1.1	(0.65-1.89)	*0.698*
before eating	**1.8**	**(1.05-2.95)**	***0.022****
after using toilet	1.5	(0.96-2.44)	*0.059*
after house cleaning	0.5	(0.08-2.28)	*0.288*

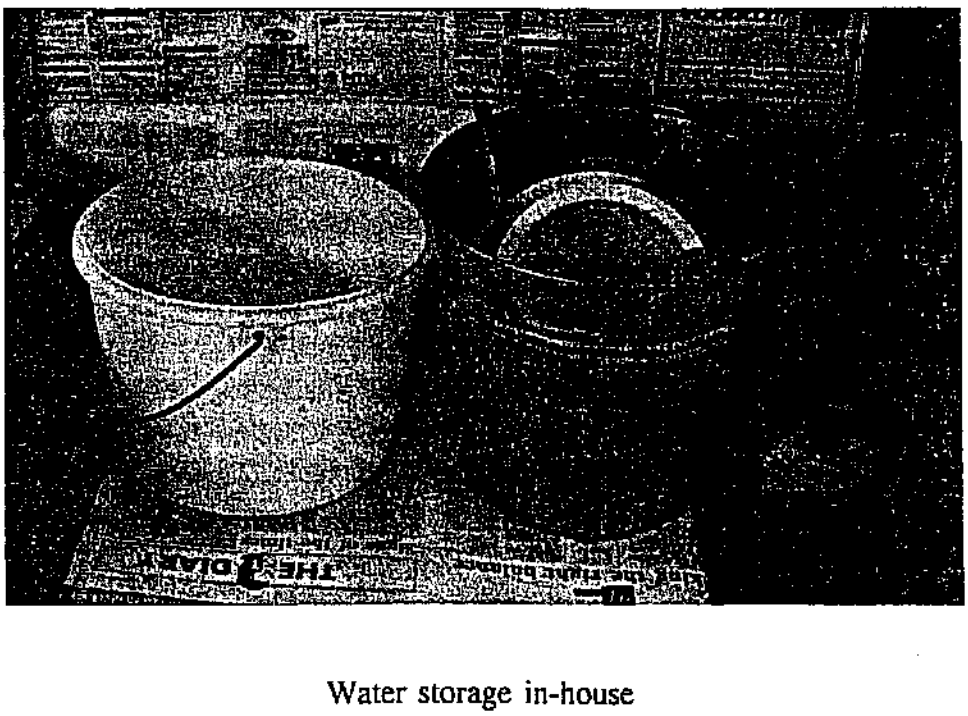
* Significant at the 95% level

Table 6: Matched Statistical Analyses for Selected Variables
(controlling for age)

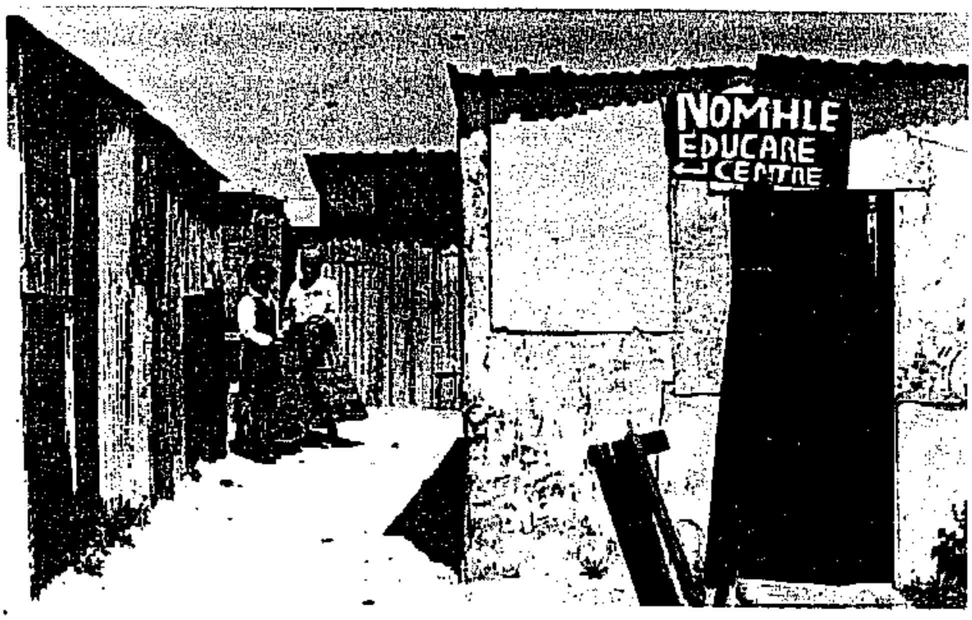
Risk factor/ Variable	Odds Ratio	95% CI	P-value	Unmatched Odds ratio & (P-value)
age of mother	0.94	(0.91-0.98)	0.003	- (0.0006)
non-relative day carer	2.9	(1.2-7.14)	0.018	2.2 (0.034)
creche/day care centre	5.31	(1.8-15.4)	0.002	3.8 (0.002)
Knowledge of diarrhoea symptoms and causes:				
frequent passing of watery stool	3.39	(1.5-7.7)	0.004	1.8 (0.010)
unhygienic handling of food	0.41	(0.15-1.06)	0.066	0.5 (0.020)
Reported hand-washing with soap before eating	2.3	(1.2-4.4)	0.015	1.6 (0.043)
Reported hand-washing without soap before eating	3.5	(1.6-8.1)	0.003	1.8 (0.022)

Variables previously identified to be of significance in the unmatched analysis were shown to be consistently significant when using the matched statistical method. Odds ratios calculated using the matched analysis were higher than for the unmatched analysis, indicating the relevance of the variables identified to be risk factors for diarrhoea.

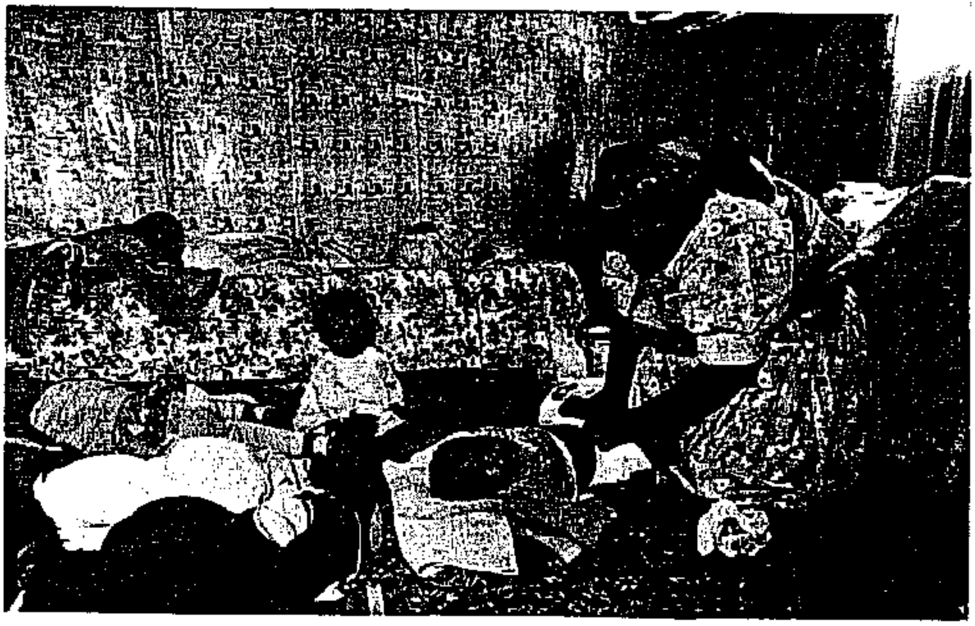
Illustrations of water storage practices and day care facilities are provided below.



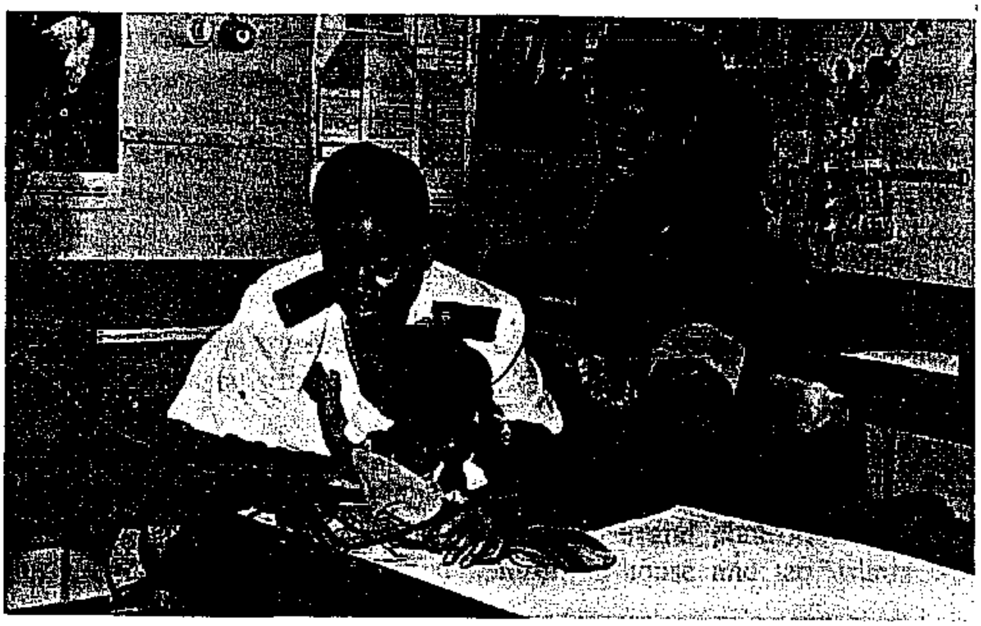
Water storage in-house



Child day care facility



Child day care facility



Oral rehydration unit: Khayelitsha Site B Clinic

4.2.2 Microbiological water quality

Summary statistics and analysis of variance (ANOVA) for standard plate counts (SPC), total and faecal coliforms, *E. coli*, phages and chlorine concentrations for the 633 water samples (including cases and controls, in-house and tap water samples) are provided in Appendix 3 (Tables 1-6, Figures 1-4). Two sample comparisons (t-test of log transformed data) between case and control, tap and in-house water samples are provided in Appendix 3, Table 7. In general, the source waters (tap waters) were of an acceptable water quality as defined by the SABS specifications for domestic water supply (1984) and the Department of National Health and Population Development (DNHPD) guidelines (Aucamp and Vivier, 1990). The SABS specifications require that the standard plate count (SPC) be <100/mℓ; total and faecal coliforms should be 0/100mℓ and no more than 5% of samples may be coliform positive. The DNHPD guidelines are based on a three tiered system, ranging from recommended levels to a maximum level for low risk. The in-house water samples of both cases and controls deteriorated significantly after storage, with statistically significantly higher number of indicator organisms detected in stored (in-house) water samples.

Figures 1-4 below indicate the pertinent factors of the water quality analyses. Geometric means of both in-house and tap waters were low for all parameters tested. The 95 percentiles of tap water samples complied with guideline values for SPC, total coliforms, faecal coliforms and *E. coli* (with the exception of SPC in case tap waters, where a 95 percentile of 162/mℓ was observed). The in-house water samples exceeded the guideline values by 1-6 orders of magnitude for all parameters. In addition, maximum counts were significantly higher in the in-house water samples than in the tap waters for both cases and controls. A maximum count of $4,38 \times 10^9$ and $3,8 \times 10^8$/100mℓ was detected for total and faecal coliforms, respectively in case in-house samples. Analysis of variance (Appendix 3, Figures 1-4) indicated *no significant difference between case and control water samples*. Two sample analysis (Appendix 3, Table 7) supports these findings. Significant differences were observed between in-house and tap waters for both cases and controls, with the exception of *E. coli* levels; where control in-house and tap samples were not significantly different, as was observed for cases. The 95 percentiles and maximum *E. coli* counts observed in in-house samples were higher than in the case in-house samples, although this difference was not statistically significant.

Phage counts were low for all water samples analysed with no significant differences being observed between case and control waters, or between in-house and tap waters. Means for phage counts were <1/10mℓ for case and control, tap and in-house samples. 95 percentiles for case and control, in-house and tap waters were also <1/10mℓ (Appendix 3, Table 5).

Enteric viruses were not detected in any of the water samples. Protozoan parasites (*Giardia* cysts) were detected on one occasion in both a case and a control water sample.

Chlorine (free chlorine) was detected in >85% of tap samples and >58% of in-house samples, with geometric mean values for tap and in-house samples of 0,4 and 0,2mg/ℓ respectively (Appendix 3, Table 7). Significant differences between in-house and tap waters were observed, however, no difference between case and control samples were detected (Appendix 3, Table 8).

Analysis of variance of the water quality according to the various types of water supply demonstrated that the communal water supplies were significantly more contaminated for SPC compared to indoor taps, private outdoor taps and no formal water supply. The same trend was observed for the other microbial parameters even though this difference was not statistically significant (Appendix 3, Figures 5-8, Table 8).

The water quality was found to improve significantly during the course of the study, which coincided with the installation of a new pipeline to the area and a resultant increase in chlorine concentrations (Appendix 3, Table 9). During installations of new pipelines, it is common practice to add large doses of chlorine to ensure adequate disinfection of the water, as contamination from the installation process may easily occur. After installation of the new pipeline the water source supplying the study area was also considerably closer than was previously experienced. This would also result in higher chlorine levels being detected.

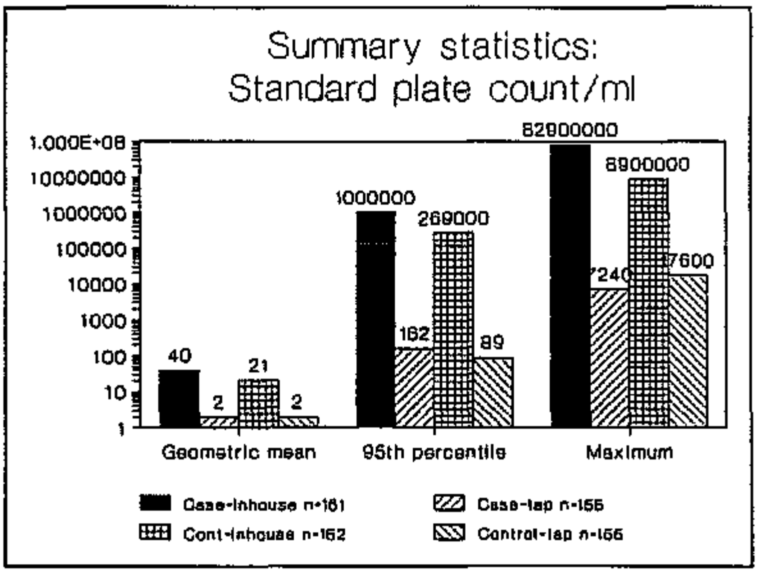


Figure 1. Summary statistics: standard plate count

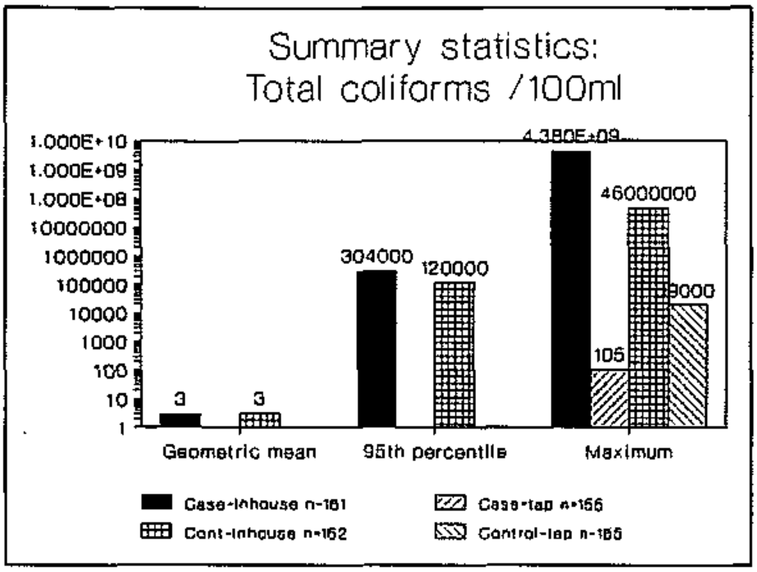


Figure 2 Summary statistics: total coliforms

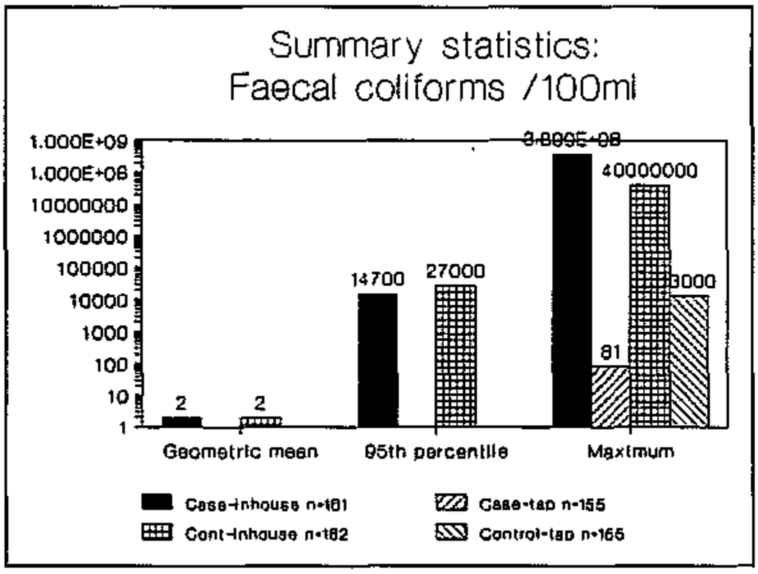


Figure 3 Summary statistics: faecal coliforms

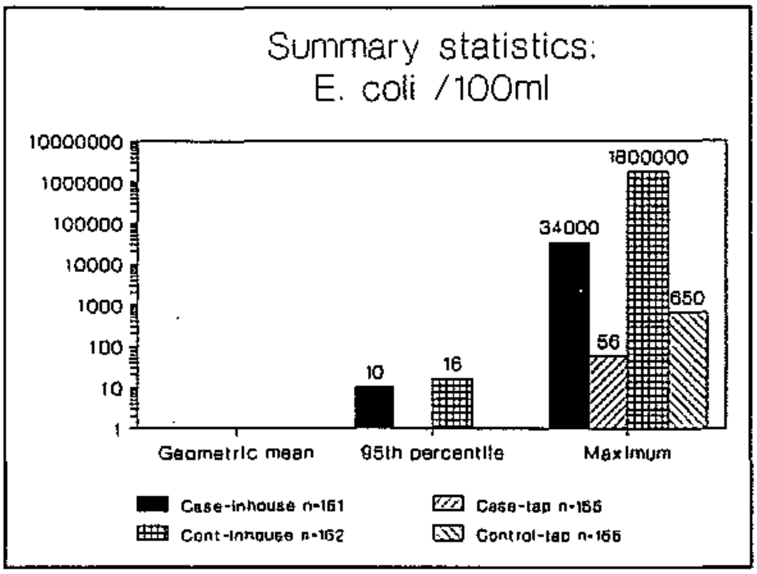


Figure 4 Summary statistics : *E. coli*

4.2.3 Determinants of diarrhoea and water quality

The overall water quality as demonstrated using a water quality index, classifying the water quality according to all the indicator organisms showed no significant differences between cases and controls (Table 7, below). Comparisons of whether water complied with guideline values or not, between cases and controls, also did not show significant differences (Table 8, below).

Table 7. Water Quality Index (100 represents water that complies with SABS guidelines, 0 represents the worst quality water detected)

	0-20	21-40	41-60	61-80	81-100
cases n (%)	15 (8.6)	10 (5.7)	4 (2.3)	78 (44.8)	67 (38.5)
controls n (%)	13 (7.7)	13 (7.7)	3 (1.8)	65 (38.5)	75 (44.4)

$\chi^2 = 0.167$ (p=0.68)

Table 8. Comparison of whether water complied with SABS guideline values for case and control in-house waters

	complies	does not comply
cases n (%)	102 (64)	59 (36)
controls n (%)	117 (72)	45 (28)

χ^2 =2.91; OR =1.50; 95% CI = 0.92-2.47; (p= 0.11)

There appears to be a trend where the proportion of water quality that exceeds SABS guidelines increases from the 'worst' facility (communal taps) to the 'best' facility (in-house taps), with communal taps exceeding guideline values consistently more frequently than either 'site and service' or in-house taps (Table 9, below). This is particularly noticeable with HPC and *E. coli*. Caution should be exercised when interpreting these statistical results, since some of the cells contain low numbers.

Table 9. Comparison of whether in-house water complied with SABS guideline values according to type of water supply

	Type of water supply / complies with or exceeds SABS guidelines	In-house taps	Site & service	communal taps	χ^2 and p values
HPC	within n(%)	21(88)	117(86)	104(68)	χ^2 = 14.9 p= 0.01*
	exceeds n(%)	3(12)	19(14)	49(32)	
Total coliforms	within	23(96)	122(90)	126(82)	χ^2 = 5.3 p= 0.07
	exceeds	1(4)	14(10)	27(18)	
Faecal coliforms	within	23(96)	121(89)	127(83)	χ^2 = 4.1 p= 0.13
	exceeds	1(4)	15(11)	26(17)	
E. coli	within	24(100)	129(95)	135(88)	χ^2 = 6.6 p= 0.04*
	exceeds	0(0)	7(5)	18(12)	

4.3 Cross-sectional study

Data from the 2 different seasons were combined for the purpose of this study. Risk factors related to water and sanitation would not have changed significantly over time between the two seasons.

A total number of 752 children were included in the study, 284 during the winter week of data collection and 468 during the summer week of data collection.

The age of the children ranged between 1 month and 5 years and 11 months. Just over half of the sample (52%) were female and just under half (48%) male. 20% of the children's mothers worked while 31% of the children attended a day care facility. Of all the children included in the study, 40% were severe cases of diarrhoea:, *i.e* those referred for oral rehydration.

As expected, more cases of diarrhoea were recorded during the summer (65%) than the winter (35%). Of cases recorded 31% attended a day care facility. Cases in the 'formal' and 'no facility' categories occurred in proportion to the availability of these sites (Figure 5). There are notable differences between the case frequencies and population frequencies in the 'tap on site' and the 'communal tap' categories. A smaller proportion of the cases than that of the overall population seem to use a tap on site (39% vs. 60%). A larger proportion of the cases than that of the overall population seem to use a communal tap facility (39% vs. 17%).

The sanitation facility profile of the cases is very similar (in all the categories) to the overall sanitation available (Figure 6). A slightly higher proportion of the cases use flush toilets and a slightly lower proportion use the bucket system compared to the overall population.

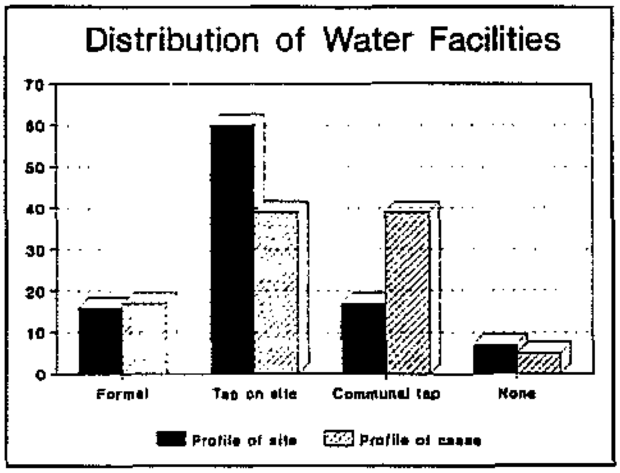


Figure 5. Water facilities for the general study population and cases

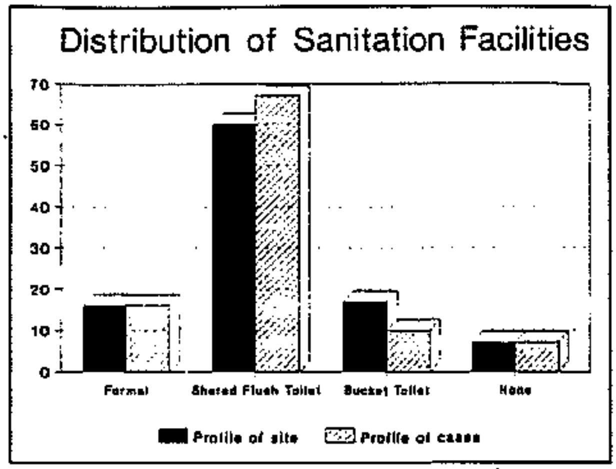


Figure 6. Sanitation facilities for the general study population and cases

5. DISCUSSION

Even though no statistically significant association between poor in-house water quality and diarrhoea was observed, analysis of questionnaire and observational data of the case-control study identified some risk factors for severe diarrhoea among pre-school children. A strong association was found with the child's attendance at a day care centre or creche. This association remained when controlling for potential confounders in a logistic regression model. Variables of statistical significance were included in a matched analysis and consistently shown to be risk factors for diarrhoea, but with increased significance. This finding is consistent with results of studies conducted in the USA, which show that the risk of diarrhoea is significantly greater for child day care centre attenders and that the temporary absence of a mother increases the risk of diarrhoea (Laborde *et al.*, 1993; Hillis *et al.*, 1992; Reves *et al.*, 1993). Studies in Colombia have also shown that the incidence of diarrhoea was greater for day care centre attenders than for non-attenders (Briscoe *et al.*, 1985).

A significant implication of this finding is that day care centres, particularly those in peri-urban settlements, should be investigated as to the adequacy of their hygiene practices. Subsequent discussions with people in the community have revealed that some unemployed mothers run informal crèches which working mothers often use as day care facilities for their children. Many of these are said to be unregistered. Day care facilities may be a potential source of widespread contamination, spread and outbreak of disease and should therefore be targeted in any campaign against childhood diarrhoea. We believe that such an intervention has the potential of significantly lowering the incidence of diarrhoea among crèche attenders.

The potentially lower cost of interventions designed to improve hygiene behaviour compared to interventions aimed at improving water and sanitation facilities have resulted in several studies aimed at identifying hygiene behaviours which, when changed or improved, could assist in reducing water and sanitation related diseases. Most hygiene behaviours in this study were measured using the observable effects of such behaviours rather than performing continuous observations to note the behaviours as they occur. The focus was on potentially modifiable risk behaviours that may be associated with diarrhoea. Our results show that poor kitchen hygiene had a significant association with diarrhoea. This finding is similar to the findings of Baltazar *et al.*,1993, who found a strong association between indices of overall cleanliness and kitchen hygiene and the risk of hospitalisation with severe diarrhoea. The potential use of this finding is the promotion of kitchen hygiene to prevent diarrhoea.

Questions measuring knowledge of diarrhoea showed that caretakers of cases knew the symptoms of diarrhoea better than the caretakers of controls. They also reported the desired hand washing behaviours more frequently than caretakers of controls. This may be explained by the fact that they had just experienced an episode of diarrhoea and also that they had just received some health education at the health centre. With regards to the causes and prevention of diarrhoea, caretakers of controls tended to be more knowledgeable than those of the cases. Though not statistically significant, our results show that poor knowledge of the causes and prevention of diarrhoea was associated with the disease. However, caretakers' recognition that hygienic food handling has a protective effect had a strong association with absence of disease. It is therefore important to improve mothers' and caretakers' knowledge of proper and hygienic handling of food.

A major potential source of bias in this study is that case or control status of subjects was not concealed from the fieldworkers. One argument is that there could have been differential administration of the data collection tools and differential information assessment between case and control households. However, the research hypotheses were not known to the interviewers, thus it is unlikely that there could have been differential administration of the tools between cases and controls. There is no evidence from our data to show that cases were consistently rated negatively compared to the controls. For some indicators, such as the cleanliness of the child under study the controls were consistently rated as dirtier than the cases. This is not unexpected since children are usually bathed and well dressed before being taken to a hospital or clinic.

Random validation interviews which were conducted to cross check the validity of information collected by the fieldworkers did not show any flaws. The highly structured data collection instruments which were used had been pretested and ensured that interviewers asked questions in a standardised manner. Also, interviewers underwent in-depth theoretical and practical training which greatly improved their subsequent performance in data collection. During data collection the investigators made random supervisory visits to the fieldworkers in order to ensure that data collection was going according to plan and to resolve any problems in the field.

Selection of diarrhoea cases from a secondary source (hospital) rather than a primary base (the community) was carried out for logistical reasons because of the difficulty of finding sufficient numbers of cases from a cross-sectional community survey. Misclassification was also significantly reduced in having cases defined by trained health staff. A disadvantage could be that the cases may not have been representative of all cases in the community. However, there is evidence to show that almost all moderate to severe episodes of diarrhoea present at health facilities, and over 72% of the diarrhoea cases in this community present at the two public health facilities which were used in this study. The data from the cross-sectional study, using all cases occurring over a defined period, confirmed the representativeness of the case-control sample and therefore indicates that the study results are generalisable to the community.

An advantage of selecting neighbourhood controls is that many potential confounders were controlled using this design. For example socio-economic status was controlled by selecting cases and controls from the same neighbourhood. In addition, the impact of any unknown confounders associated with neighbourhood was eliminated.

Observational studies showed generally poor hygienic conditions, such as presence of flies in the kitchen and toilet in both case and control households. It has also shown the potential for using spot check observations as a rapid and cheap method of assessing household hygiene, compared to conducting long continuous observations aimed at observing hygiene behaviours as they occur (Tempongko, 1991; Bentely *et al.*, 1991).

Storage of drinking water in the home where water may become contaminated is common practice in peri-urban developing communities, where 'serviced sites' and communal taps are prov' -d. In this study, water quality was shown to deteriorate significantly after handling ıd storage, with increased levels of all indicator organisms analysed, with the exception of phages. This was assessed by collecting water samples from the household's water source and storage container. Studies conducted in developing countries have found similar results with variations in faecal coliform concentrations between source and stored water (Feachem *et al.*, 1978; Lindskog and Lindskog, 1988; Mertens *et al.*, 1990; Verweij *et al.*, 1991). The type of water container was found to have an effect on stored water quality in these studies. Using a specifically designed "safe" storage container has been shown to reduce the diarrhoea rates in pre-school children (Mintz *et al.*, 1995). This study could not examine this effect as 97% of cases and controls made use of plastic storage containers.

The source water was of good quality, with 95% of samples having no total or faecal coliforms present. In the case-control study, no association was found between the resultant poor water quality in the stored water samples and diarrhoea, thereby *not providing evidence* that in-house contamination *per se* is a risk factor for diarrhoea.

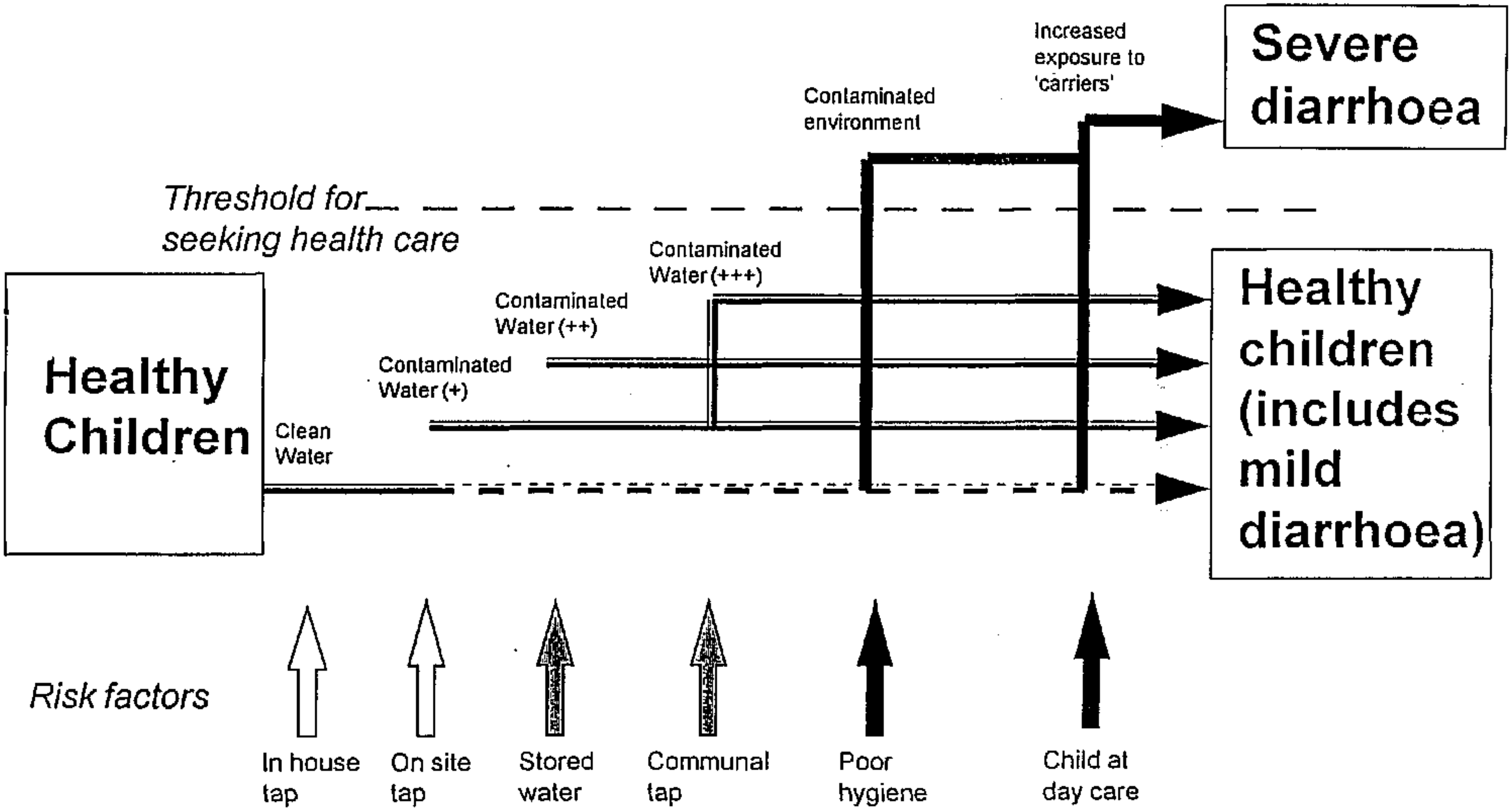
The poorer water quality observed where communal taps are used together with the increased incidence of diarrhoea observed in the cross-sectional study may suggest that contamination of in-house water from a source other than from a family member poses a greater risk for diarrhoea, or the converse; contamination within the household does not pose a risk for diarrhoea. These findings are in agreement with results from a study conducted in the Philippines (van Derslice and Briscoe, 1993) where it was found that "all coliforms are not created equal". They postulated that there are important differences between in-house contamination by "internal" pathogens from family members and contamination of one's water source by "external" pathogens. Therefore, by improving *source* water quality, substantial impacts on diarrhoea may be realised. Van Derslice and Briscoe (1995) further propose that by improving water quality alone, no impact on diarrhoea would be seen for infants living in highly contaminated neighbourhoods. They calculated that improving water supply services to indoor connections would only result in a 12% reduction in diarrhoea, compared to a 42% reduction where private sanitation is provided. Eliminating in-house contamination may have little impact on reducing diarrhoea unless other factors, such as contamination from day-care centres and poor hygiene, are eliminated as well. The comparative reduction in diarrhoea rates, observed in the cross-sectional study, where 'site and service' facilities are used, supports this theory.

It is known that households with access to communal facilities are forced to store water in containers in the home in order to avoid making several journeys between the home and the shared facility, to collect water. As opposed to the households that have access to communal taps, 'site and service' households have their water source on the plot or on the neighbour's plot, *i.e.* easy access means that no long-term storage of water is required. Improvements in water quantity is often regarded as more important than water quality in the reduction of diarrhoeal diseases (Esrey and Habicht, 1986; Cairncross, 1987). Access to a private outdoor tap compared to a communal tap will allow larger quantities to be used, as individuals will not need to travel as far to collect water. This may be an additional explanation for our findings that 'site and service' facilities provide a protective effect. Formal households have taps inside the house and therefore no storing of water is required. A tap on site appears to have a protective effect as opposed to communal water facilities which seem to increase the health risk of childhood diarrhoea. The small differences observed between the sanitation categories suggest that within this study population, sanitation facilities have less of an impact on the occurrence of childhood diarrhoea than water supply. These small differences are probably due to sample variation and small sample size. It is known that one site is often occupied by more than one household. This may explain why there is an excess of cases at 'site and service' facilities (a flush toilet). One might, for the same reason, also argue that what appears to be a protective factor with the water facility in the site and service category, is probably even greater than indicated here.

Epidemiological studies are designed to identify predominant risk factors that play a role in the health status of populations. Analytical epidemiology describes the occurrence of disease and other health-related characteristics in human populations in terms of person, place and time. The risk factors for diarrhoea in this study are probably a combination of a number of factors; namely, attendance of a crèche, a lack of basic hygiene, environmental factors such as contaminated water from communal taps, direct contact, and/or contaminated food.

A model postulating the interactions between water quality and diarrhoea is shown in Figure 7, below. This model shows an additive process whereby the various risk factors 'push' a child from a healthy to an unhealthy status. The order of events is not necessarily sequential (as shown) nor are all the steps necessary determinants of the diarrhoea outcome. Further research of the case-control data will be required to determine the relative importance of the various steps. Essentially a child may be exposed to the various risk factors shown as vertical arrows and these impact on the determinants of health status in the environment. Contaminated water results from the type of supply and storage, but these factors are insufficient to cause severe diarrhoea. The additional contamination of water and food related to poor hygiene appears to cause diarrhoea as does increased exposure to carriers of diarrhoeal pathogens associated with the child attending a crèche.

Fig 7. Simplified model of the effects of water quality on diarrhoea in children



6. CONCLUSIONS AND RECOMMENDATIONS

Water supplied to the study population was of high quality, whereas the water that was used after storage was significantly more contaminated and did not comply with guidelines for drinking water. This indicates that water handling and storage increases the likelihood of deterioration of water quality and non-compliance with guidelines. Even though the stored water was more contaminated, an association between the poor water quality and diarrhoea was not observed in the case-control study. Attendance of day care centres or creches was identified as a risk factor for diarrhoea, indicating that interventions aimed at health promotion and improving these facilities, promoting better kitchen hygiene and improving child caretakers' knowledge of the causes and prevention of diarrhoea may have a greater benefit than solely attempting to improve the water quality after storage.

These results imply that interventions should also be aimed at health promotion striving to alter behaviours that lead to increased risk, and to improve child caretakers' knowledge of causes and prevention of diarrhoea, rather than exclusively improving in-house water quality and sanitation in these types of peri-urban communities. Such interventions may be as important as water quality and supply which have been the focus of interventions against water-related diarrhoea. Health promotion interventions would be less expensive and may have a greater significance in reducing the risk of diarrhoea among preschool children. Deteriorated water quality *per se* does not seem enough to cause diarrhoea, but in association with other risk factors it appears to contribute to affecting health.

The type of water facility used appears to have a notable impact on the occurrence of childhood diarrhoea. This could be due to the effect of water storage (a common practise with the communal tap system), as well as the impact of 20 or more households sharing a tap (the likelihood of contamination increases with the number of people sharing a tap).

The majority of the objectives of the study, as specified in the proposal, were achieved.

a) Water quality at point of collection and after storage was adequately assessed. Water was significantly more contaminated after handling and storage than at the source. During the course of the study a new pipeline was installed with corresponding high free chlorine concentrations, which influenced the water quality significantly. Seasonal variations could therefore not be determined due to the change in the supply source.

b) The patterns of water usage, quantity of water used and treatment of water by the end-user was determined. The average quantity of water used was calculated as 50ℓ/week, which was based on the participants' response to a question enquiring how often their water containers were filled per week. This amount obviously does not reflect the amount of water actually used, but rather the amount that was stored within the household, and was the closest possible estimate.

c) No *direct* relationship between water quality and diarrhoea was found, even though a high level of water contamination was found after collection and storage; controls (with no diarrhoea) were found to have an equally poor water quality after collection and storage, and even higher levels of *E. coli* counts were observed in control in-house samples. The poorer water quality observed where communal taps are available, and the comparatively larger proportion of diarrhoea cases recorded in the cross-sectional study from areas where communal taps are used, in comparison to private outdoor taps, indicates that a private outdoor tap is the level of service to aim for in the provision of water in developing communities. Obviously many other factors such as: whether children attend a day care centre or are cared for by a non-family member; hygiene practices; and knowledge of causes and prevention of diarrhoea were shown as important factors impacting on the health of the population in a developing community.

In assisting in providing policy guidelines for the provision of water in developing communities, it appears that the provision of private outdoor taps will reduce the risk associated with water-related diarrhoea, compared to communal taps, where more than 100 people may share a tap.

Further research should focus on appropriate holistic health promotion programmes to address the range of issues around water usage, storage and environmental hygiene. The Peninsula Technikon (funded by the Foundation for Research Development) is currently addressing some of these issues in a health and hygiene promotion programme in the community. A more in-depth holistic intervention programme aimed at a national level is recommended. The situation with respect to day care centres regarding hygiene practices and water quality should be investigated to establish minimum requirements and a management system for such facilities as well as differentiating between problems related to formal and informal day care facilities.

Possibly the reason that no differences were observed between the water of cases and controls was that the indicator organisms which were used in this study did not provide a complete picture of the actual water quality. The suitability of the present indictor organisms used for assessing drinking water quality for indicating the health risks associated with contaminated water is tenuous. At present there is no absolute indicator organism which complies with the criteria specified for the ideal indicator organism. The WHO guidelines (1993) recommend that the thermotolerant coliform group (faecal coliforms), and more specifically *E. coli,* is the indicator of first choice. However, this indicator group has its limitations in that certain viruses and parasites are known to be more resistant to disinfection than *E. coli* and the absence of the latter will not necessarily indicate freedom from the former. A search for more suitable indicator organisms is required and recommended. There would be merit in investigating the association between bacterial pathogens and indicator organisms.

Investigations into the activities leading to contamination of water occurring at communal taps are recommended, since the provision of 'site and service' facilities as a minimum service level to all households within the peri-urban context is unlikely to occur within the immediate future. In addition, the development of methods (engineering approaches) to reduce contamination of water during collection from communal taps should be explored.

7. TECHNOLOGY TRANSFER

It is recommended that the results of this study be distributed to various authorities involved in policy decisions for water and sanitation supply and health policies, such as the Department of Water Affairs and Forestry; Departments of Health (local, regional and national); and local and metropolitan councils. Feedback to the community involved in this study should be provided, possibly through local radio. In addition a short summary has been distributed to environmental health officers and clinic staff (seen on the following pages), with the possibility of providing a more formal presentation to the health workers.

8. ARCHIVING OF DATA

Data from the study is available from Environmentek, CSIR, Stellenbosch and the National Urbanisation and Health Research Programme of the Medical Research Council, Tygerberg.

The Effect of Different Types of Water Supply on the Health of the Community

It is often assumed that when clean water is supplied to a community, a positive effect on health will follow. However, research has shown that this is not necessarily true.

A study by the CSIR and the Medical Research Council was funded by the Water Research Commission to examine the effects of different types of water supply on health.

The water sources available in the study area (Khayelitsha) included:

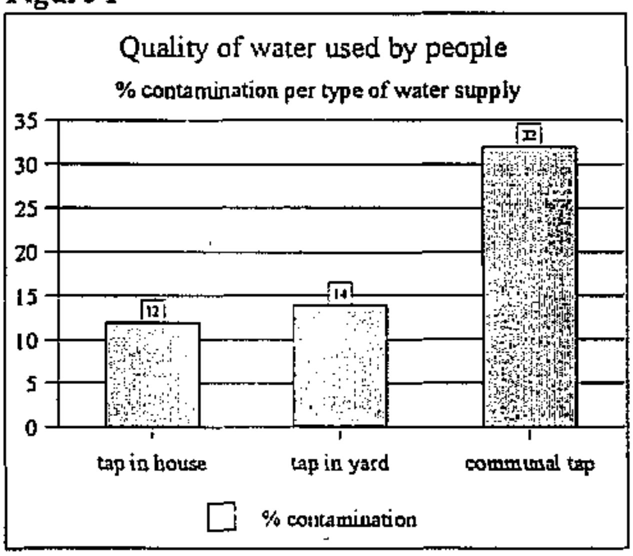
- tap inside the house;
- private tap in the yard;
- communal tap;
- or no formal water supply by local authority

Information was collected from more than 300 households to assess the risk of diarrhoea associated with water quality in preschool children. Interviews with child minders were conducted, collecting data on the source of the water, sanitation facilities, and education regarding hygiene practices. Water quality from taps and from water containers in these households were analysed.

Another study investigated the same water-related problems, by looking at pre-school children with diarrhoea brought to clinics in Khayelitsha.

The results of this research showed the following:
- Water provided to the area was of good quality
- Water stored in household containers was often of poor quality
- The contamination of stored water was a bigger problem where people used communal taps (Fig.1).

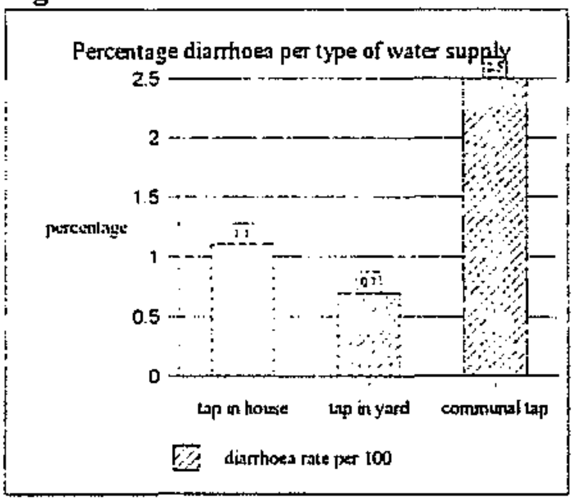
Figure 1



Some *risk factors* identified for diarrhoea among preschool children were as follows:

- the highest percentage of diarrhoea among pre-school children was found among households making use of communal taps (Fig. 2).
- children in the care of child minders were more likely to get diarrhoea than those cared for by family members
- poor kitchen hygiene and poor knowledge of food handling and hygiene were risk factors

Figure 2



The conclusions drawn from these results show that:

- Poor water quality alone does not necessarily cause diarrhoea - it is usually associated with other risk factors
- There is a need to promote good hygiene practices
- The problems associated with contamination at communal taps need to be addressed
- There is a need for research and education regarding hygiene practices, not only for water contamination, but general kitchen practices and especially for child minders and day care centres.

9. REFERENCES

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Appendix I
Khayelitsha Demographics

Schedule of Available Sites and Squatter Density: KHAYELITSHA (Source: Lingelethu West City Council. 15 February 1993)

Status area	Potential	Developed	Occupied	Type of structure	Type of site	Status
Bongweni	358	358	179	Permanent house	Formal sites	serviced
Ikwezi Park	551	551	395	Permanent house	Formal sites	serviced
Tembani	183	183	183	Permanent house	Formal sites	serviced
Washington Square	341	1	1	Permanent house	Formal sites	serviced
Site C	3717	3465	3465	Formal Squatters	Rudimentary	Rudimentary
Site C (backyard)	0	0	3465	Informal Squatters	Open ground	Must move
Site C Buffer & open areas	1000	0	4270	Informal Squatters	Open ground	Must move
Town 1 Village 1	2835	2835	2835	Core Houses	Formal Sites	Serviced
Town 1 Village 1 (backyard)	0	0	2500	Informal Squatters	Open ground	Must move
Town1 Village 1 (Demo)	33	33	30	Demo Houses	Formal sites	Serviced
Town 1 Village 2	2471	2471	2469	Core Houses	Formal sites	Serviced
Town 1 Village 2 (Backyard)	0	0	2000	Informal Squatters	Open ground	Must move
Town 1 Village 3	3819	3819	3819	Formal Squatters	Site&service	Serviced
Town 1 Village 3	0	0	7000	Informal Squatters	Open ground	Must move
Town 1 Village 3 (P Selfhelp)	51	51	51	Selfhelp Houses	Formal sites	Serviced
Town 1 Village 3 (L Selfhelp)	50	50	50	Selfhelp Houses	Formal sites	Serviced
Town 1 Village 4	5122	5101	5101	Formal Squatters	Site&service	Serviced
Town 1 Village 4	0	0	4884	Informal Squatters	Open ground	Must move
Town 1 Village 4 (Y Selfhelp)	101	101	101	Selfhelp Houses	Formal sites	Serviced
Town 2 Village 4C	1533	1533	1533	Formal Squatters	Site&service	Serviced
Town 2 Village 4C (Selfhelp)	49	49	49	Selfhelp Houses	Formal sites	Serviced
Greenpoint South	0	0	75	Formal Squatters	Rudimentary	Rudimentary
Greenpoint Bush	0	0	149	Informal Squatters	Open ground	Must move
Greenpoint North	0	0	200	Informal Squatters	Open ground	Must move
Site B North	0	0	1500	Informal Squatters	Open ground	Must move
Silvertown	0	0	765	Formal Squatters	Rudimentary	Rudimentary
Silvertown South	0	0	620	Informal Squatters	Open ground	Must move
Bermuda	0	0	350	Formal Squatters	Rudimentary	Rudimentary
Bermuda (open ground)	0	0	100	Informal Squatters	Open ground	Must move
Site B Buffers & Greenpoint	1800	0	0	Formal Squatters	Site&service	Unserviced
Non Status Area						
Town 2 Village 1	3382	3382	1618	Formal houses	Formal sites	Serviced
Town 2 Village 3	4427	4427	2450	Formal houses	Formal sites	Serviced
Town 2 Village 3 (Backyard)	0	485	485	Informal Squatters	Open ground	Must move
Town 2 Village 2B	5040	0	0	Formal houses	Formal sites	Unserviced
Town 2 Village 4A	331	331	219	Formal houses	Formal sites	Serviced
Town 2 Village 4B	498	498	178	Formal houses	Formal sites	Serviced
Town 2 Village 2A I	1511	1511	1511	Formal Squatters	Site&service	Serviced
Town 2 Village 2A II	2801					
Town 3 Village 3A	2328	2801	2801	Formal Squatters	Site&service	Serviced
Town 3 Village 3B	980					
I		2328	2328	Formal Squatters	Site&service	Serviced
Town 3 Village 3B II	97	980	980	Formal Squatters	Site&service	Serviced
Town 3 Village 4	910	97	97	Formal Squatters	Site&service	Unserviced
Town 3 Village 5A	314					
Town 3 Village 5 IDT	4100	910	910	Formal Squatters	Site&service	Serviced
Town 3 Village 1	3400	314	314	Formal Squatters	Site&service	Serviced
Town 3 Village 2	3000	2536	2536	Formal Squatters	Site&service	Unserviced
Town 4	3400					
		0	0	Formal Squatters	Site&service	Unserviced
		0	0	Formal Squatters	Site&service	Unserviced
		0	0	Formal Squatters	Site&service	Unserviced

Appendix 2
Questionnaires
Case-control study

PERMISSION TO PARTICIPATE IN A RESEARCH PROJECT

The effect of water supply, handling and usage on water quality in relation to health indices in developing communities

We are trying to find out how water supply and use effects people's health. To do this we would also like to know some details about your household, your water supply and your children's health. The information you give us will help decide on what type of water supplies and sanitation are needed and contribute to the design of health education programmes.

The study has been discussed with local community leaders and they have given it their support. Your participation is entirely voluntary and the information will be treated as strictly confidential. Nobody will be identified by name in the results.

Dr John R Seager, BSc Hons, PhD.
Urbanisation & Health, Medical Research Council.

Mrs Bettina Genthe, BSc Hons, MSc
Watertek, CSIR

I ________________________________(fieldworker) have explained the study to ____________________________________ (the participant) and he/she has agreed to participate. Date ______________

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QUESTIONNAIRE FOR THE CASE-CONTROL STUDY

Instruction: Interviewer read out the contents of the consent form to the caretaker of the child. If the caretaker agrees to participate in the study fill in the consent form.

ID number

Date of Interview: (Indicate DD,MM,YY)

Time: (Indicate HH,MM)

Day of week:...

Name of Interviewer: ....

Town/Site ....

House Address/number: ....

Type of water supply:
1. In-house tap 2. Communal tap (less than 100 people)
3. Communal tap (>100 people) 4. No formal water provided

Child status: 1. Clinic case 2. Neighbour

PART 1: DEMOGRAPHIC DATA

1. Gender of child: 1 = Male 2 = Female

2. Date of birth of the child: ...../......./19.......

3. Age of mother of the child: ....

4. Age of the respondent:...............................

5. Relationship of respondent to the child
1. Mother 2. Grandmother 3. Other

6. How many people live in this household?................

7. Give a breakdown of the sex and age.

Children under 6	:Male........	
	:Female......	
Children aged 6-14	:Male........	
	:Female......	
Adults (15+)	:Male........	
	:Female......	

8. Have you always been living in Cape Town? 1 = No 2 = Yes

9. If no, where did you live before coming to Cape Town?
rural area........1
urban area........2

Part 2: ENVIRONMENTAL ISSUES

Water supply and storage

1. What is your household's principal source of drinking water?

   1.Inhouse piped water   2.Outdoor private tap
   3.Communal tap   4.Neighbour's private tap
   5.Other (specify).......................................

2. Is the water source private or communal? 1 = Private   2 = Communal

3. If communal, how many households share the water source?
   Indicate number.............Dont Know......XX

4. How far is the principal water source from your home?
   (Indicate distance in metres, 0 metres if in the home)...........

5. How do you get this water home? (leave blank if not applicable)

		No	Yes
	hand-carried container	1	2
	vehicle	1	2
	rolling the container	1	2
	other (specify)..........	1	2

6. Do you store water at home?   no..............1
   yes.............2

7. What type of containers do you use to store water?
   1. Plastic only   2. Tin/metal only
   3. Tin and plastic   4. Other   5. N/A

8. Is the container(s) kept inside or outside? Is it open or closed?
   open outside..........1
   closed outside........2
   open inside...........3
   closed inside.........4

   Container 1.......................

   Container 2.......................

   Container 3.......................

9. What size is the (largest) water container used to store water at home?   litres..........

10. How often do you fill the largest water container per week?
    times..................

11. How often is it cleaned?
at least daily........1
at least weekly.......2
at least monthly......3
rarely or not at all..4

12. If ever cleaned, how is it cleaned?
Water only............1
Soap..................2
Bleach/disinfectant....3
Other.................4
N/A...................5

13. Do you treat or boil the water you use? 1. No 2. Yes

14. If yes, how do you treat the water?
Boiling.....................1
Disinfectant................2
Boiling and disinfectant....3
Other.......................4
N/A.........................5

15. Are there times when the principal water source is interrupted or unavailable?
no................1
yes...............2

16. Did you have any interruptions of water supply from this source over thelast 3 weeks? 1 = Yes 2 = No

17. If yes, what other water source did you use?
tap water.........1
other.............2
N/A...............3

18. Do you ever get drinking water from sources other than the principal water source?
no...............,1
yes...............2

19. Does your child ever drink water from open waterways, such as rivers, streams, ponds etc?
never................1
sometimes............2
frequently...........3
dont know............4

20. Do you pay for the use of your principal water source?
no..............1
yes.............2

ID Number

Sanitation

21. What type of toilet facility does the household have?
1. Inhouse flush toilet 2. Outdoor flush toilet
3. Bucket system 4. Pit latrine
5. None 6. Other (specify)...................

22. How many people other than members of this household use this toilet facility? Indicate number............ Dont know....XX

23. If the household does not have a toilet, where do members normally defecate?..

24. Are there times when it is not convenient to use the toilet, and household members (over 2 years old) relieve themselves (defecate) elsewhere, although they are in the vicinity of the house?

no................1
yes...............2

25. Under what circumstances?

	no	yes
children cannot always be bothered to use toilet.............	1	2
toilet is sometimes out of order............................	1	2
at night..	1	2
other (specify)...	1	2

26. Do you normally experience problems with regard to using this toilet facility? 1 = No 2 = Yes

27. If yes, what problems do you normally experience?......................
....
....

28. Did the household have any problems with the toilet over the past 3 weeks which resulted in the use of other toilet facilities? No = 1 Yes = 2

29. Do you have a chamber in this household? No = 1 Yes = 2

30. How often is it cleaned?

at least daily........1
at least weekly.......2
at least monthly......3
rarely or not at all..4

31. If ever cleaned, how is it cleaned?

Water only............1
Soap..................2
Bleach/Disinfectant....3
Other.................4

32. Where does the sullage (grey water from washing, etc. including faecal material) often go?

same as sewerage...1
closed separate drain2
open separate drain.3
nearby waterway....4
dumped in street...5
dumped in yard.....6
other.............7

Solid waste

33. How do you store waste (before taking it outside) in your home?

don't store.........1
have open container..2
have closed continer.3

34. How do you store waste (before disposal) outside your home?

don't store outside..1
open container.......2
closed container.....3

35. Is any of your solid waste collected from your home by a collection service?
no..................1
yes.................2

36. How often is waste collected?
times a month.........
N/A.................X

37. Is there a problem in your neighbourhood due to solid waste being dumped carelessly and fouling the environment?
no..................1
yes.................2

38. Do you have flies in your kitchen during the day?
almost never.........1
occasionally.........2
usually.............3

39. Do you have flies in your toilet during the day?
almost never.........1
occasionally.........2
usually.............3
not applicable.......4

40. Do you keep any animals at this residence?
no..................1
yes.................2

Part 3: BEHAVIOURAL VARIABLES AND HYGIENE STATUS DATA

Food contamination

1. Which of the following types of food does the child under study often eat?

	no	yes
freshly cooked	1	2
heated leftover	1	2
cold leftovers	1	2
from vendors	1	2

2. Do you regularly buy prepared food from vendors for use in this household?
no.................1
yes................2

3. How many times did you buy prepared food from the vendor for consumption in this household last week? times..........

4. How do you normally store the following kinds of food?
CODE:refrigerator=1; cupboard=2; open air=3; covered container=4; uncovered container=5 dont store = 6
raw vegetables........
raw meat..............
leftovers.............
milk..................

Child care

5. Who normally looks after the child during the day?
....

6. Does your child attend a day care centre/ creche? No = 1 Yes = 2

7. Is the child breast feeding? No = 1 Yes = 2

8. If no, at what age did the child last breast feed?
< 3 months.......1 3-6 months.......2
7-12 months......3 13-18 months.....4
19+ months.......5 never............6

Water usage

9. How often do you wash clothes with children's faeces in a week?
times.......... N/A....XX

10. How often do you bath the child per week? ....

11. List 3 occasions when you usually wash your hands each day?
....
....

12. List 3 occasions when you usually wash your hands with soap?
....
....
....

13. Do you currently have a bar of soap in this household?
No = 1 Yes = 2

14. If no, when did you last have a bar of soap?
This week.............1 Last week......................2
Last month............3 More than a month ago..........4
N/A...................5

Toilet use

15. At what age do children start using the latrine?
Indicate age.............................

16. What do you normally use for anal cleansing in this household?
....
....
....

17. Where do you dispose of children's stools?
....
....
....

Part 4: SOCIO-ECONOMIC STATUS DATA

1. How many rooms do you have in this household?
Indicate number.....................

2. What is the highest number of people who sleep in one room?
Indicate number..................

3. What fuel do you use for lighting your house?
Electricity.......1 Gas.......................2
Parafin...........3 Candle....................4
Other...5

4. What fuel do you use for cooking?
Electricity.......1 Gas......................2
Parafin...........3 Wood/coal................4
Other..5

5. Which of the following appliances do you have in working condition?

	Yes	No
TV	1	2
Refrigerator	1	2
Stove	1	2
Oven	1	2
Radio	1	2

6. What is the highest educational level of the mother of the child?
No schooling.......1 Sub A/B............2
Standard 1-3.......3 Standard 4-6.......4
Standard 7-10......5 Other..............6

7. What is the occupation of the mother of the child?
....

8. What is the occupation of the father of the child?
....

Part 5:<u>HEALTH INFORMATION</u>

1. Have any of the pre-school children in this household been ill during the past two weeks? no................1 yes...............2

2. Have any of your pre-school children had diarrhoea (local word) at any time in the last two weeks? Please include only those cases where the person had at least three loose stools a day for a period of at least two days. none..............0 number of children....

3. What do you think caused the diarrhoea?

	No	Yes
home prepared food	1	2
pre-prepared food	1	2
food eaten out	1	2
dirty water	1	2
teething	1	2
other..............	1	2

4. What are the signs and symptoms of diarrhoea?

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

5. What do you think causes diarrhoea?

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

6. How do you think diarrhoea can be prevented?

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

7. Respondent's comments

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

8. INTERVIEWER'S COMMENTS

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

PART 6: OBSERVATIONAL DATA

Interviewer must record the following information at the end of the interview.

ID number

House observation

1. House type

1.Brick under tiles/iron/asbestos
2.Tin/iron 3. Mud 4.Plastic 5.Other.............

Drinking water containers

2. Are the containers covered

don't have..............1
covered.................2
not covered.............3

Kitchen or principal room where food is handled:

3. Note number of flies:

0...................0
1-10................1
11+.................2

4. General conditions of the kitchen

	No	Yes
Food and other dirt particles on the floor	1	2
Unwashed or dirty utensils, pots or plates	1	2
Animals/poultry in the kitchen	1	2

5. Any cooked food which is stored uncovered? 1 = No 2 = Yes

Toilet

6. Type of latrine

None...........................1
Flush..........................2
Pit............................3
Bucket.........................4
Other..........................5

7. Note number of flies

0...................0
1-10................1
11+.................2
Not applicable......9

8. General conditions of the latrine:

	No	Yes	N/A
Faeces on the toilet floor	1	2	9
Toilet paper available?	1	2	9
Is the toilet ventilated?	1	2	9

9. Is there soap available?
no..................1
yes.................2

10. Is chamber present? 1 = No 2 = Yes

11. Is chamber any faecal matter visible in the chamber?
1 = No 2 = Yes 3 = N/A

12. Where is the chamber kept?..............................

Cleanliness of the child

13. Cleanliness of:

	Clean	Dirty	None
Hands of the child	1	2	
Hair of the child	1	2	
Face of the child	1	2	
Body of the child	1	2	
Clothes of the child	1	2	
Child's milk bottle	1	2	3

14. Garbage container in the house
dont have...........1
closed/covered......2
open................3

15. ANY OTHER COMMENTS
....
....
....
....
....
....

PERMISSION TO PARTICIPATE IN A RESEARCH PROJECT

The effect of water supply, handling and usage on water quality in relation to health indices in developing communities

Sizama ukuphanda amanzi eniwasebenzisayo, nendlela athi achaphazela ngayo impilo yabantu. Ukwenza oku sithanda ukwazi inkcukaca ngempilo yabantwana nendlu yonke. Inkcazelo oyakuthi usinike iyakusinceda ekubeni sazi uhlobo lwamanzi nendlela i toilet ezifuneka ngayo. Lonto iyakutsho incede uhlobo lwemfundiso ngezempilo.

Oluphando seluxoxiwe nenkokheli zabahlali zaluxhasa. Inxhanxheba yakho isekuthandeni kwakho. Lo nkcazelo usinikileyo yoba yimfihlelo. Eziphumeni zoluphando akukho gama la mntu lakupapashwa.

Dr John R Seager, BSc Hons, PhD.

Urbanisation & Health, Medical Research Council.

Mrs Bettina Genthe, BSc Hons, MSc

Watertek, CSIR

I ________________________________(fieldworker) have explained the study to ________________________________ (the participant) and he/she has agreed to participate. Date _____________

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Appendix 3
Microbiological data

Table 3. Summary statistics: Faecal coliforms (CFU's/100mℓ)

	Case in-house	Case tap	Control in-house	Control tap
sample size	161	155	162	155
average	$1,7X10^6$	0,7	$2,54X10^5$	128,9
median	0	0	0	0
geometric mean	1,88	<1	2,0	<1
minimum	0	0	0	0
maximum	$3,8X10^8$	81	$4,0X10^7$	$1,30X10^4$
lower quartile	0	0	0	0
upper quartile	0	0	0	0
95th percentile	$1,47X10^4$	0	$2,7X10^4$	0
% = 0/100mℓ	85,1	96,8%	83,3%	96,1%
% ≤1/100mℓ	85,7%	97,4%	84,6%	96,1%
% ≤10/100mℓ	89%	99,4%	85,8%	96,8%

Table 4. Summary statistics: *E. coli* (CFU's/100mℓ)

	Case in-house	Case tap	Control in-house	Control tap
sample size	161	155	162	155
average	384	0,4	$1,11X10^4$	5,1
median	0	0	0	0
geometric mean	<1	<1	<1	<1
minimum	0	0	0	0
maximum	$3,4X10^4$	56	$1,8X10^6$	650
lower quartile	0	0	0	0
upper quartile	0	0	0	0
95th percentile	10	0	16	0
% = 0/100mℓ	90,1	98,1%	92%	96,8%
% ≤1/100mℓ	91,9%	98,7%	92,6%	96,8%
% ≤10/100mℓ	95%	99,4%	94,4%	97,4%

Table 1. Summary statistics: Standard plate counts (CFU's/mℓ)

	Case in-house	Case tap	Control in-house	Control tap
sample size	161	155	162	155
average	$6,83 \times 10^5$	98,4	$1,14 \times 10^5$	160,3
median	2	1	1,5	1
geometric mean	39,8	2,12	20,9	1,7
minimum	0	0	0	0
maximum	$8,29 \times 10^7$	$7,24 \times 10^3$	$8,9 \times 10^6$	$1,76 \times 10^4$
lower quartile	0	0	0	0
upper quartile	$4,47 \times 10^2$	4	60	2
95th percentile	$1,03 \times 10^6$	162	$2,69 \times 10^5$	89
% ≤100/mℓ	70%	94%	79%	96%
% ≤1000/mℓ	76%	98%	83%	99%
% ≤10000/mℓ	83%	100%	86%	99,4%

Table 2. Summary statistics: Total coliforms (CFU's/100mℓ)

	Case in-house	Case tap	Control in-house	Control tap
sample size	161	155	162	155
average	$2,8 \times 10^7$	1,3	$3,17 \times 10^5$	178,2
median	0	0	0	0
geometric mean	3,34	<1	3,35	<1
minimum	0	0	0	.0
maximum	$4,38 \times 10^9$	105	$4,6 \times 10^7$	$1,90 \times 10^4$
lower quartile	0	0	0	0
upper quartile	1	0	0	0
95th percentile	$3,04 \times 10^5$	0	$1,2 \times 10^5$	0
% = 0/100mℓ	74,5	95,5%	78%	96,5%
% ≤5/100mℓ	83,9%	96,8%	83,3%	96,1%
% ≤100/100mℓ	89,4%	99,4%	87%	97,4%

Table 5. Summary statistics: Phage (PFU's/10mℓ)

	Case in-house	Case tap	Control in-house	Control tap
sample size	161	155	162	155
average	26,5	0	0,24	0,1
median	0	0	0	0
geometric mean	<1	<1	<1	<1
minimum	0	0	0	0
maximum	4268	0	32	8
lower quartile	0	0	0	0
upper quartile	0	0	0	0
95th percentile	0	0	0	0
% = 0/10mℓ	98,8%	100%	97,5%	99,4%
% ≤10/10mℓ	99,4%	100%	99,4%	100%
% ≤100/10mℓ	99,4%	100%	100%	100%

Table 6. Summary statistics: Chlorine concentrations (free Cl_2mg/ℓ)

	Case in-house	Case tap	Control in-house	Control tap
sample size	155	150	155	149
average	0,2	0,48	0,25	0,5
median	0,05	0,4	0,1	0,4
geometric mean	0,2	0,4	0,2	0,4
minimum	0	0	0	0
maximum	1,25	2	1,5	2,0
lower quartile	0	0,1	0	0,1
upper quartile	0,4	0,8	0,45	0,8
95th percentile	0,9	1,25	0,8	1,5
% ≤ 0,2mgℓ	61,9%	36,7%	61,9	34,9
% = 0mg/ℓ	41,3%	14,7%	37,4%	12,1%

Table 7 Two Sample Comparison: t-test (comparison of log bacteria counts)

	Case in-house vs tap	Control in-house vs tap	In-house case vs control	Tap case vs control
SPC	sig. diff* t= 6.35 sig. level = 7.33e-10	sig. diff t= 5.75 sig. level = 2.37e-8	no sig. diff t= 1.25 sig. level = 0.24	no sig. diff t= 0.72 sig. level = 0.47
total coliforms	sig. diff t= 4.25 sig. level = 2.78e-5	sig. diff t= 4.02 sig. level = 7.18e-5	no sig. diff t= -0.002 sig. level = 0.998	no sig. diff t= -1.02 sig. level = 0.308
faecal coliforms	sig. diff t= 3.76 sig. level = 1.99e-4	sig. diff t= 3.45 sig. level = 6.34e-4	no sig. diff t= -0.12 sig. level = 0.91	no sig. diff t= -1.38 sig. level = 0.17
E. coli	sig. diff t= 2.65 sig. level = 8.44e-3	no sig. diff t= 1.64 sig. level = 0.10	no sig. diff t= 0.09 sig. level = 0.93	no sig. diff t= -1.22 sig. level = 0.23
Phages	no sig. diff t= # sig. level = #	no sig. diff t= -1.02 sig. level = 0.31	no sig. diff t= 0.26 sig. level = 0.80	no sig. diff t= # sig. level = #
Chlorine	sig. diff t= -5.34 sig. level = 1.87e-7	sig. diff t= -5.69 sig. level = 3.03e-8	no sig. diff t= -0.16 sig. level = 0.87	no sig. diff t= 0.43 sig. level = 0.67

*sig. diff = significant difference # = could not be calculated

Table 8 Analysis of Variance: Type of water supply vs log bacterial numbers

Log bacterial numbers	Case in-house	Case tap	Control in-house	Control tap	Combined results
SPC/ml	F= 5.200 p=0.0019	F=3.734 p=0.0127	F= 2.582 p=0.0556	F= 1.748 p=0.1599	F= 8.469 p=0.0000
Total coliforms	F= 0.951 p=0.4178	F= 1.609 p=0.1898	F= 1.023 p=0.3844	F= 0.169 p=0.9174	F= 1.392 p=0.2442
Faecal coliforms	F= 0.799 p=0.4962	F= 1.061 p=0.3679	F= 0.952 p=0.4172	F= 0.194 p=0.9005	F= 0.833 p=0.4760
E. coli	F= 1.303 p=0.2758	F= 1.067 p=0.3650	F=0.427 p=0.7342	F=0.598 p=0.6173	F= 1.625 p=0.1825
Phage	F= 0.766 p=0.5144	F= #	F= 1.812 p=0.1475	F= 1.214 p=0.3070	F= 0.571 p=0.6341

could not be calculated

Table 9 Comparison of Phase 1 & 2 : Nonparametric pairs test(Mann-Whitney)

Indicator	Case in-house	Case tap	Control in-house	Control tap	Combined
SPC	Z=-7.81 p=5.77e-15	Z=-7.48 p=7.37e-14	Z=-8.21 p=2.2e-16	Z=-6.74 p=1.59e-11	Z=-14.64 p=0
Total coliforms	Z=-9.85 p=0	Z=-11.88 p=0	Z=-10.53 p=0	Z=-12.18 p=0	Z=-21.95 p=0
Faecal coliforms	Z=-11.40 p=0	Z=-12.24 p=0	Z=-11.29 p=0	Z=-12.21 p=0	Z=-23.51 p=0
E. coli	Z= =11.85 p=0	Z=-12.3 p=0	Z=-11.98 p=0	Z=-12.24 p=0	Z=-24.22 p=0
Phage	Z=-12.57 p=0	Z=-12.41 p=0	Z=-12.54 p=0	Z=-12.37 p=0	Z=-25.01 p=0

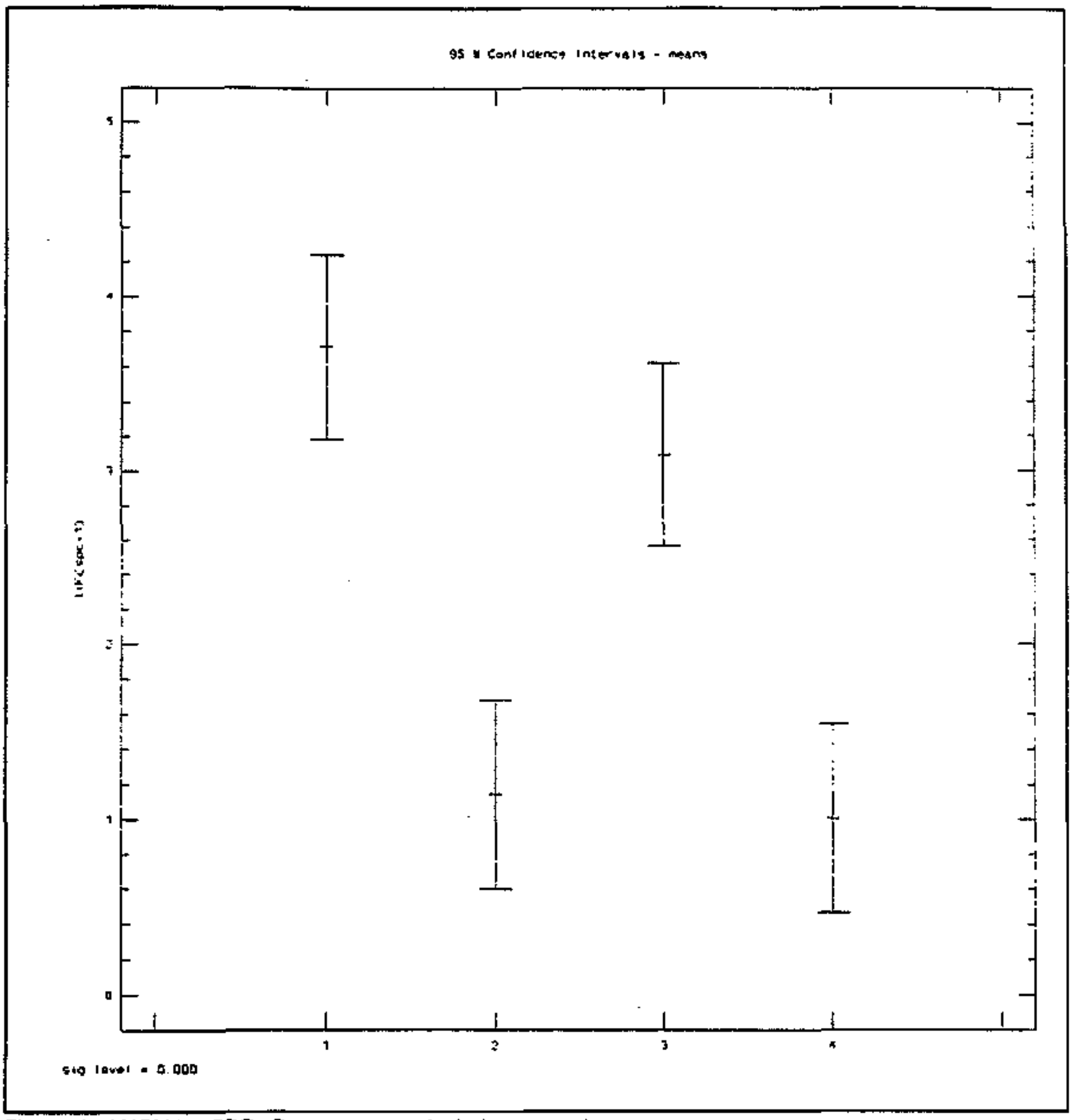

Figure 1. ANOVA - SPC Case vs control ; in-house and tap waters

1 = case in-house
2 = case tap
3 = control in-house
4 = control tap

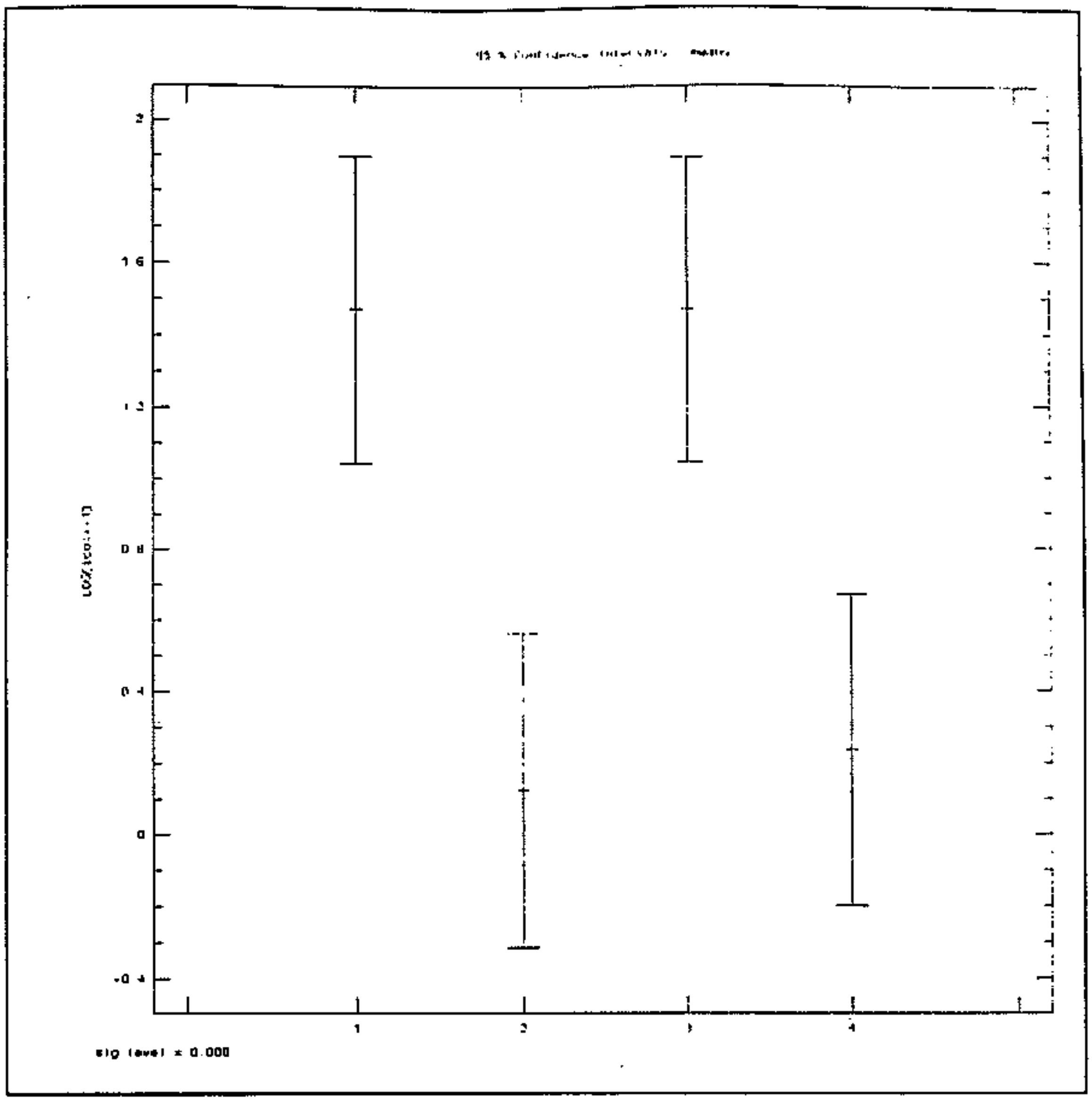

Figure 2. ANOVA - total coliforms   Case vs control: in-house and tap water

1 = case in-house
2 = case tap
3 = control in-house
4 = control tap

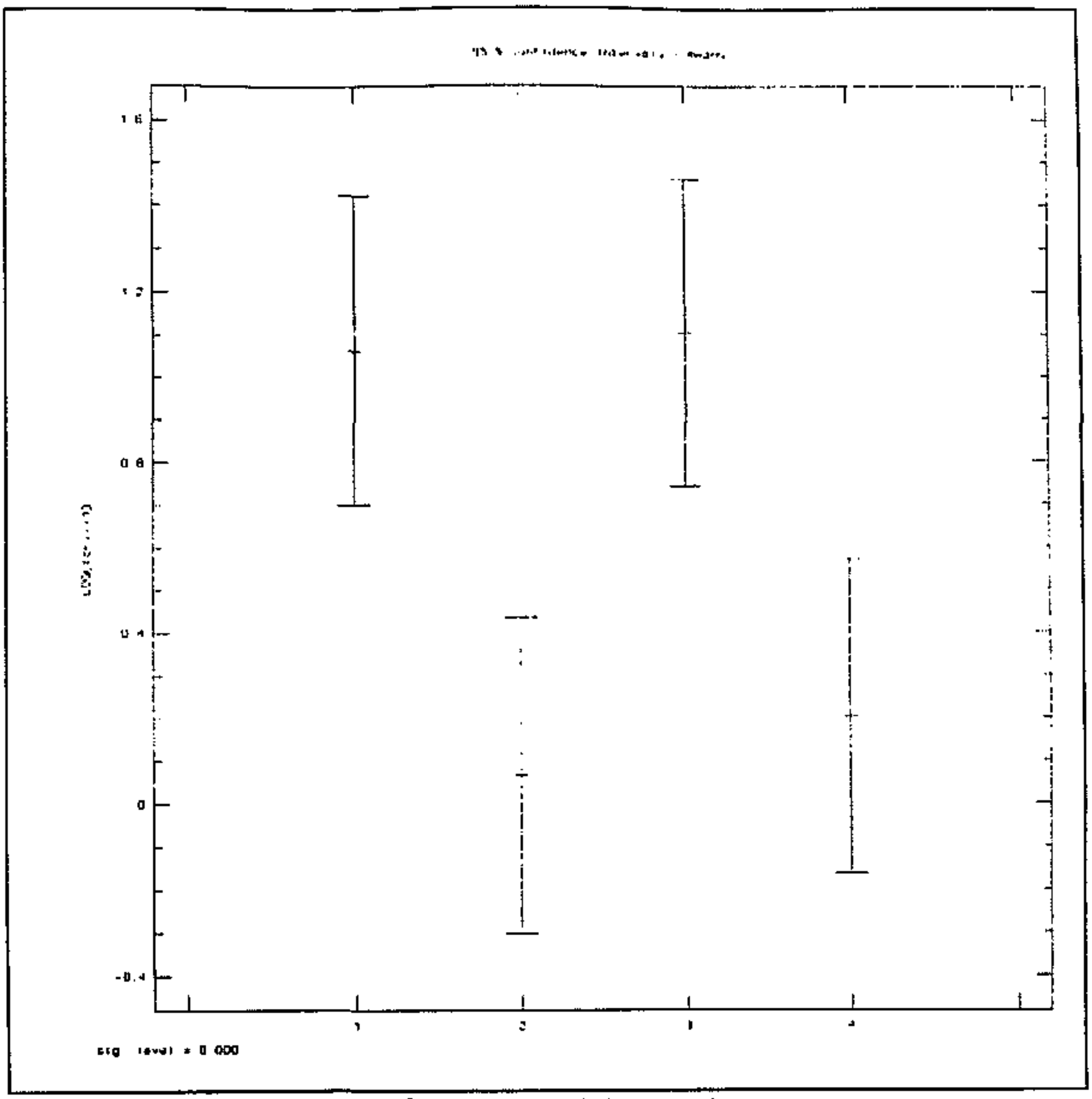

Figure 3. ANOVA - faecal coliforms Case vs control: in-house and tap waters

1 = case in-house
2 = case tap
3 = control in-house
4 = control tap

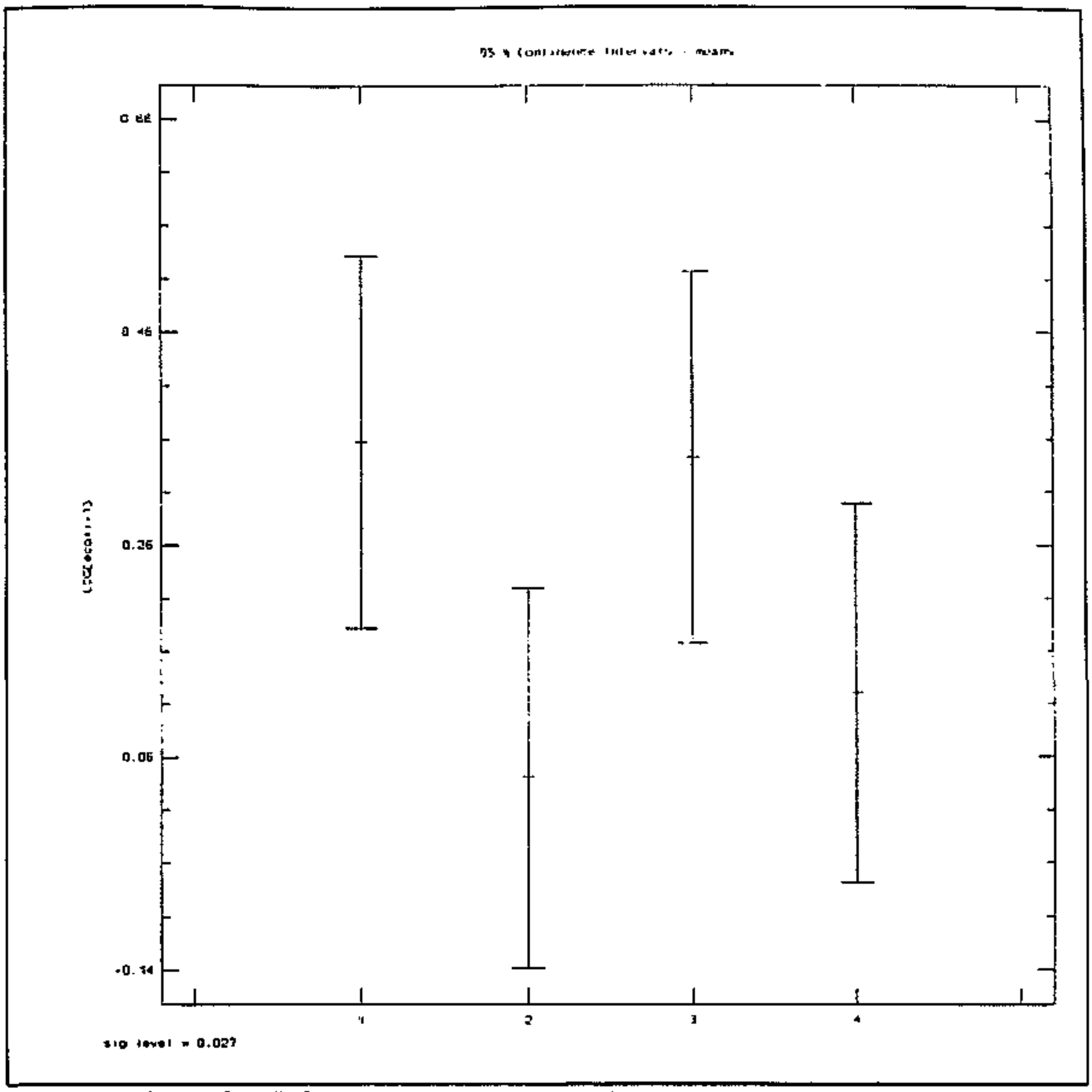

Figure 4. ANOVA - *E. coli* Case vs control: in-house and tap waters

1 = case in-house
2 = case tap
3 = control in-house
4 = control tap

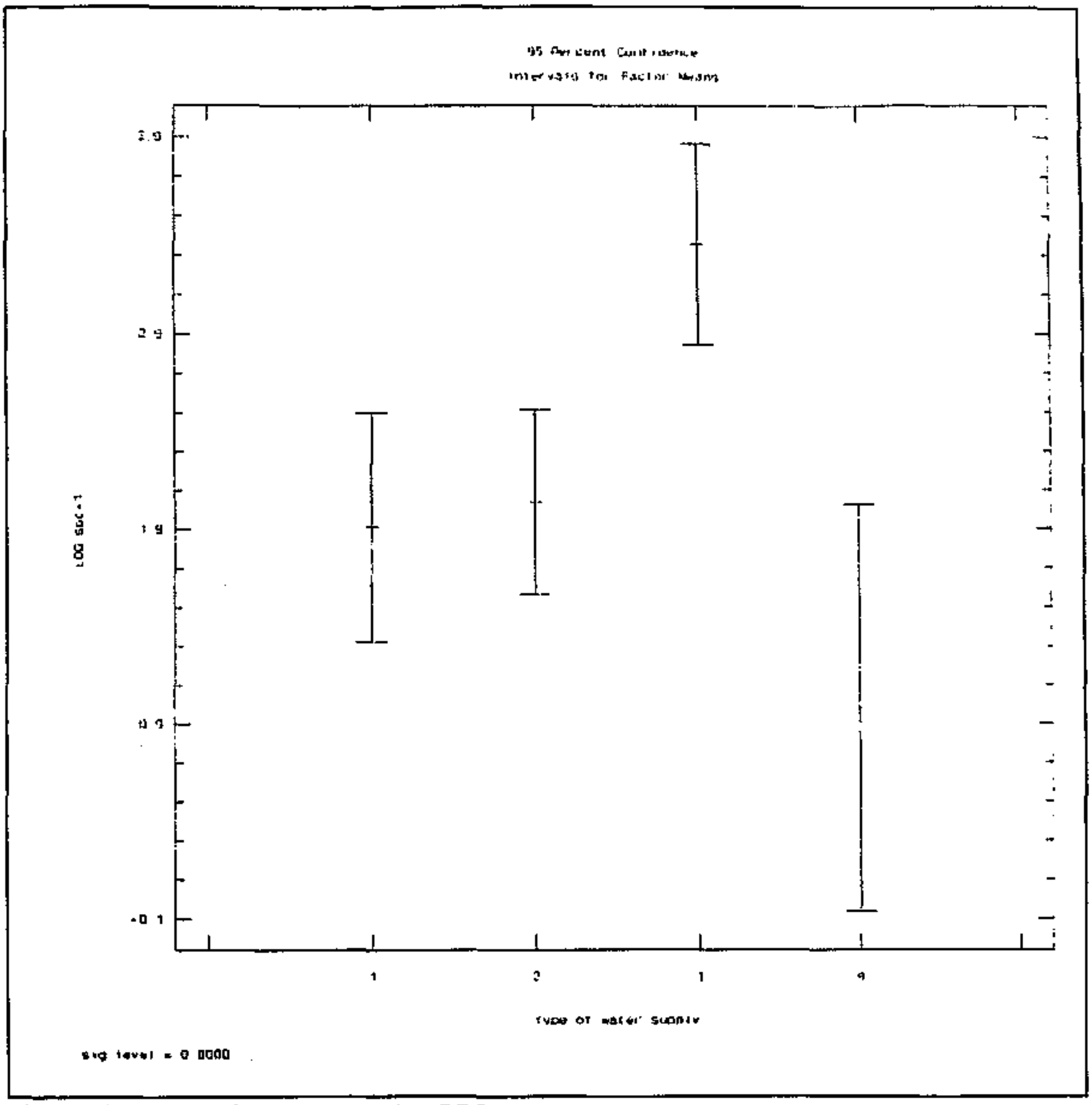

Figure 5. Type of water supply: SPC

1 = in-house taps
2 = outdoor private taps
3 = communal taps
4 = no formal supply

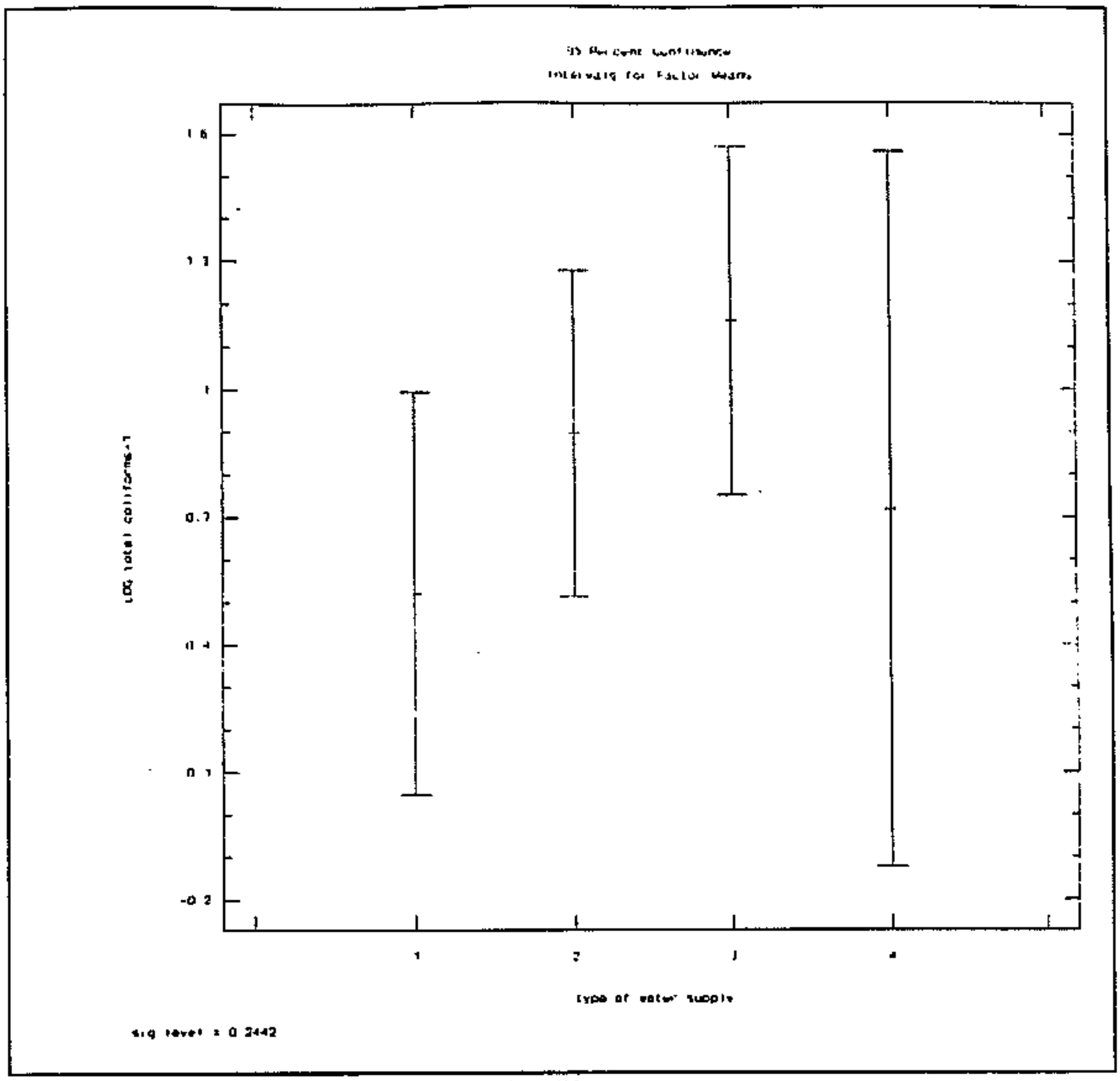

Figure 6. Type of water supply: Total coliforms

1 = in-house taps
2 = outdoor private taps
3 = communal taps
4 = no formal supply

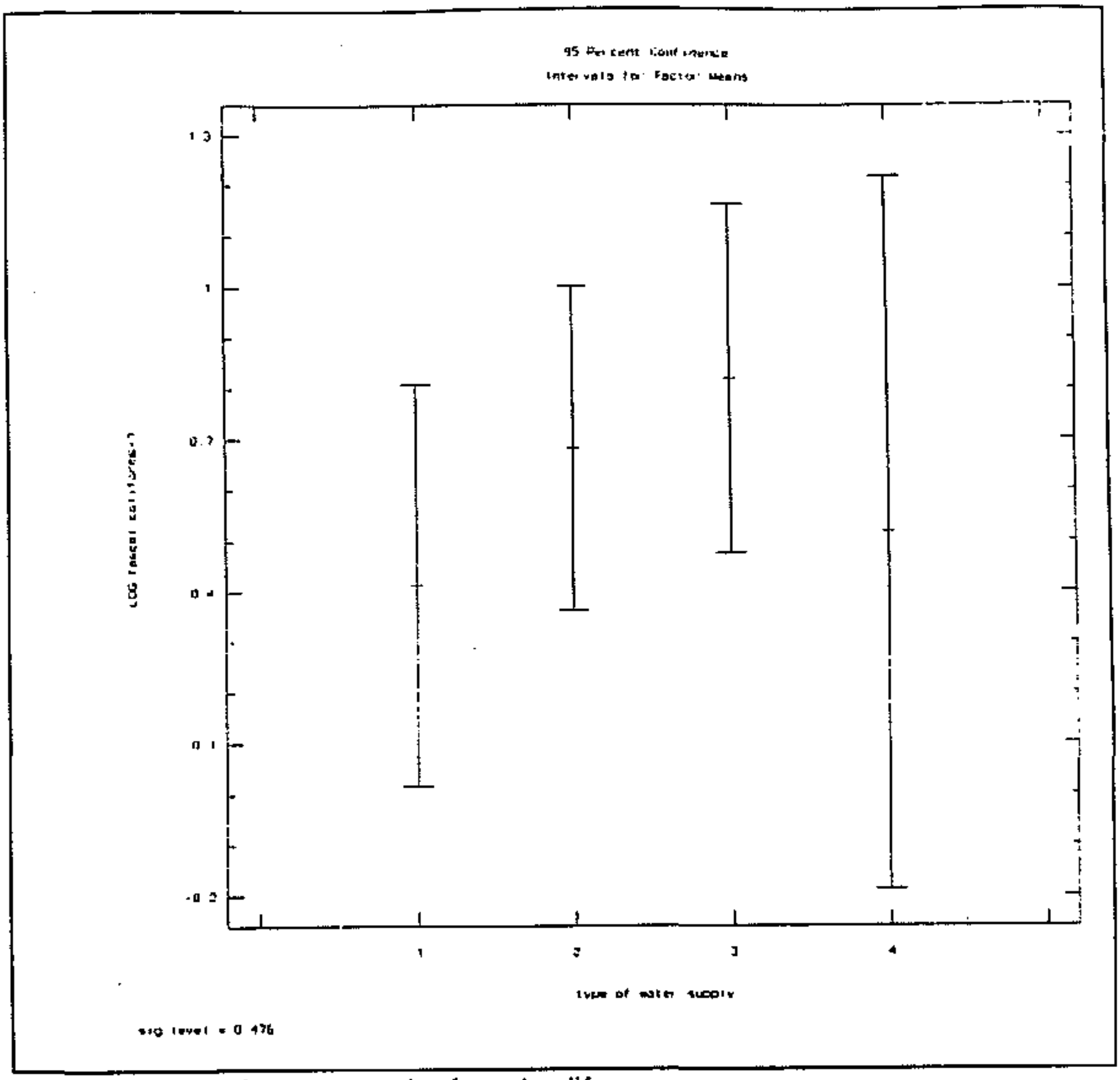

Figure 7. Type of water supply: faecal coliforms

1 = in-house taps
2 = private outdoor tap
3 = communal tap
4 = no formal supply

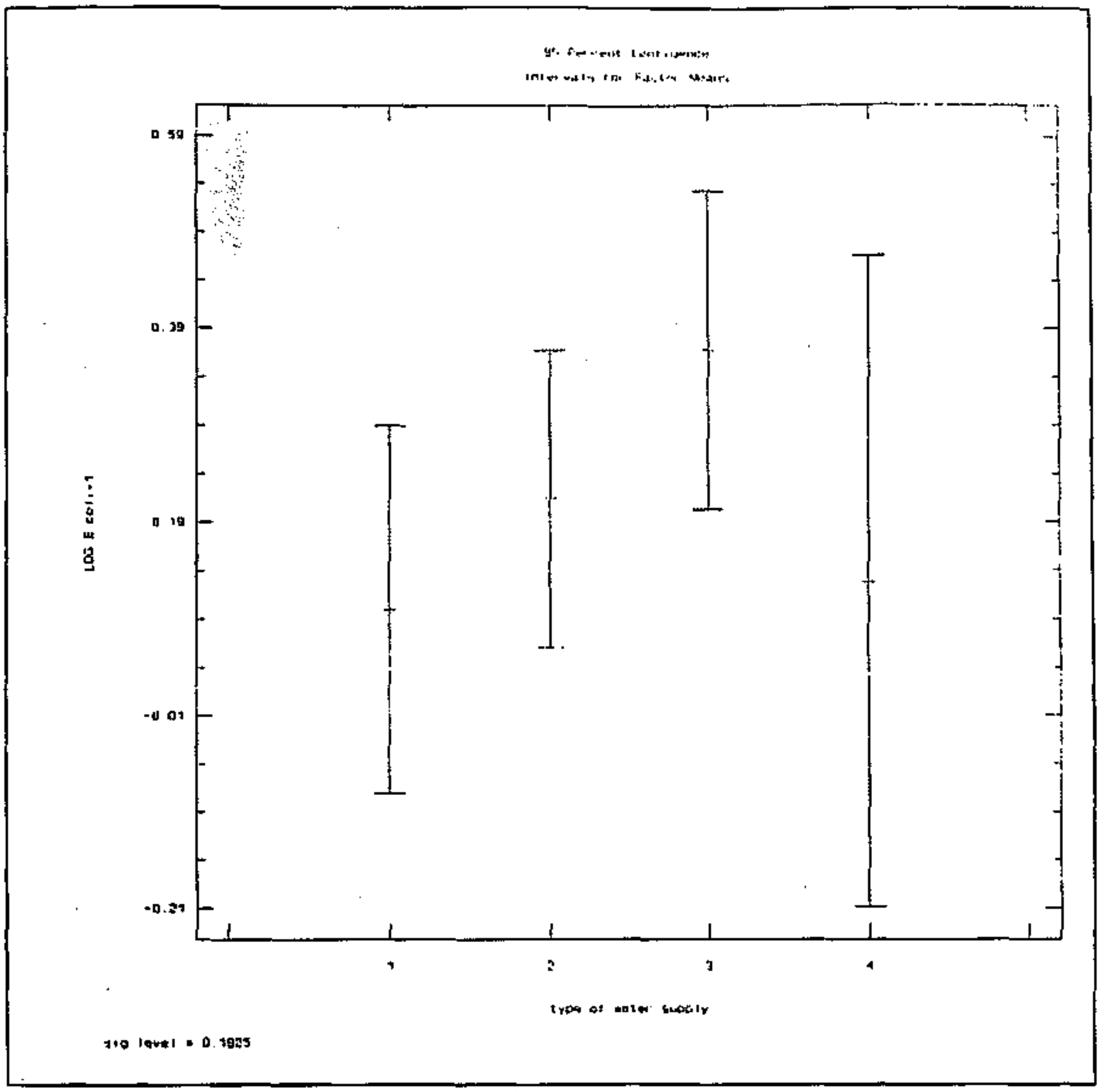

Figure 8. Type of water supply: *E. coli*

1 = in-house taps
2 = private outdoor tap
3 = communal tap
4 = no formal supply

Appendix 4
Questionnaire
Cross-sectional study

MRC - CSIR HEALTH STUDY

Interviewer : ______________

Clinic : ______________

Date : ☐

1. Name of Child ______________________________

2. Age/Birth date

D	D	M	M	Y	Y

3. Gender Male ☐

   Female ☐

4. Where does the child currently live?

   Suburb : ______________________________

   Address : ______________________________

   ____

5. What is your (the respondent's) relation to the child?

   ____

6. Does the child's mother work? YES ☐ NO ☐

7. Does the child go to a crèche or any other daycare facility?

   YES ☐ NO ☐

8. What type of water facility is provided at the child's home?

   ____

9. What type of sanitation is provided at the child's home?

   ____

10a. Does the child have any older brothers or sisters? YES ☐ NO ☐

   H .. many? ______________

......./2

10b. Does the child have any younger brothers or sisters? **YES** ☐ **NO** ☐

How many? ____________________

11. How many times since birth has this child been sick (including this time)? __________________

12. **(ON EXIT)**
Where are you going now? Oral Rehydration Clinic? **YES** ☐ **NO** ☐