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THE EVALUATION OF THE QUALITY OF SANITATION AND STORED WATER FOR DOMESTIC USE IN THE UMLAZI P SECTION INFORMAL SETTLEMENT IN SOUTH AFRICA.

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ABSTRACT

Background
South Africa is faced with a struggle to manage the supply of water due to growing informal settlements where infrastructure is limited resulting in the contamination of water during collection and storage. The researcher aims to determine the level of knowledge and awareness of water contamination and the safety of water in terms of microbial and chemical content.

Aim: This study aimed to investigate the quality of stored water and the handling of storage vessels for domestic use at the informal settlement of the Umlazi P Section, in the south-west of Durban.

The study objectives: The objectives of the study were to determine the knowledge and awareness of water contamination using a questionnaire and investigate the exposure of water to microbial agents due to poor hygiene and storage.

To test stored water samples for pathogenic organisms as well as compliance with the South African Water Quality Guidelines for domestic use.

Methodology
Data collection entailed the administration of a questionnaire to 269 participants, including the laboratory analysis of water samples collected from water storage containers used in each household.

Results
A positive total coliform count was found among 13 (5%) households in the study of 269 households rendering their drinking water a high risk for domestic use despite only accounting for 5% of the population. The remaining 256 showed to have a negligible exposure to waterborne contamination. The *Escherichia coli* was not detected making drinking water acceptable in terms of fecal coliform bacteria.

Conclusion
The data collected from the study showed that poor hygienic practices and infrastructure were at the center of water contamination.

Recommendations
The study recommended infrastructure development, hygiene monitoring tools, and cost-effective water treatment products.

Keywords: *Contamination, Hygiene practices, Water quality, Infrastructure, Laboratory testing methods*
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INTRODUCTION

In South Africa, informal dwellings such as shacks, shelter thousands of people who are deprived of adequate water resources and quality infrastructure 1. The Department of Water and Sanitation (DWS) infrastructure and access to quality drinking water is still a problem in most parts of the country 2. The contamination of domestic water, unhygienic practices, and the lack of basic education remain major challenges among the large communities in need of water and sanitation services 3. Contamination becomes a threat to the quality of water due to poor water and sanitation and ultimately a threat to the health of the community 4. There is always a potential danger of contamination as people store water in their homes due to inadequate and irregular water supply. This practice may lead to the rise of a variety of waterborne diseases such as diarrhea, especially if hygiene is not properly monitored.5

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The quality of water is known to decline considerably and this increases the chances of bacterial contamination from the point of collection to the household water storage for domestic use 6.

In this study, stored water samples were collected and laboratory tested for waterborne pathogens as well as pH to get an idea of the quality of the water. A questionnaire focusing on the variables around collection and storage was used to determine if any factors influence contamination.

Due to the increasing difficulty that citizens experience regarding access to safe drinking water, many people die from preventable illnesses. Such deaths occur through the ingestion of water contaminated by human or animal excreta or urine containing pathogenic bacteria 7. The biggest health problem related to waterborne infections in developing countries is diarrhea, which accounts for 4 million deaths annually, and about 2 million of these deaths are children below the age of five 8. South Africa is still faced with low-income housing challenges lacking a water tap nearer to the toilet for handwashing.

The study area, the Umlazi township is located as a peri-urban area of Ethekwini Municipality with challenges of high rates of unemployment, high levels of poverty, low levels of skills and literacy as well as limited access to basic household amenities 9. This township is also characterized by high levels of HIV infection and tuberculosis due to socio-economic conditions including smoking, alcohol abuse, rapid urbanization, and poverty 10. There is always a need to store increased volumes of water due to unforeseen lengthy water disruptions and also to avoid collecting water from outside sources during night hours 11. However, the storage containers used are often not clean enough and are exposed to organic material, dust as well as pests, and insects. The corrosion of metal containers such as copper containers can lead to gastrointestinal problems in the short term as well as kidney failure and liver damage over some time 12. The fecal contamination can be caused by children putting their hands into the water storage and also failure to adhere to hygienic practices when handling stored water 6.

Waterborne infections are caused by the ingestion of water contaminated by human or animal excreta containing pathogenic bacteria 7. The excreta-related contamination is caused by direct or indirect contact with pathogens associated with excreta and/or vectors breeding in excreta. The Umlazi township is experiencing excessive illegal dumping resulting in the deterioration of vegetation, contamination of water, and organic material releasing heavy metals such as copper 13. Some of the dumped material can produce pathogens that release toxins that infect groundwater which can be carried through to water distribution systems that supply drinking water 14.

The presence of toxic chemicals, as well as coliform bacteria, indicate that water is a health risk for household use 15. Coliforms represent a subgroup of intestinal bacteria that may be found in human feces and animals16. Gastrointestinal diseases associated with contaminated water and food transmitted through water are cholera, salmonellosis shigellosis, and diarrheagenic *Escherichia coli* (*E. coli)* 17. In this study, *E. coli* was tested as it is the best bacterial indicator for the presence of fecal coliform bacteria which are a subgroup of total coliform bacteria that exist in the intestines of human and animal feces that can cause contamination of drinking water.

The total coliform count may also indicate the presence of other organisms that might have entered water streams through vegetation and soil but may be harmless. *E. coli O157: H7* can produce powerful toxins that cause diarrhea. *E. coli* infections can give rise to hemolytic uraemic syndrome, a disease similar to dysentery which is potentially life-threatening 18. When *E. coli* has been isolated in a drinking water system it immediately poses a health risk to the community 19. However, with stringent health monitoring programs in place for quality delivery of water, diarrhea associated with *E. coli* infections can be eradicated. This study aimed to identify possible microbial contamination of water storage as a result of the handling of water and to assess the level of knowledge concerning hygiene as well as the protection of water resources from bacterial contamination among the people living in an informal settlement.

METHODOLOGY

Study Design

This was a descriptive cross-sectional quantitative study, designed to evaluate the quality of stored water, sanitation, and overall hygiene practices in handling water resources in the informal settlement located at Umlazi P Section. Data was collected among 269 participants from 800 homes using questionnaires.

Participants eligibility criteria

A letter of permission was obtained from a local counselor to conduct research in Umlazi P informal settlements. Informed consent forms were distributed among the community members who were willing to participate in the research study. Participation in the study was completely voluntary, no participants were coerced into joining the study.

Sample size

The study consisted of a sample size of 269 participants selected through a random sampling technique.

Sample collection

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Water samples were collected from the water storage vessels from consenting participants for further laboratory analysis. Samples were collected in the afternoon into sterile sample containers. All samples were temporarily stored in a light-proof insulated box containing melting ice or ice packs with water to ensure rapid cooling to preserve the integrity of samples for laboratory analysis.

Biases of the research

Each household was given a special code to ensure the confidentiality of the results as well as eradicate biases in the analysis of the results. The selection of houses was randomized, there was no particular sequence in house visits for the collection of water samples and questionnaire administration. A small sticker was placed on the right side of the door to indicate that the house had already been visited by the researcher to avoid repeated visitation.

Laboratory experiments

The water samples were tested for the pH level using a pH dipstick to see if any dissolved chemical substances were affecting the quality of the water. The water samples were also tested for the presence of *E. coli* and total coliform count to establish whether the water used for domestic purposes was safe for human consumption. Laboratory tests were performed using a 3M *E. coli* Coliform petrifilm. A 1 ml sample of water was dispensed and inoculated onto the entire surface of the petrifilm. The samples were then incubated at 37°C for 24 hours. If *E. coli* is present, blue-green colonies with bubbles would appear. The Total coliform count colonies would appear red with gas around it. The colony count was performed on samples with positive growth. A significant result for *E.coli* would be $\geq$ 1CFU per ml and a substantial total coliform count would be $\geq$ 100 per ml. The *E. coli* 0157:H7 human type was used as a quality control organism for the laboratory testing of water samples.

Data collection

A questionnaire and informed consent forms were distributed to each household to cover their demographic and behavioral characteristics. The questionnaire gave insight into the type of storage containers used, the methods used to clean the containers, and the chemical treatments used to keep the water clean. Through the questionnaire, we were able to determine the level of basic health education about the use of water. It also helped provide knowledge of the type of waste generated, and the Municipality services provided regarding waste removal.

Variables

Categorical variables were summarized by frequency and percentage and presented using bar charts and other figures. The odds ratios and the corresponding 95% confidence intervals were determined for 2 × 2 cross-tabulations and *p*-values less than 0.05 were considered significant. The variables were outlined on the questionnaire ranging from education levels, hygiene practices, ablution facilities, water storage facilities, water and sanitation infrastructure, and water collection behaviour.

Statistical Methods

Data obtained was captured using Microsoft Excel and thereafter exported to IBM SPSS Statistics software 24.0 25. Descriptive statistics were used in this explorative study.

Ethical Consideration

A full ethical approval letter was granted by Durban University of Technology University to conduct research and do data collection. The Ethics number for the research study is IREC 116/18

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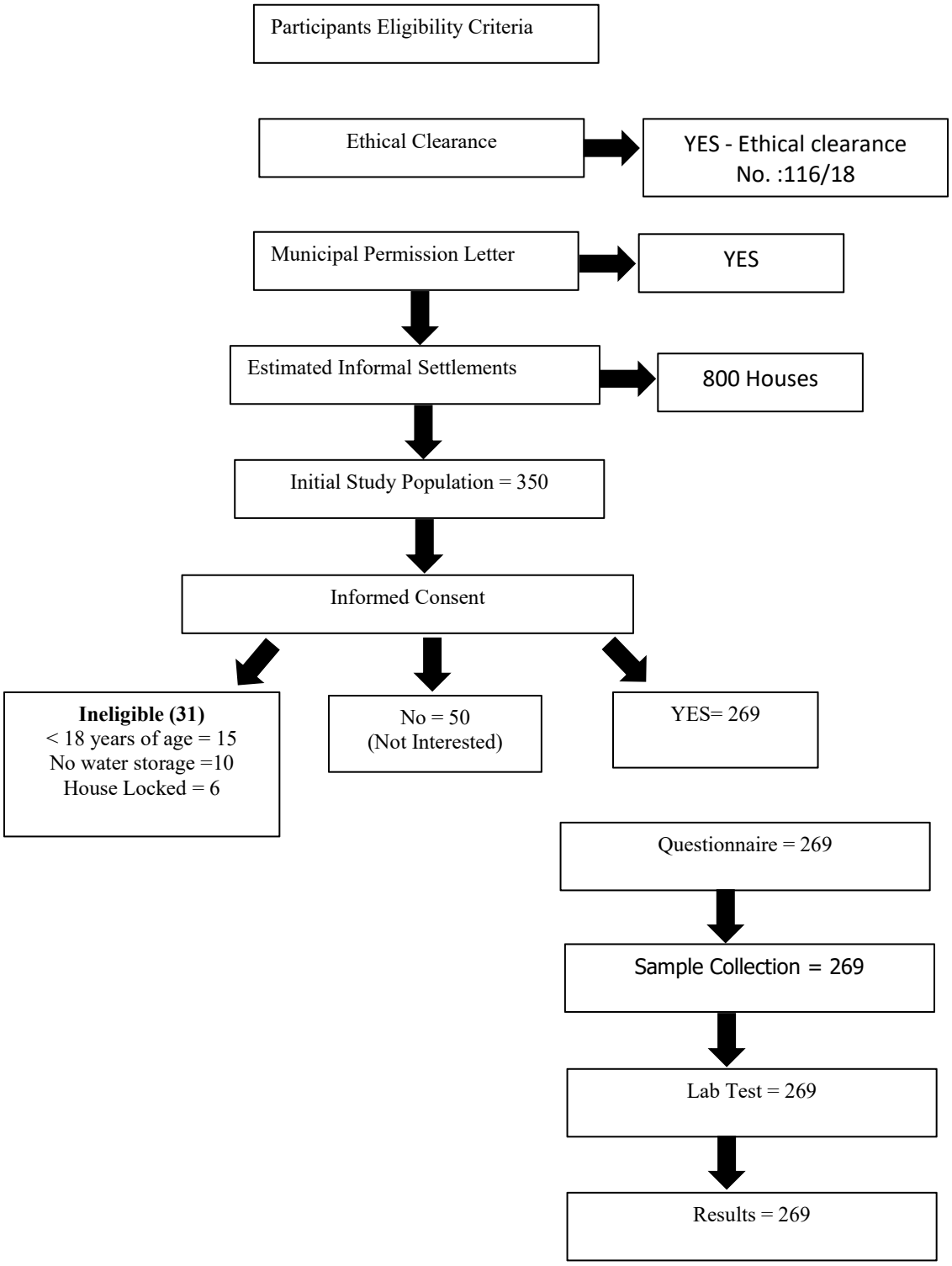
RESULTS

Figure 1: Participants Eligibility Criteria



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Knowledge of the source of water and quality

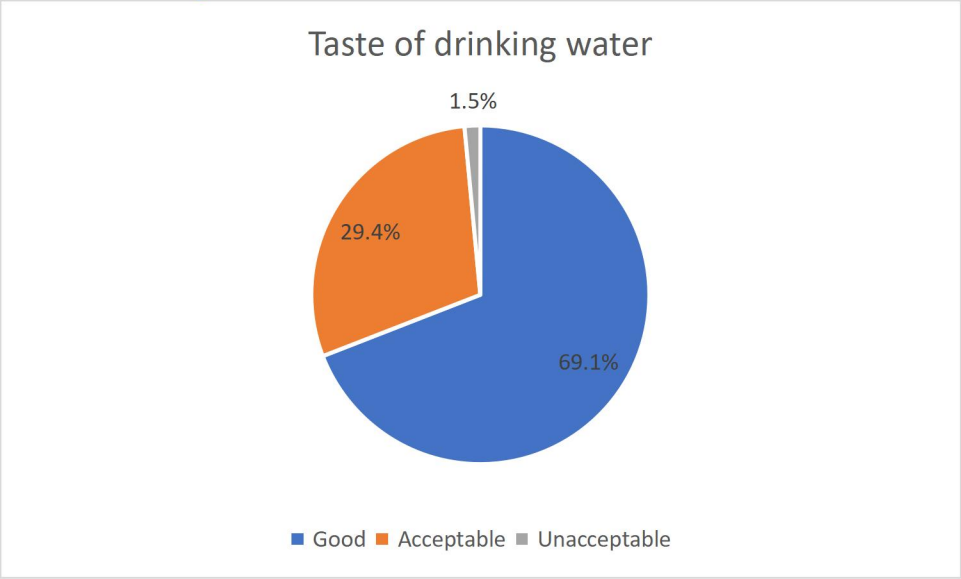
The findings in Table 1 indicate that 265 respondents (98.5%) received municipal piped water. All of the respondents indicated that the primary source of water for domestic use in their household, for example, cooking – was obtained from piped water from the Municipality. Of those that received piped water, 69.1% rated the quality of water as being good, with 1.5% indicating that the quality was unacceptable and 29.4% as acceptable.

Table 1. Sources of water

Source	Number of participants	Percentage
Municipal piped water	265	98.5
River	1	0.01

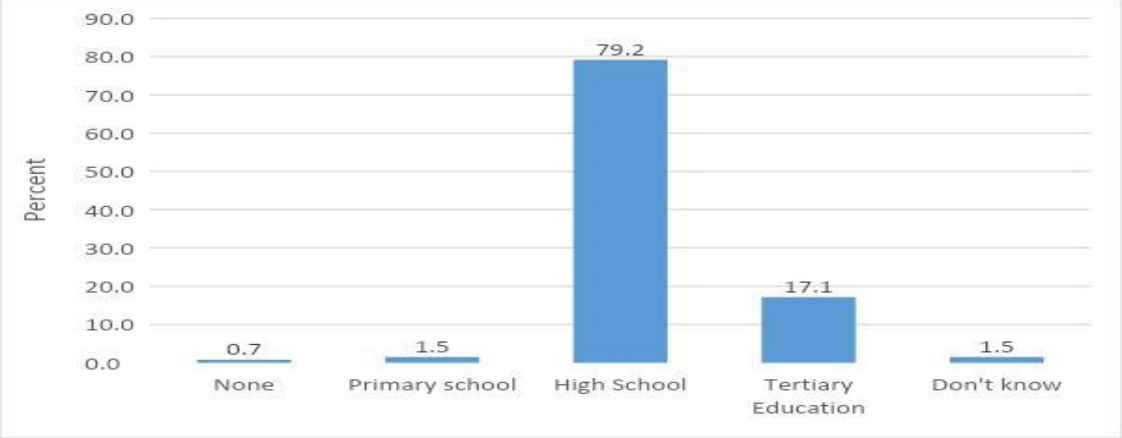
Participant's responses on knowledge of water source and quality of water taste

Figure 2: Taste of drinking water



Levels of education among respondent

Figure 3: Levels of education



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The majority of respondents, 213/269 (79%) had a high school level of education, whilst four respondents only had a primary level of education, altogether making up (81%) of respondents with just basic education. Approximately 17% had a tertiary qualification ($p < 0.001$), which indicates that the majority of the respondents did not have a higher qualification as seen in Figure 2.

The Sanitation infrastructure

Figure 3: Types of Sanitation Infrastructure

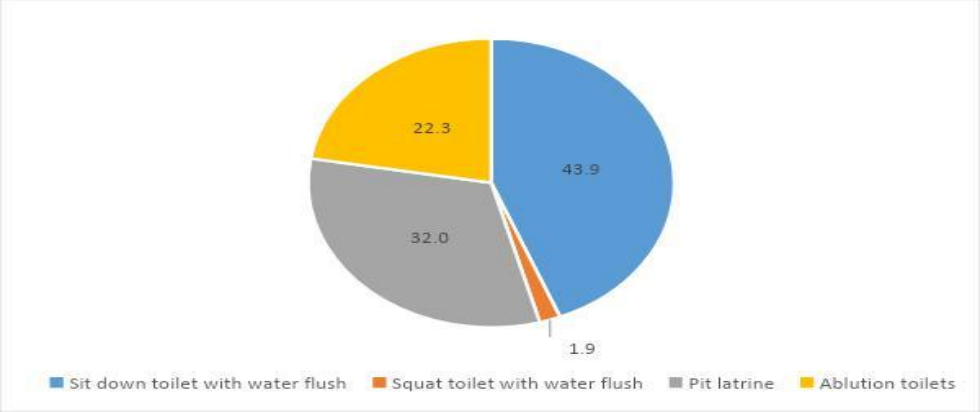

Figure 3 shows a total of 87 respondents (32%) almost a third of the respondents had pit latrines where fecal waste is not removed but treated with antimicrobial chemicals.

The water storage hygiene knowledge

Table 2 shows that more respondents 237 indicated that they had not received basic education ($p < 0.001$). This result helped determine the level of understanding about contamination of stored water at a household level.

Table 2. Participant's education on water knowledge

Basic health education	Frequency	Percent
Yes	31	11.5
No	237	88.1
Maybe	1	0.4
Total	269	100.0

Respondents understanding of water contamination

Table 3 shows that a total of 206 respondents of participants lacked an understanding of how water contamination of water occurs.

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Table 3. Participant's understanding of water knowledge

Water contamination knowledge	Frequency	Percent
Yes	63	23.4
No	206	76.6
Total	269	100.0

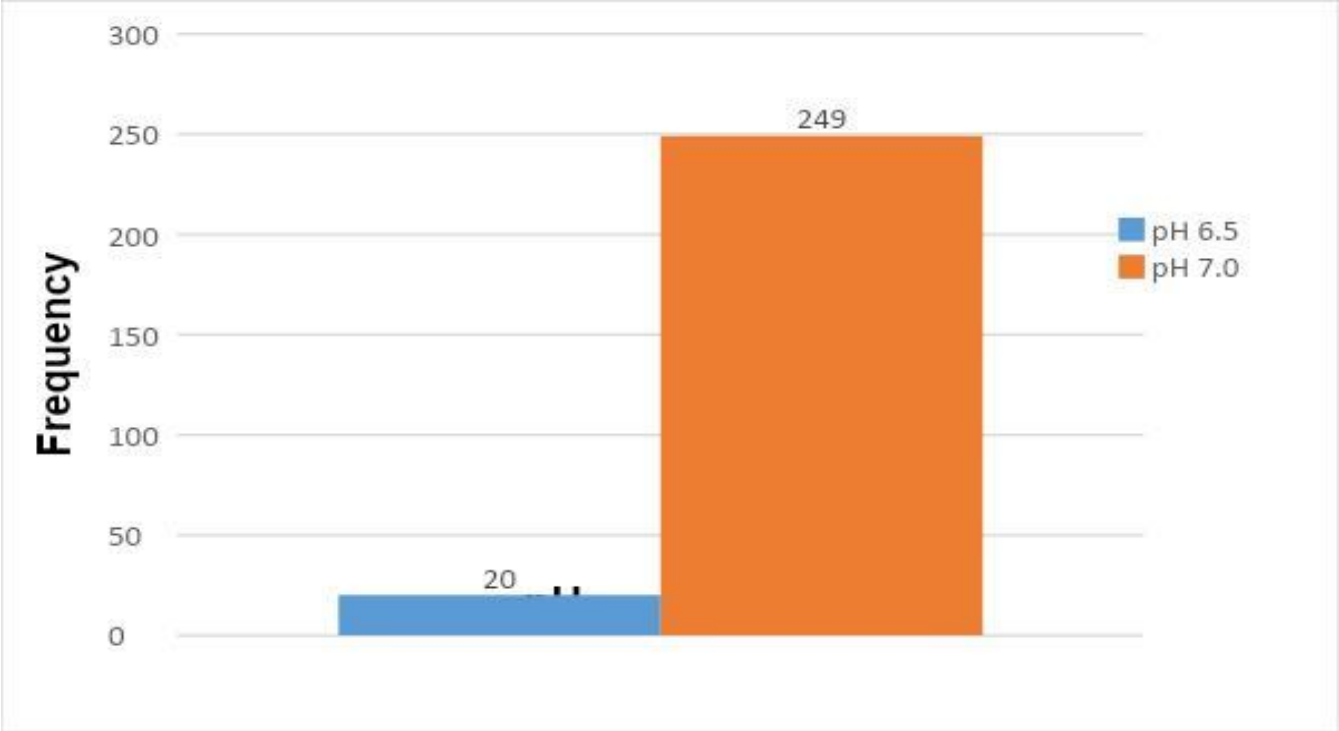
The pH of collected water samples

Table 4 shows that all the samples tested fell within the acceptable range with 249 samples testing 7.0 and 20 samples testing 6.5.

Table 4. PH range of collected water samples.

pH results	Frequency	Percent
≥ 5 to ≤ 9.7	269	100.0

Figure 5: The PH of collected water samples



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Microbiological testing for Total coliform & Escherichia coli

Table 5 shows the total coliform count on water, 5% of households had exposure to contaminated water and the results indicated that they have a coliform count exceeding 300 coliform per ml [27].

The Zero counts of *E. coli* detection in Table 5 indicated that there was no fecal contamination in drinking water. In this study population, these results indicated that the drinking water met the expected standards according to SANS 241:2015.

Table 5. The criteria and risk category of microbial water quality in this study

Households (n=269)	Total coliform count (CFU/ml)	*E. coli* count	SANS 241: 2015 Guidelines *E. coli* < 1, Total Coliforms ≤ 100 per mil
256	<1, ≤100	0	Low risk
1	300	0	High Risk
1	500	0	High Risk
1	600	0	High Risk
2	800	0	High Risk
2	1200	0	High Risk
1	1500	0	High Risk
1	1700	0	High Risk
1	1900	0	High Risk
1	3600	0	High Risk
1	4800	0	High Risk
1	5800	0	High Risk

The fundamental overview of results

The hypothesis of the study was that water gets contaminated from the point of collection to the point of storage exposing it to waterborne pathogens. This compromises the quality of domestic water and may lead to diseases. The results obtained in the study showed that the overall hygiene practices were of poor standard. The services provided by the Municipality seemed inadequate in ensuring the quality of water and sanitation infrastructure hence their debilitation exposes the community to the risk of infections. The exposure to infections is expressed in the 5% coliforms detected in water as a result of different factors noted in the results. This 5 % coliform detection has the potential of rising to an endemic infection as bacteria spread over some time if interventions are not put in place immediately. South Africa is a developing country with limited resources to deal with endemic diseases if it later rises to a larger scale of pandemic disease can become a health crisis which can raise hospitality mortalities to unacceptable levels. The biggest world health crisis as a result of poor water and sanitation infrastructure is diarrhea, which accounts for 4 million deaths annually, and about 2 million of these deaths are children below the age of five (Heibati et al. 2017)

DISCUSSION

This study aimed to evaluate the quality of stored water, hygiene practices, and the extent of contamination of water that is used for domestic purposes in the Umlazi P informal settlement. A comprehensive questionnaire was developed and administered to participants to give insight on water hygiene practices including the level of health awareness with regards to water contamination and disposal. This

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questionnaire also contained areas that provided insight into the evaluation of the quality of water and sanitation infrastructure and other methods of solid waste removal. This study unveiled challenges faced by the residents of the informal settlements at Umlazi P section with regards to quality water as well as other related practices affecting water quality

Knowledge of contamination, water storage, and hygiene practices

The prevalence of waterborne infections is commonly associated with drinking contaminated water giving rise to infections such as diarrhea, dysentery, typhoid fever, and cholera (Kurui *et al.* 2019). Even when water is from a reliable source, the quality may be jeopardized by poor handling and unhygienic storage practices.

In this study, most residents (88.1%) did not have any prior education on water storage and 76.6% indicated a lack of understanding of water contamination. Most of the residents (79.2%) indicated that they only had a high school level of education with no basic health education training. Furthermore, the study results indicated that half of the residents in the population were unemployed, making access to quality health

education and training unaffordable. Contamination is likely to be higher in poor households as they cannot afford to purchase products to safeguard their water from contamination 13

Water storage and hand hygiene

The data obtained from this study showed that there was an imminent exposure of water to contamination showing about 5% of the residents being at a risk of getting infections. The inadequate hand hygiene has a direct link to the spread of infections within a community potentially exposing stored water to contamination 22. Contamination may be progressive in families of low income with this study results already showing that 50% of residents are unemployed making it difficult for them to afford water treatment chemicals and soaps for cleaning.

Almost all respondents indicated that they stored their domestic water in buckets that were kept closed when not in use, and 83.3 % indicated that they cleaned the storage containers by washing them in cold water only. Soap must be applied when washing hands especially after defecation or before handling water storage and touching food 8. This study has shown that some of the residents only use tap water to clean their storage containers, whilst research has shown that the application of soap and the use of other chemical detergents can be effective in removing pathogens 19.

Solid waste removal and greywater

The generated waste influences the changes in soil, air, water, and microbial content of the environment which has a direct impact on human health 16. Research has shown a connection between environmental pollution and waterborne infections such as diarrhea, typhoid, cholera, hepatitis, and respiratory infections14. In this study population, 29.7% of the participants indicated that they have sewage water accumulating in their yards generated from laundry wash-off, bathing, cleaning, food material, and storm-water drainage, human and animal fecal matter. However, the eThekwini Municipality has been able to effectively remove generated solid waste with (94%) of the participants indicating that their waste is collected weekly. Notably (5.6%) use other means of waste disposal such as burning or disposing of waste in illegal dumping areas or vacant spaces close by or in the river which can expose them to infections. The waste material does release powerful toxins that prove to be dangerous to people especially if waste is not handled correctly 8.

Water and sanitation infrastructure

The water and sanitation infrastructure such as toilets, water distribution pipes, and sewage systems must be effective enough to deal with the amount of fecal waste generated by humans and animals 21.

This study has shown that residents use different types of toilets such as flushing toilets, ablution toilets, and pit latrines. The ablution toilets are a Municipal facility that provides communal toilets and showers which are used by the community. The cleanliness of the ablution facility is important because 22.3% of the study population confirmed to be using these facilities for washing, laundry, bathing as well as for their toilet needs.

This study showed that just about half of the study population is unemployed and 32% of them use pit latrines as toilets. The pit latrines in some instances may be used for the disposal of other waste materials such as diapers, condoms, pads, and tampons and over time the pathogen concentration becomes higher and waste takes longer to be degraded inside the pit 23. The high concentration of pathogens in the fecal sludge may include bacteria, parasites, and viruses, when transmitted via the oral route may cause severe diarrhea in humans 17. The current study showed that 9/13 positive samples for total coliform count were collected from households that use pit latrines as a waste removal system.

Laboratory investigation

Macroscopic appearance and Physical substances

The first step of the experimental work was to investigate the macroscopic appearance of water to see any presence

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of physical substances that could influence color, odor, or taste. The macroscopic examination showed just about 0.4% of water samples to have visible substances in them and 1.5% showing cloudiness. This could be due to the aging of water distribution pipes allowing physical substances such as mud, sand, and other organic material to enter the distribution system 23. However, a total of 100 % of residents reported the taste of drinking water testing to be acceptable.

The significance of pH measurement

As water distribution systems age with internal corrosion of pipes resultant corrosive products may be found dripping in communal taps 24. The pH measurement gives an idea as to the extent of dissolved substances present in water either making it too acidic or basic 24. In this study water samples were tested for pH to determine the extent of corrosive substances dissolved in drinking water. A total of 269 (100%) samples fell within an acceptable pH range of ≥ 5 to ≤ 9.7 according to SANS 241: 2015 drinking water standard.

The significance of the total Coliform count results

The water samples were tested for total coliform count which represents all organisms that may be present in the environment even those which are not of fecal origin 23. These bacteria may be introduced into the water system through contamination of the water source and the distribution system 4. The detection of coliforms in water exceeding 300CFU/ml when using a 3ml petrifilm indicates that water has been contaminated by microbial pathogens and is unsuitable for human consumption 22. The results from the present study showed a positive total coliform count of the samples collected from 13 households in the study population rendering their drinking water a high risk for domestic use. This finding is of concern, despite it only accounting for 5% of the study population since the tested water samples were collected from the municipal water supply.

The significance of E. coli water testing results

The water samples were tested for the presence of *E. coli* as an indicator of fecal contamination. This is the best indicator used worldwide as a standard method in testing drinking water quality22. *E. coli* represents the entire group of bacteria found in the feces of human beings and animals 16. *E. coli* strains such as *E.coli O157: H7* are known to produce harmful toxins that cause diarrhea 17. The present study results revealed that water quality met the South African standard for drinking water since the *E. coli* count of all the samples tested was < 1CFU/100ml.

CONCLUSION

The bacterial contamination of domestic water is a serious problem that accounts for many health concerns globally. Water is essential for human life, therefore it must be delivered at a quality that is fit for human consumption. Access to adequate quantities of water is critical to maintain cleanliness and household hygiene. Due to the distance between households and communal taps, some residents in this study employ a method of storing water for domestic use. This study aimed to evaluate the quality of water stored for the domestic needs of residents in Umlazi P informal settlements.

The data collected from the study highlighted significant challenges with hygienic storage practices and infrastructure. These challenges are augmented by unemployment, poverty, education levels, financial resources, population growth, and poor housing structure. In conclusion, a combined collaborative effort between the community and all stakeholders such as the Department of Works, Department of Health, Department of Water and Sanitation, and the Department of Human Settlements is critical in addressing problems of safe drinking water. At the center of these efforts infrastructure development and health education programs should be implemented in an emergency. This will go a long way in assisting the Umlazi P section community to improve their health and living conditions. After this study was conducted, KwaZulu-Natal was affected by severe flooding in 2022, which has also affected the quality of tap water and related infrastructure in the province, many of the recommendations mentioned for this would possibly play a more significant role in light of this as well.

LIMITATIONS

The study was a cross-sectional study, samples that were collected were only tested once, the study results might have been strengthened if several samples were collected from the same households to evaluate the quality of water about the length of storage. There should be more follow-up tests on water samples to close the gaps and make a more comprehensive report on possible microbial contaminants other than *E.coli.*Some houses were leased to occupants; this was a limitation to some of the information required as per the questionnaire. The consenting age for the present study was 18 years and above, households headed by those under the age of 18 were therefore excluded from the study. The houses that had no registered house numbers for records and follow-up were excluded. During the study design, the researcher wished to collect water samples from the municipal taps, however, this was prohibited by the Municipality since they indicated that all tapped water is tested already. The consultation was made with the eThekwini Municipal Institute of Learning where engagements made did not result in the approval of testing

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piped water. This is viewed as a limitation since it was not possible to determine if there was a difference between the water from the municipal taps and water in stored containers.

RECOMMENDATIONS

The eThekwini Municipality has provided water and sanitation infrastructure for the delivery of safe water and removal of solid waste, however, some of the informal settlement residents at the Umlazi P Section still cannot access proper and effective water and sanitation services. The challenges of safe water delivery arise when residents illegally connect water pipes to a communal standpipe to receive water at their homes. These improper connections sometimes leave distribution systems at risk of contamination, particularly at the main distribution point. The improvement of infrastructure becomes vital in protecting water distribution points to curb the spread of infections.

Recommendation on basic health education

It is recommended that educational programs that will address a lack of health knowledge about water storage practices and hygiene are developed and implemented in communities in which access to water and sanitation is strained. This may be conducted by creating group classes for the community, developing posters, and periodically doing home visits.

Infrastructure development and maintenance

As shown through this study South Africa still lacks basic infrastructure to supply adequate quantities of water and sanitation to all citizens. Due to the limited number of communal taps, crowding around taps becomes unavoidable leaving taps unhygienic and dirty. The provision of quality infrastructure will go a long way in improving the health conditions of informal settlement dwellers. The infrastructure should include piped water and sanitation facilities for each household. A program of maintenance must be in place to monitor its functionality.

Removal of solid waste

All informal settlement residents must be integrated into Municipal services for the removal of solid waste to avoid certain sections of residents having to employ unsafe methods of waste disposal. Residents should also be encouraged to avoid dumping waste in rivers and non-designated areas, to minimize the adverse effects of environmental pollution.

Low-cost Storage and Treatment

It is recommended that SABS-approved water storage containers and water treatment chemicals be made available at a low cost that can be affordable to the communities to ensure improved water quality and storage.

Legislation and Infrastructure

The Municipality needs to establish stringent laws and monitoring programs that protect water and sanitation infrastructure from any form of vandalism that puts end users at health risk.

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LIST OF ABBREVIATIONS

°C:	The degree Celsius
DOH:	Department of Health
DUT:	Durban University of Technology
DWS:	Department of Water and Sanitation
***E. coli*:**	*Escherichia coli*
EHEC:	*Enterohemorrhagic E. coli*
ETEC:	*Enterotoxigenic E. coli*
ETKM:	EThekwini Municipality
GR:	Groundwater
mg/l:	Milligrams per litre
MUT:	Mangosuthu University of Technology
NHLS:	National Health Laboratory services
pH:	Measure of how acidic/basic water is
SANS:	South African National Standards
WS:	Wastewater
WHO:	World Health Organisation

Research project Funding: The success of the study research depended on the availability of finances to purchase all required material for experiments, printing, test kits, traveling, and also participating in academic activities such as presenting on research days in Institutions of Higher learning. The research project was registered to obtain a Master's degree in Health Science (Laboratory Science) at Durban University of Technology.

SOURCES OF FUNDING

- Mangosuthu University of Technology
- Durban University of Technology

CONFLICT OF INTEREST

There was no conflict of interest.

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