NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

ASSESSMENT AND PERCEPTION OF WATER QUALITY ON THE HEALTH OF GRÜNAU AND BETHANIE RESIDENTS, NAMIBIA

By

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Thesis submitted in fulfilment of the requirement for the Award of a degree in Master of Health Sciences

In the Department of Health Sciences

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At Namibia University of Science and Technology

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JUNE 2021

ABSTRACT

Water quality is an important aspect of water provision services to ensure the water does not possess any possible threat to its consumers. Water quality perception surveys are ideal tools when exploring the feelings, opinions and attitudes people have towards their water. This includes the human-water interactions involved as well as behaviour and consumption practices they have with their water. The purpose of this study was to investigate the perception of consumers towards their water and determine the water quality and its effect on human health – a case of Grünau and Bethanie residents. This was an observational study, where questionnaires were administered, and water quality tests were carried out to determine the physical, chemical and biological contaminants of public water supply in Grünau and Bethanie settlements. The study sample consists of 384 participants selected using the convenience sampling method. Data from the questionnaire were recorded and analysed using Statistical Package for the Social Sciences (SPSS) version 21 as well as the descriptive analysis. Ethical clearance was sought from The Namibia University of Science and Technology, the Ministry of Health and Social Services as well as the respective village councils. Confidentiality and anonymity of the respondents were maintained during the study. The study revealed that consumer perception of the quality of public water supply in the study area is based mainly on organoleptic features, such as taste, colour and turbidity. In addition, the study found that 64.6% of the participants in the study area were strongly dissatisfied or somewhat dissatisfied with the taste of their water while 52.1% were strongly dissatisfied or somewhat dissatisfied with the colour. The smell of the water did not seem to affect the respondents as only 2.3% of the participants were strongly dissatisfied or somewhat dissatisfied with the smell of the water. The study further revealed that 59.9% of the participants perceived their water to be highly unsafe or somewhat unsafe. The water quality laboratory analysis revealed that the water contains several minerals such as magnesium, calcium, and fluoride in large quantities, which correlate to the “unpleasant” taste of the water as described by the community. The study recommends a more thorough treatment process by NamWater to remove excess minerals (magnesium and calcium) that are responsible for the hardness and lime taste of the water.

DECLARATION

I, Benisia Nambundunga, hereby declare that the work contained in this thesis, entitled Assessment and perception of water quality on the health of Grünau and Bethanie residents, Namibia, 2021, is my own original work and that I have not previously, in its entirety or in part, submitted it at any university or other higher education institution for the award of a degree.

Signature: Date: 11/06/2021

Retention and use of thesis

I, Benisia Nambundunga, being a candidate for the degree of Master of Health Sciences of the Department of Health Sciences, accept the requirements of the Namibia University of Science and Technology relating to the retention and use of theses deposited in the library and information services.

In terms of these conditions, I agree that the original of my thesis deposited in the library and information services will be accessible for purposes of the study in accordance with the normal conditions established by the librarian for the care, loan or reproduction of theses.

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Supervisor: Date: 11/06/2021

ACKNOWLEDGEMENTS

I wish to thank God Almighty for the strength and guidance on this journey. I also wish to thank my supervisors, Dr Sylvanus Ameh Onjefu and Prof Nnenesi Kgabi, for their supervision, support and positive criticism. I further wish to thank Tuhafeni Shipanga and Ndaindila Haindongo for their assistance, support and effort they have put in this research.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter introduces the entire research by providing the background of the study and outlining the factors that prompted the study. The problems/gaps that were identified and subsequently led the researcher to carry out this research was also discussed. This chapter also outline the research aim and specific objectives as well as the research questions. The chapter further discussed the significant role that the research plays and the importance of carrying out this study. Ethical considerations and study limitations that the researcher have encountered throughout the study were also outlined in this chapter.

1.2 Background of the study

Water is a vital resource for everyday life activities. The sustainability of social wellbeing and economic development will become challenging without clean and reliable water supply. Water is generally regarded as a valuable resource due to its scarcity. In Namibia, water accessibility has been a burning issue for several years. Namibia is regarded as an arid country and relies heavily on groundwater and the predicted increase in both temperature and rainfall variability due to climate change will increase this reliance.

According to Crovello, Davidson & Keller (2010), Namibia only receives about 360 millimetres of rainfall annually. Of this rainfall, 83% evaporates, 14% is used by vegetation and 1% recharges groundwater, leaving only 2% (7.2 mm) for useable surface runoff. Furthermore, evapotranspiration can often exceed rainfall, leading to a depletion of groundwater (Frenken, 2005 as cited in Crovello et al., 2010). The inland of the country only receives surface water in summer when there is high rainfall. However, those living in remote arid areas depend on groundwater for their everyday needs.

Over the past century, more than 100 000 boreholes have been drilled in Namibia, and half of these are still in operation and produce groundwater for industrial, municipal and rural water supply (Christelis & Struckmeier, 2011). The boreholes provide drinking water to humans, livestock and game, irrigation water for crop production and supply distant mines. “A borehole is a hydraulic structure that permits the abstraction of water from an underground water bearing formation” (Christelis & Struckmeier, 2011). Small towns in southern Namibia such as, Maltahöhe, Aroab Kalkrand, Berseba Bethanie and Gibeon, mainly depend on groundwater (Christelis & Struckmeier, 2011).

Groundwater sources occur almost everywhere, hence relatively more dependable, and naturally less susceptible to evaporation (Alley, 2009). Ground water also tends to be less polluted, compared to surface water (Beckie, 2013). However, pollution can occur when contaminants are discharged, deposited on or leached from the land surface above the ground water as a result of anthropogenic activities, such as chemical leachate from landfills, septic systems, industrial and agricultural activities (Beckie, 2013).

Groundwater may also be associated with a high concentration of natural minerals/elements. Water, being such an excellent solvent, is inevitably enriched in foreign substances or dissolved minerals, as the water moves through the hydrological cycle. Total Dissolved Solids (TDS) is the criterion used to measure all the dissolved substances, which is normally the first order indication of the water quality (WHO, 2003). Most of the dissolved minerals are harmless, while others are beneficial, provided they occur in the acceptable levels. It is these minerals that give ground water its tangy taste enjoyed by many people. The most common dissolved mineral substances are sodium, calcium, magnesium, potassium, chloride, bicarbonate and sulfate Oram (2020).

Brindha and Elango (2011) explain that when groundwater contains chemical composition above the maximum permissible levels, it becomes unfit for human consumption. Heavy metals, radio nuclides and minerals such as Boron, Fluoride, Arsenic, Iron, Nitrate and Manganese are some of the most common contaminants that pose a threat when present in amounts above maximum permissible levels (Brindha & Elango, 2011). According to the World Health Organisation (2012), ingestion of water with excess Fluoride, for example, can cause fluorosis, which affects the teeth and bones. Groundwater in the Kalahari, along the banks of the Orange River, often shows poor quality due to its Iron and Manganese content, which exceeds the limits for drinking water (Christelis & Struckmeier, 2011). Groundwater around the study area (Grünau and Bethanie) is currently classified in group B-C of the Namibian drinking water quality standards, which is regarded as acceptable but not the best quality (Adaptation Fund, 2014). It is also known that there is an increasing salinity and fluoride concentration in the water, which makes the ground water non-potable. Residents in these areas generally complain about their water quality and are unsure about its safety for human consumption (Christelis & Struckmeier, 2011).

1.3 Problem statement

Water quality in rural areas remains a problem despite the increase in water supply over the years (Christelis & Struckmeier, 2011). Although piped water is generally regarded as safe, it may still be associated with a risk of contamination – for example, chemical contamination as a result of water pipe's corrosion and leakage and microbial contamination, which may result in diarrhoeal disease. According to the Ministry of Health and Social Services (MoHSS) (2014), diarrhoeal remains the leading cause of child morbidity in Namibia. It is seen more in rural areas and parts of the country where water and sanitation are a problem. The table below illustrates the top 10 causes of death in Namibia, with diarrheal diseases indicated as 5th cause of death.

Table 1.1: Top 10 causes of death in Namibia (MoHSS, 2014)

Top 10 causes of death in Namibia	
1. HIV	6. Tuberculosis
2. Cancer	7. Ischemic Heart Disease
3. Stroke	8. Diabetes
4. Lower Respiratory Infections	9. Interpersonal Violence
5. Diarrheal Diseases	20. Malaria

Water supplied to the public is normally treated to ensure it meets the drinking water quality standards. However, consumers may not always be satisfied with the water due to reasons such as the process used for water treatment, the physical state of the water or the effect that such water presents after consumption. Consumers, therefore, become doubtful about the water, subsequently affecting the usage of such water. It is against this background that there has been a growing focus on consumers' satisfaction with tap water and an increasing effort to supply drinking water that has the trust of consumers (Miguel de França, 2009). Physicochemical parameters: total dissolved solids, hardness, pH, non-toxic compounds, such as sulphate, manganese, iron and phosphate ions do not necessarily pose any health concern when present in water within the recommended levels. However, they may pose a health risk when in excess. These parameters also determine the organoleptic and aesthetic quality of water, which affects the acceptability of the water by the consumers (de Franca Doria, 2010). The World Health Organisation (2017), therefore, recommends that it is wise to be aware of consumer perceptions and to consider both health related guideline values and aesthetic criteria when assessing drinking-water supplies and developing regulations and standards.

People living in impoverished communities in southern Namibia face more challenges – not only due to lack of water but also with poor quality water. It is, therefore, pertinent to understand the residents' sources, perception, and uses of water in their areas to solve these challenges.

Research has documented many problems that occur because of poor water quality such as aesthetics and gastrointestinal illnesses. Examples of aesthetic problems are terrible taste and odour, scaling of taps and kitchen utensils. These factors influence perceptions of risk and quality (Jaravani, Massey, Judd, Allan & Allan, 2016). Risk perception and drinking water quality satisfaction are therefore closely related (Yasar, Khan, Batool, Tabinda, Mehmood & Iqbal, 2011).

Jaravani et al., (2016) also state that the negative perception of the safety of drinking water affects the development and improvement of water management programs and the ability of water provision utilities to effectively communicate with the public about risks associated with their water. For instance, poverty, negative perception, and insecurity of drinking water causes consumers to divert to expensive sugary beverages and bottled water, which can exacerbate diseases such as obesity and diabetes in communities (Jaravani et al., 2016). In other words, awareness on communities' social connection to drinking water, their perception regarding water quality as well as their level of satisfaction with the water can determine people's behaviour and choices. Furthermore, poor perception of water quality can prevent people from pre-treating their water prior to drinking, which may strike serious health implications (Cairncross & Valdmanis, 2016). Therefore, the perception on water quality plays an important role in determining the preventive measures against different water borne diseases. Public perceptions may not always be enough to draw conclusions of the actual water quality. With this in mind, public perception investigations can be done parallel to actual water quality evaluation.

De Franca (2009) advises that a better understanding of the factors that influence public perceptions plays a vital role in the management and improvement of water resources, the acceptability of water recycling and risk communication as well as the surveillance of drinking water quality. These considerations encouraged the main objective of this study. This study is based on the assessment of the perceptions towards water quality in Grünau and Bethanie. These villages have for long been supplied with groundwater extracted from local boreholes, which is thought to be of poor quality (Smit, 2017). The water in Grünau and Bethanie is believed to be responsible for several health problems such as gastrointestinal illnesses for people living in this area. The water is also believed to leave a brownish stain on the consumers' teeth (Smit, 2017). In order to understand the decisions individuals, make regarding their water in Grünau and Bethanie villages, the study was done to determine residents' perception on the quality of their drinking water as well as its impact on consumers.

1.4 Significance of the study

The evaluation of the health impact of water on consumers is of vital importance to identify any present or potential water contamination and guard public health. Similarly, the assessment of consumers' perceptions towards drinking water and their acceptance play an important part in the drinking water provision systems. It is vital to consider the public perception of water quality to foresee problems related to drinking water supply and become proactive in attending to these challenges.

This study unearthed water quality information to consumers and suppliers, which will be relevant to making informed decisions regarding water consumption and provision, especially in the study area. The purpose of this study is therefore, to determine the public's drinking water quality perception and determine the quality of water and its impact on Grünau and Bethanie residents. The study will contribute to the development and implementation of effective interventions directed towards people's interactions with their water and to meet their water-related needs. Furthermore, the study will increase people's knowledge of health risks associated with poor quality water. An important database will be created for future studies to be carried out in this setting.

1.5 Research objectives

The main aim of the study is to determine the perception of consumers towards the water and assess the water quality and its impact on Grünau and Bethanie residents.

Specific objectives

1. To determine the perception of Grünau and Bethanie residents towards the quality of public water supplies in the areas.
2. To assess the quality of public water supplies in Grünau and Bethanie villages.
3. To survey the health effects of public water supplies among Grünau and Bethanie residents.

Research questions

1. What are the public opinions, behaviour, and attitudes towards water quality in Grünau and Bethanie?
2. What are the physical, chemical, and microbiological characteristics of the water in Grünau and Bethanie?
3. What water quality-related problems do/have the Grünau and Bethanie residents experience(d)?

1.6 Ethical considerations

Ethical clearance to carry out this study was sought from the Ministry of Health and Social Services (MoHSS) as well as the Namibia University of Science and Technology prior to the commencement of the study. The research also sought consent from community leaders (Bethanie and Grünau village councils). In addition, consent was obtained from participants (by signing a consent form) after the researcher explained the objectives and benefits of the study. Participants in the study were not requested to disclose their names to adhere to the purpose of confidentiality. Participants also understood that participation in the study is voluntary, and they could withdraw any time from the study without any penalty. In the same vein, due to their vulnerability, the study excluded children under the age of eighteen (18).

1.7 Limitations

Language barrier between the researcher and the participants proved to be a limitation in this study, as most of the residents are predominantly Khoekhoegowab language speakers, and most do not understand the official language, English. An interpreter's services were, therefore, sought to facilitate communication. In addition, the Covid-19 pandemic proved a challenge during data collection due to the movement restriction that was imposed, extending the data collection process.

1.8 Summary

This chapter provided the background of the study. It also discussed the problem statement in detail. In addition, the research aims which give a broad overview of what the study hoped to achieve and the specific objectives that informed the main goal were also outlined. This chapter further described the significance of the study as well as the limitations that the researcher encountered during the cause of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter focused on the review of similar literatures, which helped in shaping the study. It also states the current data and information related to the study.

2.2 Water quality health problems

Water quality problems are among the top issues facing developing countries. Water quality assurance is important to protect human health and sustain life. Research has shown that water quality is a global concern and problems related to water are usually similar throughout the world. Water quality problems have been studied from a number of perspectives, such as the sustainability of water use, the association between environmental and water conservation attitudes and domestic water end use. Some scholars focused on the impact human activities have on ground water and perceptions in relation to home water treatment uptake such as household filtration, boiling or chlorination. Other studies focused on the association between how communities perceive their drinking water and the measured drinking water quality and gastrointestinal diseases. Furthermore, other researchers focused on the opportunities and threats to the availability of good quality water and the health risks it may pose to humans.

There are different types of water-borne bacterial pathogens, such as Vibrio, Campylobacter, Escherichia coli O157, Salmonella and Shigella. They are generally classified as enterobacteria, a group of contaminants, which results from poor hygienic practices (Jack & Read, 2008). Faecal coliform, a sub-set of this family, and their presence is usually taken as an indication of faecal contamination and the possible presence of enteric pathogens (Jack & Read, 2008). Most of these pathogens are responsible for the gastrointestinal illnesses that occur from drinking contaminated water. The WHO (2017) states that the detection of these pathogens act as a sign of pollution. For example, diarrhoeal may occur because of toxigenic Vibrio Cholera in water. When it is left untreated, the fatality rate becomes high (WHO, 2017). Large waterborne outbreaks caused by Vibrio Cholerae still occur to date.

According to Jack & Read (2008) E. coli O157 and other enterohaemorrhagic strains of E. coli occur quite frequently, with are severe symptoms which include haemolytic uraemic syndrome and even death. It is also more dangerous as the infective dose is very low (fewer than 100 organisms) (Jack & Read, 2008). Shigella bacteria is responsible for over 2 million infections every year worldwide, as well as 60 000 deaths, which are mostly in developing countries (WHO, 2017). WHO (2017) further states that non-typhoidal Salmonella seldom causes water-borne outbreaks, but it is still responsible for many outbreaks of waterborne typhoid.

2.3 Perception of drinking water quality

Human–water interaction involves the perceptions and beliefs that individuals have about water, as well as the specific behavioural and consumption practices they engage in in relation to available water resources (Coetzee, Nell & Bezuidenhout, 2016). Data collected from consumers through different studies are used to evaluate drinking water risks associated with water. Studies conducted to describe perceptions on water and water supplies have shown that the perception of the safety of drinking water is commonly related to water taste, smell, and turbidity (Harris, 2015).

Harris (2015) for example carried out a study in Thailand to understand the public's perceptions of drinking water quality at the village level in rural Thailand (Thakhonyang, Nong Khon and Don Man villages). The study revealed that half of the participants in all three villages either perceived their primary source as unsafe or expressed a level of uncertainty regarding the safety of their primary source in any given season. It was also shown in the study that 98% of households that have piped water connections do not drink from their piped connections in both Thakhonyang and Nong Khon. Only one household, which was in Nong Khon, indicated that they drink from their piped connection; however, the water is filtered through a water filter and then strained through a cloth prior to consuming. This additional line of defence is indicative of the consumer's perception of their drinking water as unsafe due to its colour, taste and odour, despite the fact that it is piped water (Harris, 2015).

A similar study assessed public knowledge about the safety of their drinking water and awareness of water contamination events in rural areas of China with two rural counties of Hainan Province chosen as experimental locations for investigation (Wang, Zhang, Lv, Zhang and Ye, 2018). In this study, Wang et al., (2018) explored the degree of public satisfaction with drinking water quality, the public trust of drinking water safety, as well as public awareness about drinking water problems and solutions. The results of this study showed that only 20.5% of participants agreed they were very satisfied with the quality of their drinking water, 59.8% were relatively satisfied and 78.8% of the participants were comparatively more attentive to the drinking water quality and contamination events. The study further noted that 52.4% of the respondents solve drinking water problems on their own, without the assistance of external institutions. Moreover, the study found that respondents who are more informed about their water quality are more assertive in their drinking and more supportive towards water sources protection and water pollution prevention.

In Latin America, Colombia (Medellín rural area), a study assessed the perception and health risks associated with water quality. In this study, Rojas & Fernanda (2013) concluded that the main factors influencing peoples' water quality perception are its colour and appearance, which form a sort of quality standard used to evaluate the water quality – even that of raw water (Rojas & Fernanda, 2013). The study further revealed that a small group of consumers have a perception that there is an association between water pollution and waterborne illnesses.

In a more recent study, a qualitative evaluation of water safety at household level was undertaken in Lesotho, Maseru district. Workman (2019) interviewed participants from the Maseru District to address how people decided if their water was safe, their understanding of the linkage between water and enteric illness, and health-seeking behaviour. Like some of the above-mentioned studies, respondents mainly determined the cleanliness and safety of their water by visual inspections, although not all respondents linked the consumption of unclean water to diarrheal diseases experienced. Moreover, despite stating that their water was not clean/safe, more than 50% of the respondents did not boil their water (Workman, 2019). These findings indicate that people can have information essential to ensure water safety – but for a variety of reasons, such as financial difficulties or habits, people do not implement any interventions (in this case, boiling).

Orgill, Shaheed, Brown and Jeuland (2013) tested the hypothesis that households' willingness to pay for improved water quality depends on individual perceptions of the safety and acceptability (e.g., with regards to the taste and appearance) of existing drinking water sources in Cambodia. Orgill et al., (2013) revealed that respondents' willingness to pay for improved water quality is affected by their beliefs regarding the present water quality, while their water quality perception is associated with taste. However, the measured water quality is unrelated to the water quality perception. Their findings concluded that any interventions that are aimed at improving water treatment should take into consideration the perception regarding water quality.

In Tanzania, Sherry (2017) examined the perception of water services and introduction of innovative ways like the use of solar power and mobile prepayment systems to improve water services at individual and community levels in rural and urban Tanzania. The study targeted the usage of ICT in the Water, Sanitation and Hygiene (WASH) sector, such as "using mobile phones to crowd-source data about a water point, mapping water points, disseminating water service information to relevant stakeholders, water quality monitoring and smart water metering" (Sherry, 2017). The study indicated that perceptions differed between urban and rural areas – and many participants indicated serious challenges with the current water system. The perceived challenges included water-related health problems, poor reputation of the water utility provider and the continuous provision of poor water quality (Sherry, 2017). Generally, rural community members believe solar energy will decrease the cost of acquiring water and will also increase water service delivery, while those in urban areas were not familiar with solar power technology. Sherry (2017) further explains that the respondents understood that the mobile prepayment can be a solution to water provision service challenges; however, cost may still be a challenge to the poor. It is, therefore, critical to assess the level of acceptability as well as affordability of modern systems prior to its implementation, as this may be a barrier. Sherry (2017) further revealed that the combination of beliefs, attitudes and perceptions towards water services plays a role in the acceptance and long-term sustainability of water services. Sherry (2017) therefore, concluded that as resources are capitalised in the improvement of water services, it is equally important to consider the acceptability and effectiveness of these innovations prior to their implementation.

In South Africa, a study was undertaken to explore trends in perceived drinking water safety and its association with disease outbreaks, water supply and household characteristics. Wright et al. (2012)

revealed that perceived drinking water has remained relatively stable over the past years, despite there being a Cholera outbreak at the commencement of the study.

2.4 Water quality perception vs actual water quality

Generally, consumers make individual judgements on water quality, based on taste, colour and smell, which are highly subjective parameters. However, data has shown that consumer perceptions of water quality do not always correlate with measured microbial water quality. It is, therefore, significant to conduct comparative studies. Wedgworth, Brown, Johnson, Olson, Elliott, Forehand and Stauber (2014) conducted such a study to determine the association between consumer perception (through interviews) and measured water quality data. The objective of their study was to determine whether consumer perception correlates with the independently measured water quality data; the study was conducted across 910 households in three counties. The study discovered that aesthetic conditions, which were reported to habitually occur, had no statistically considerable association with any water quality parameters. For instance, there was no difference in the measures of total and free chlorine as well as turbidity for consumers who reported experiencing taste problems at least once a month and those who never experience taste problems.

2.5 Method of water treatment

Prior to distribution into the communities, water is treated by NamWater to ensure its safety. The water undergoes a variety of treatment processes such as sand filtration, chlorination, etc. Despite these efforts, water may still become contaminated throughout the distribution system, posing a health risk at the consumer level, hence the need for home water treatment interventions. In some areas, mostly rural areas, people rely on natural sources of water, which may be more prone to contamination, also prompting the need for treatment at the household level.

Household water treatment is a very common exercise throughout the world, which is mainly practiced when consumers perceive their water as unsafe or simply to make it more palatable. There are various methods of home water treatment methods such as boiling, chlorination and filtration. These methods are practised to improve the water quality for its consumers. Studies have shown that consumers who have a certain level of knowledge about water quality and its effects mainly practise these treatment methods. However, consumers who have very little or no knowledge about water quality are usually not concerned about the safety of the water. In addition to home water treatment, other alternatives to unsafe water consumption have been identified, such as consuming bottled water. However, bottled water is not affordable by consumers who are mostly affected by water quality problems, as most are already faced with other socio-economic challenges; therefore, the options for bottled water become more limited in these populations. For example, in Alabama, Wedgworth (2014) reveals that the only alternative drinking water sources are private wells and bottled water. However, it is costly to dig and maintain the wells. In addition, it is suspected that the wells in the region face a threat of contamination from nearby septic systems due to the nature of the ground and geological conditions.

Home water treatment methods may vary depending on the characteristic of the water, the people as well as the availability of resources. In his study, Workman (2019) discovered that people in Bohare and Mosela (Lesotho) had a habit of not boiling their water, even though they reported getting sick from the water and not necessarily because of lack of resources. "When people have to wait a day or two to draw water, when they do get it, boiling it is the last thing on their minds" Workman (2019).

In his study, Khalid (2018) indicates that home water treatment was widely practised, and that there was a correlation between gender and the use of water treatment (such as chlorination and boiling filtration). This is evident in the study by Khalid et al., (2018) in which the data showed most of the males (37.5%) use water without treating it, while females (23.6%) treat their water before use. Other parameters, such as age, family type, employment, education, and marital status did not have any association with the type of home water treatment used.

2.6 Data collection methodologies

Different types of methodologies (quantitative and qualitative), such as water quality tests, questionnaire and focus group discussions (FGDs) are used to collect data for different studies of interest. These instruments are necessary to deduce different types of information. Questionnaire and FGDs are mostly used to derive qualitative data, such as consumers' perceptions and get people's views and opinions on water provision, quality, and possible solutions. Data has also been collected through water quality tests to determine the safety.

2.6.1 Questionnaire

A survey can be conducted by the use of questionnaire administration, which consist of the following sections: water quality perceptions, aesthetics, self-reported enteric illnesses, availability and accessibility of sanitation facilities and socio-economic status (Wedgworth et al., 2014). For example, a state-wide survey was undertaken to evaluate the perception and attitude of Texans' residents towards the water resources within the state. The survey questionnaire was made up of 59 questions that targeted water resource, water quality and other environmental issues. The questionnaire consisted of the following sections: demographic information, water quality, likelihood of enough water to meet area needs, likelihood of prolonged drought, behaviour changes protecting water quality or water quantity and rainfall change because of global warming (Gholson, 2017). This study used the simple random sampling, where 1 275 randomly questionnaires were administered in Texas (Gholson, 2017).

On the other hand, convenience sampling was used in a Lesotho study, where a sample size of 25 households was used in each of the selected communities. In this study, a structured interview was conducted by going from household to household to administer the questionnaires (Workman, 2019). Focus was more directed to the female head of the household as opposed to the male, since women are more in control of attaining water and water-related activities in general, though the men were not exactly excluded. The interviews were conducted in the local language (Sesotho) by a research assistant and the responses were translated into English. The survey questions addressed the residents' experience in connection with water insecurity (water sources and shortages), common illnesses at household level and community level. Questions also focused on the association between enteric illnesses and the implementation of mitigation measures of the effects of unsafe water, such as boiling (Workman, 2019).

In Tanzania, Sherry (2017) used Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) to explore the community's perceptions of water services in three urban and three rural communities, focusing mainly on the perception towards modernisation methods to improve water services, such as the use of solar energy and prepayment methods.

2.6.2 Water sampling

Water sampling is a vital exercise to determine the actual water quality and possible threats it may pose to consumers. It is equally important for water sampling to be taken at different points of the water distribution system for a fair representation as well as to better identify the source of any contamination. Physical, chemical, and microbiological parameters are essential in determining water quality. In Alabama, Wedgworth et al. (2014) carried out microbial water analysis, whereby water samples were collected at the kitchen faucet (to determine water quality data at point of use level) and at the outside faucet (to determine water quality data at point of delivery). At both sampling points, 100 ml water samples were collected in sterile 120 ml containers with sodium thiosulfate. Any object that did not form part of the faucet, such as aerator, hose or strainer but was attached to it at the time of sampling was removed prior to sampling. The outside faucet was heat sterilised before turning on the tap to kill any microbes present, which would affect the water samples.

2.7 Linking enteric illness to unclean water

Retrospective data about the water-borne diseases is used to determine the link between these illnesses and contaminated water. All enteric diseases enter the body through the mouth, usually through contaminated water, food, or hands. Diarrheal diseases, caused by rotavirus, Shigella, Enterotoxigenic Escherichia coli (E. coli) and other pathogens are the most common enteric diseases (WHO, 2017).

In a study carried out in Lesotho, respondents were asked what the most common illness was in their area and most responded that cholera, which they also refer to as 'stomach complaints', was the most common illness (Workman, 2019). They indicated that the symptoms commonly experienced include diarrhoea, nausea and nyoko, "an indigestion associated with not eating a wide enough variety of food" (Workman, 2019, p. 7). The researcher sought to find out what happens when participants drink unclean

water; 28% of the respondents indicated that they get stomach-related illnesses such as diarrhoea, nausea or vomiting, while 64% responded they do not get affected in any way (Workman, 2019).
In a similar study, conducted in Vehari, Mailsi, the Burewala of district Vehari and other health centres in Pakistan, it found that people who were not satisfied with their drinking water quality reported more disease development (45.8%), compared to those who were satisfied (11.1%) with their drinking water quality (Khalid, Murtaza, Shaheen, Ahmad, Ullah, Abbas, Rehman, Ashraf, Khalid, Abbas & Imran, 2018).

The above-mentioned studies indicate that perceptions of water quality and risk are mainly attributed to factors such as water taste, odour, colour, and water treatment processes. These studies revealed that public sentience of drinking water safety and water accidents and pollution can be determined through water quality perception and service satisfaction studies. Understanding the factors that affect public awareness of drinking water can improve the management of water and service provision as well as the prevention and control of water pollution accidents. The continuous observation of drinking water quality and education of communities on their drinking water could affect public awareness regarding the safety of their drinking water and water contamination events.

2.8 Summary

This chapter reviewed and summarised the literature relevant to this study. It investigated the current data and information related to the study topic. The chapter further highlighted the knowledge and findings of other studies related to what has been done and what is emerging with regards to the study.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter focused on the methodology, processes, and procedures the researcher used to collect, analyse and present data. In this chapter, the design and

study setting of the research were also discussed. Details on how the sample size was determined was also provided. The researcher also describes how participants were selected and the criteria used for exclusion. The chapter further provides information on the instruments used for data collection as well as the method used for data analysis.

3.2 Study design

This study used the mixed methods research approach to gather data on the research objectives. The perception of the participants was qualitatively determined through questionnaire, while the water quality was quantitatively determined using laboratory analysis and compared to the health regulatory limits to make informed decision about the quality of the public water supply in the study area.

3.3 Study setting

Grünau and Bethanie are small villages in the southern part of Namibia, in //Karas region, with limited facilities of transportation, education, health and employment. These villages where the study was undertaken can be classified as isolated, and poverty-stricken as most members of the community rely mainly on groundwater, which makes them more susceptible to water-related problems. Namibia Water Cooperation (NamWater) is an entity that supplies water in bulk to both Grünau and Bethanie. Reticulated water is supplied to individual households in the formal areas while the informal areas have communal standpipes (Smit, 2018). Most people depend on small stock farming and tourism for income. Grünau and Bethanie are very dry villages, with the annual average rainfall ranging between 100-150 mm (Namibia Statistics Agency, 2019). The land is extremely dry and infertile, with little vegetation, such as dwarf shrubs and a few trees in riverbeds.

Bethanie is situated at the site of a spring in an arid region; the region edges into extreme arid Namib Desert on the west. It is one of the oldest settlements in Namibia and lies west of Keetmanshoop. It lies at an elevation of 1 150 metres (The Cardboard Box, 2019). This historic little town lies in dry and barren rocky lands. Bethanie can be easily reached from the main road between Luderitz and Keetmanshoop. Grünau on the other hand, is a settlement situated in the //Karas region in southern Namibia, west of the town of Karasburg. It is connected to the South African border post close to Noordoewer. Smit (2017) states that the water in Bethanie and Grünau is believed to be of poor quality and responsible for several health problems for people living in these areas; the health issues include headaches, teeth discoloration and gastrointestinal illnesses. The villages are supplied with water from two boreholes situated within the Konkiep River, 50 metres apart and approximately 2.85 km away from the main reservoir (Smit, 2017). Figure 3.1 below shows the Google map of the study area (Grünau and Bethanie).

Figure 3.1: Grünau and Bethanie villages on the Namibian map

Source:
https://www.google.com/maps/place/Namibian+Association+of+CBNRM+Support+Organisations

3.4 Data collection

3.4.1 Study population

The current population of Grünau and Bethanie is estimated at around 500 and 2 978 residents, respectively (NSA, 2011). The //Karas region, housing the study area has the smallest population in Namibia. According to the Namibia Population and Housing Census (2011), the population of //Karas region stands at 77 421.

3.4.2 Study Sample

Participants were sampled using the convenience sampling method, based on their availability during the study period.

i) The sample size was calculated from equation 3.1:

$n = \frac{z^2pq}{d^2}$ (Khunbai, 2019)

(3.1)

Where n = the desire minimum sample size.

z = confidence interval (95%).

p = estimated population proportion (when unknown, p = 0.5).

q = the proportion of the population not having the characteristic of interest.

d = the degree of accuracy desired usually set at 0.05.

z=1.96 (Khunbai, 2019)

p=0.5

q=1.0-p

d=0.05

$$n = \frac{(1.96)^2(0.5)(1.0-0.5)}{(0.05)^2}$$

384 (Grünau: 64 and Bethanie: 320)

The ratio of the population of Grünau to Bethanie is 1:6; therefore, 64 participants were selected in Grünau and 320 participants were selected in Bethanie.

3.4.3 Questionnaires

A total of 384 questionnaires were administered, while water quality tests were taken from the reservoir. The questionnaires were divided between the two villages, using ratios. Questionnaires were administered in Grünau and Bethanie to determine people's perceptions regarding the water and how they decide whether their water is safe for consumption. The questionnaires (predominately closed ended with few open-ended questions), were used to investigate the perception of the residents on taste, odour, and turbidity of water. All respondents were issued the questionnaires to fill in the presence of a bilingual Khoekhoegowab native assistant researcher/data collector, who was trained prior to data collection. The questionnaire consists of section A and B. Section A of the questionnaire consisted of questions aimed at assessing residents' interaction with water by asking about their perceptions towards their water sources and quality as well as their beliefs about the water quality. Section B of the questionnaire was aimed at obtaining basic socio-demographic information such as participants' age, employment status, gender, and level of educational, source of drinking water and length of stay in the study area.

3.4.4 Water sampling

Two water samples were collected from each reservoir in the two study villages and analysed in the Namwater laboratory for the physical, chemical, and microbiological analysis to determine the water quality. The physico-chemical water parameters that were tested include total dissolved solids, turbidity, total hardness, pH, fluoride, iron, lead, magnesium, zinc, cadmium, sodium, potassium, sulphate, nitrate, and free chlorine. Heterotrophic Plate Count, total coliforms and faecal coliforms were the microbiological parameters analysed. To prevent sample contamination, the tap was decontaminated prior to turning on the flow to ensure any present microbes that have the potential to affect or contaminate the samples were destroyed as Wedgworth et al. (2014) suggests. The sampling bottles were then filled and transported to the laboratory for analysis within 24 hours. Temperature control was ensured by keeping the samples in a cooler box.

3.5 Data analysis

The results from the physical, chemical, and microbiological water analysis were compared to the World Health Organisation Drinking Water Quality Standards (4th Edition of 2017) as well as the Namibian Drinking Water Quality Standards as stipulated in the Water Act (Act 54 of 1956). The closed-ended questions were analysed using descriptive statistics such as simple frequency and percentage. The open-ended questions were analysed using thematic analysis method. The responses were coded into short phrases and themes were generated. Each code describes the expression of the participants. The information is presented in tables, graphs, and charts.

3.6 Summary

This chapter focused on the methodology used in this study. It provided information on the study design. Information on how many participants were selected and how they were selected was also explained. The chapter further explained the qualitative research that was used as a method of data collection. It also explained the instruments used for data collection and how data was entered and analysed.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, results from the questionnaire and the water quality analysis are presented in tables, graphs, and charts. A total of 384 participants completed the questionnaires, of which 320 were from Bethanie and 64 were from Grünau. The researcher also discusses the findings in this chapter with reference to the study aim and objectives. Therefore, this chapter presents the answers to the research questions.

4.2 Perception of Bethanie and Grünau residents towards their water quality

4.2.1 Socio-demographic information of the respondents

Table 4.1: Participants' demographic information

	Bethanie		Grünau	
Participant's age	**Frequency**	**Percent**	**Frequency**	**Percent**
18-20	5	1.6	4	6.3
21-30	85	26.6	21	32.8
31-40	84	26.3	17	26.6
41-50	52	16.3	10	15.6
51-60	29	9.1	6	9.4
>60	65	20.3	6	9.4
Total	320	100	64	100
Participant's gender				
Male	110	34.4	27	42.2
Female	210	65.6	37	57.8
Total	320	100	64	100
Highest level of education				
Never attended formal education	5	1.6	2	3.1
Primary	73	22.8	19	29.7
Secondary	167	52.2	31	48.4
Tertiary	75	23.4	12	18.8
Total	320	100	64	100
Employment status				

Employed	221	69.1	33	51.6
Unemployed	99	30.9	31	48.4
Total	320	100	64	100
Length of stay				
Less than 5 years	32	10	5	7.8
5-10 years	48	15	11	17.2
More than 10 years	240	75	48	75
Total	320	100	64	100

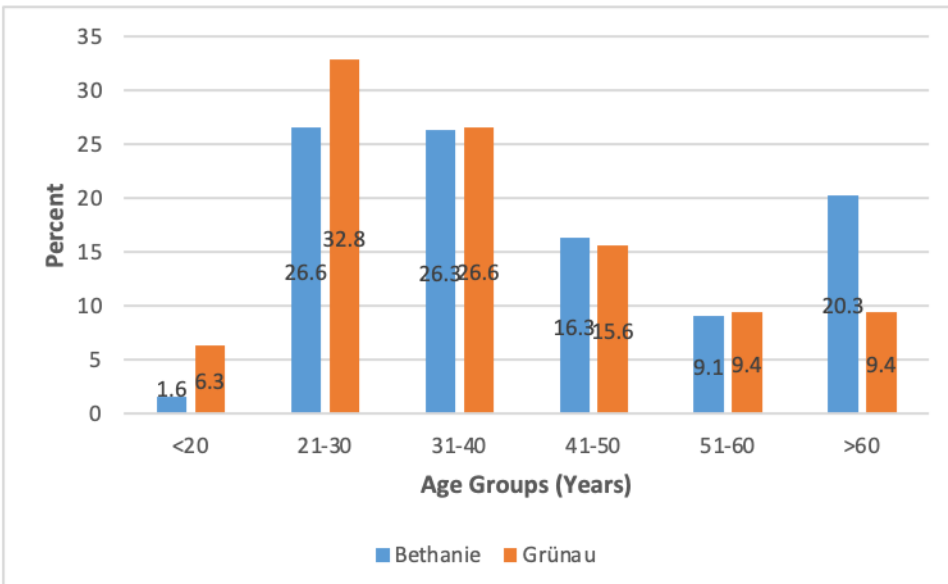

Figure 4.1: Age groups of participants.

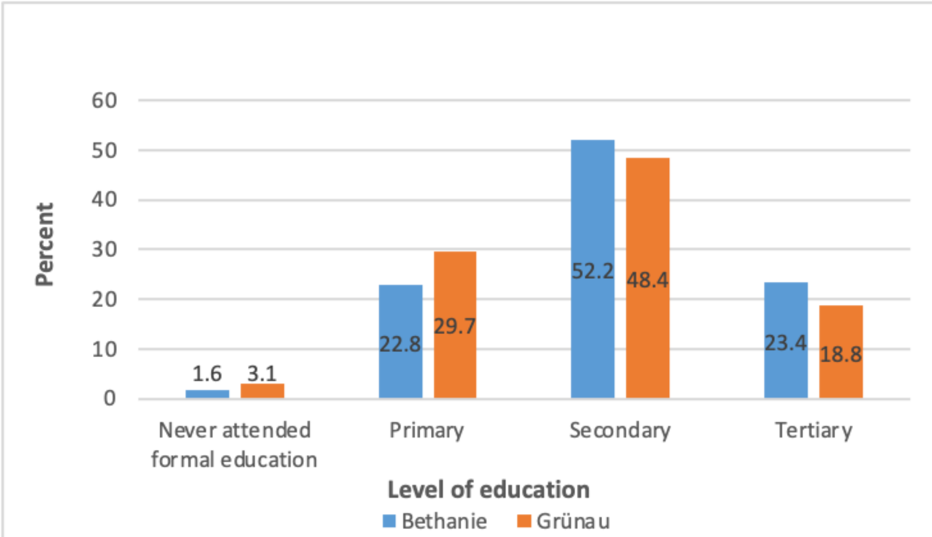

Figure 4.2: Participants' level of education.

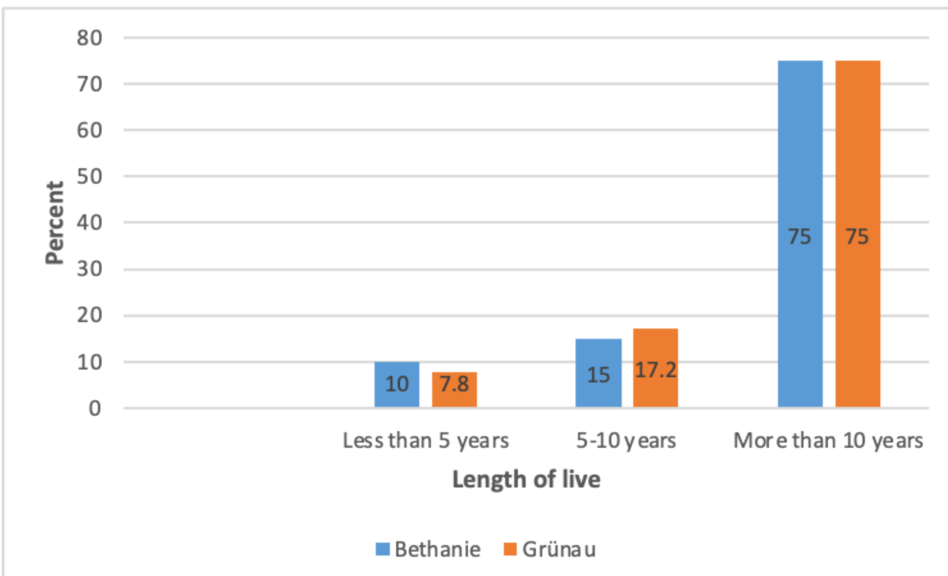

Figure 4.3: Length of live in Bethanie/Grünau.

The Socio-demographic information of the participants is presented in Table 4.1. A majority of the respondents are female (65.6% in Bethanie and 57.8% in Grünau). The dominant age group was 31-40 years and 21-30 years in Bethanie and Grünau, respectively, with secondary education predominantly being the highest level of education in both villages.

A smaller percentage of the sample population were aged between 18-20 (1.6% in Bethanie and 6.3% in Grünau), 51-60 (9.1 % in Bethanie and 9. 4 % in Grünau) and above 60 years (20.3 % in Bethanie and 9.4 % in Grünau). Therefore, the study population represented almost age groups, exempting those under 18 years.

In terms of employment status, the study predominantly consisted of employed participants, whereby 69.1 % of participants in Bethanie and 51.6 % in Grünau were employed. In terms of the length of stay in the study area, 75 % of the participants indicated that they have lived in the settlements for more than 10 years.

4.2.2 Household drinking water sources

Participants were asked to identify their primary sources of drinking water. All participants in both villages responded they have access to piped (tap) water, of whom 67.4% of the participants in Bethanie and 78.1% in Grünau use it as their main source of drinking water. The remainder (61 and 14 participants in Bethanie and Grünau, respectively) reported they have diverted to bottled water as their primary source of drinking water. They have attributed the reasons for this diversion mainly due to the unpleasant taste of the piped water and their general dissatisfaction with the water. The largest consumers of bottled water are predominantly the younger and employed people. This is attributed to the fact that they may be in a better financial position to buy bottled water.

These findings are congruent with similar studies that have indicated that when consumers are not pleased with the tap water provided to them, they often turn to bottled water (Wang, Zhang, Lv, Zhang & Ye, 2018). Many residents in Grünau and Bethanie are, however, financially challenged or earn little amount of money; therefore, diverting to bottled water may be costly to them – even if the consumers feel dissatisfied with the water. This is like the findings of Wang et al., (2018) in a study which found that in Hainan Province, bottled or barrelled water in the areas has tremendously increased in the past couple of years as an alternative to tap water.

The study also found that the participants who have lived in the study area for 5-10 years and 5 years and below are predominantly the ones who have reverted to bottled water. This may be attributed to the fact that they have not yet gotten used to the taste of the water as compared to those who have lived in the area for a longer period. The researcher has also noted how the participants who have lived in the area for more than 10 years generally indicated they have gotten used to the taste of the water despite their dissatisfaction with it. This indicates that many residents have adapted to the water they perceive as unpleasant and/or unsafe for human consumption.

4.2.3 Perceptions of residents towards the water quality

Table 4.1: Perception regarding the water quality.

	Bethanie		Grünau	
Perceived water quality	**Frequency**	**Percent**	**Frequency**	**Percent**
Very safe	25	7.8	11	17.2
Safe	65	20.3	13	20.2
Undecided	35	10.9	5	7.8
Unsafe	105	32.8	21	32.8
Highly unsafe	90	28.2	14	22
Total	320	100	64	100

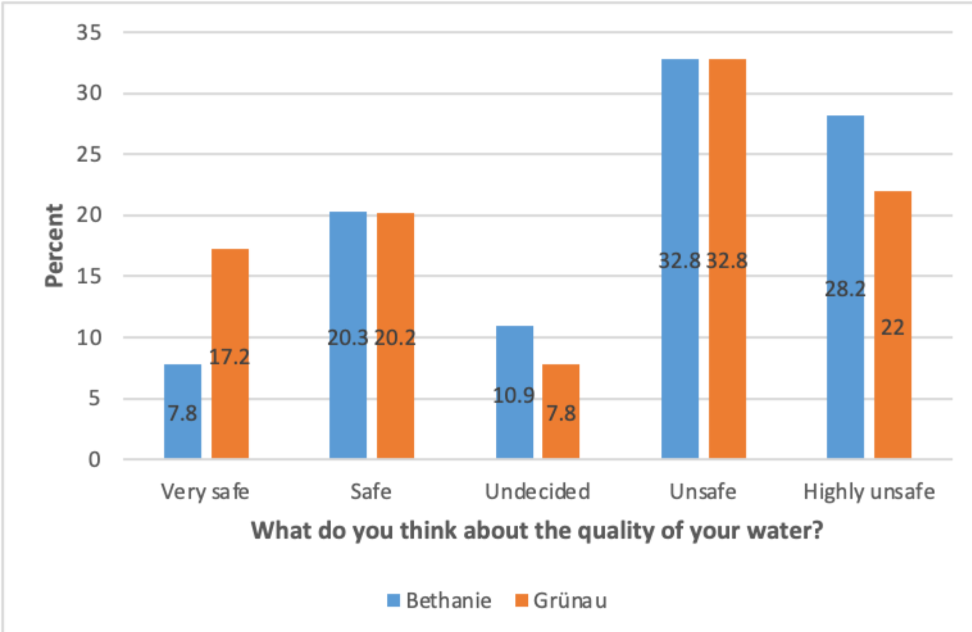

Figure 4.4: Perceived water quality

Table 4.2: Perception regarding the water quality (taste, colour and smell).

	Bethanie		Grünau	
	Frequency	**Percent**	**Frequency**	**Percent**
Do you think the taste of your drinking water is good?				
Strongly agree	28	8.8	7	10.9
Agree	49	15.3	11	17.2
Undecided	38	11.9	3	4.7
Disagree	110	34.4	22	34.4
Strongly disagree	95	29.6	21	32.8
Total	320	100	64	100
Do you think the colour of your drinking water is good?				
Strongly agree	51	15.9	6	9.4
Agree	55	17.2	10	15.6
Undecided	56	17.5	6	9.4
Disagree	90	28.1	23	35.9
Strongly disagree	68	21.3	19	29.7
Total	320	100	64	100

Do you think the smell of your drinking water is good?				
Strongly agree	176	55	38	59.4
Agree	87	27.2	21	32.8
Undecided	49	15.3	4	6.3
Disagree	2	0.6	1	1.6
Strongly disagree	6	1.9	0	0
Total	320	100	64	100

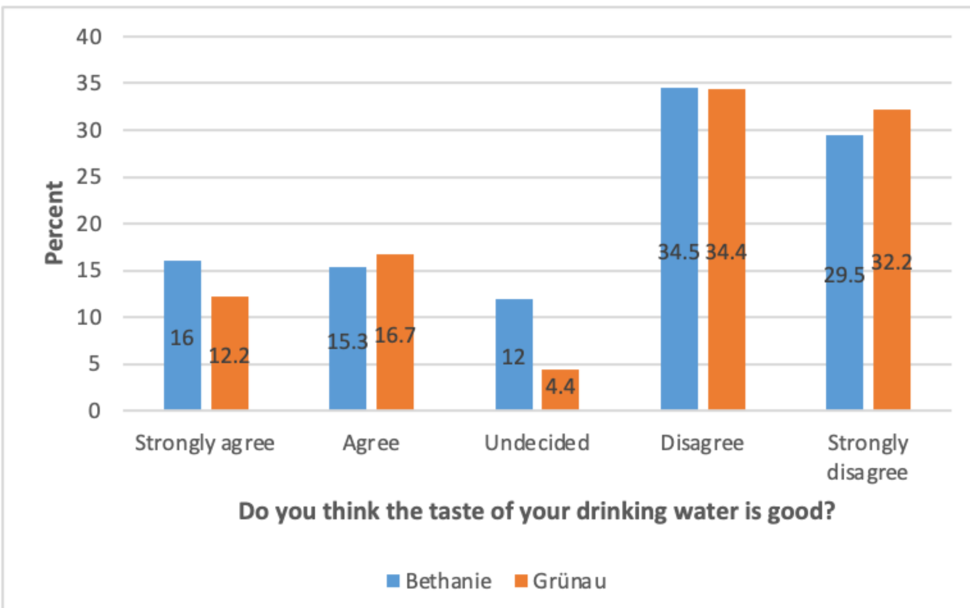

Figure 4.5: Perception on the taste of drinking water.

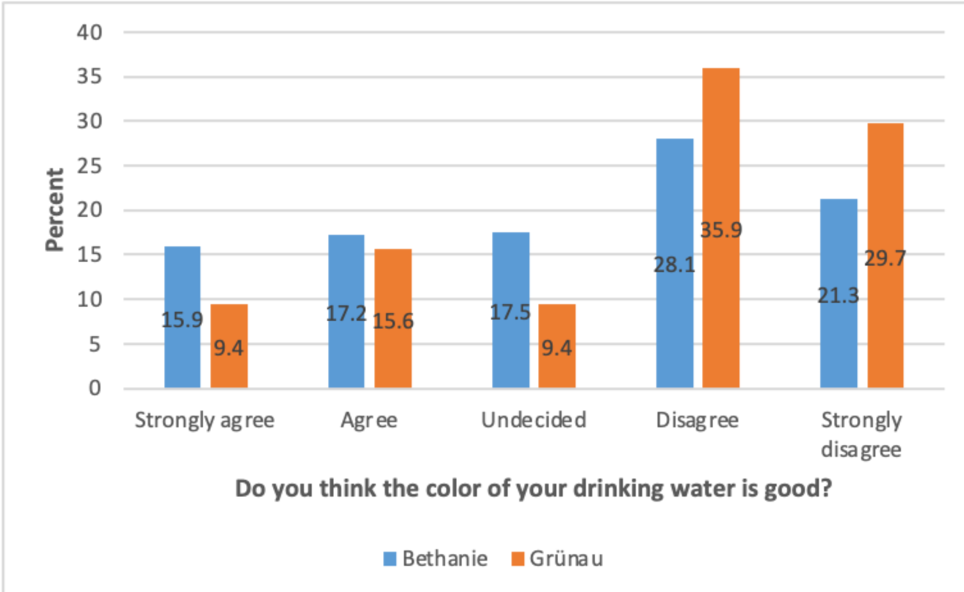

Figure 4.5: Perception on the colour of drinking water.

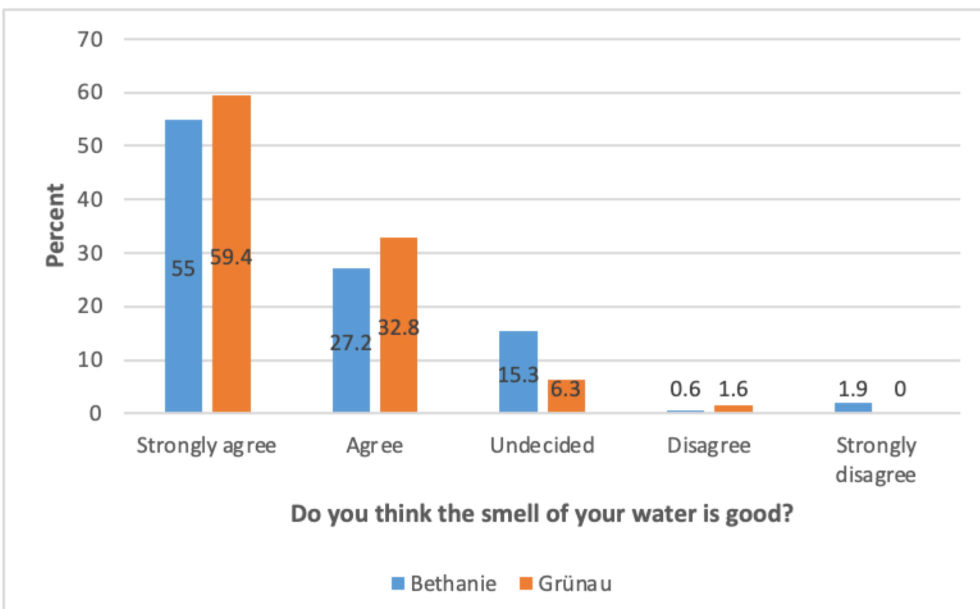

Figure 4.6: Perception on the smell of drinking water.

This segment of the questionnaire intended to discover the perception of the participants towards their water. Participants were asked to express their thoughts regarding the quality and safety of their water.

It consisted of 5-point Likert scale questions addressing the opinions, behaviour, and attitudes towards water quality in Bethanie and Grünau.

Most of the respondents (32.8%) in Bethanie and 32.8%in Grünau, indicated ‘unsafe’. The second highest chosen answer was ‘highly unsafe’ with (28.2% of participants in Bethanie and 22% of participants in Grünau describing their water supply as unsafe. The least selected answer in Bethanie was ‘very safe’ (7.8%), followed by ‘undecided’ (10.9%). In Grünau, ‘undecided’ (7.8%) was the least selected answer, followed by ‘very safe’ (17.2%). Hence, most of the participants felt that their water was highly unsafe or somewhat unsafe.

This question also gave room for the participants to elaborate on their answer. In both villages, a common theme expressed by the participants who felt that their water is unsafe and/or highly unsafe is that the water gives gastrointestinal illnesses, with symptoms such as diarrhoeal and headaches, especially among the elderly. Another common answer was that the water is responsible for teeth discoloration of many people in the area. A total of 118 respondents indicated that the water in the area is not good (referring to the taste of the water), but they drink it because they do not have an alternative. Some participants responded that the water has not made them sick in a long time now, and that they think it has improved, indicating that the water previously made them sick. For instance, participant 276 from Bethanie responded: ‘’The water here is good and does not give me any problems.”

Another common response among the participants was that they were used to the water, which means that even though the residents are dissatisfied with their water, they do not have alternatives and they have gotten ‘used’ to the taste and effects of the water. Participant number 2 from Bethanie stated, “The water is not so good, but I am now used to it”. The problems highlighted by the participants are further discussed in 4.3.

On the organoleptic water quality parameters (taste, colour, and smell), 34.4 % of the participants in Bethanie disagreed that the taste of water is good, whereas 29.6% strongly disagreed that the taste of the water is good. Furthermore, 15.3% agreed and 8.8% strongly agreed that the taste of their water is good. The other (11.9%) of the participants indicated that they were unsure/undecided about the taste of their water. Grünau residents revealed similar results to that of Bethanie, where 32.8% of the participants strongly disagreed that the taste of their water is good, 34.4% disagreed, while 10.9% strongly agreed, 17.2% agreed and 4.7% were undecided. The study found that most of the participants were dissatisfied with the taste of their water. The high level of dissatisfaction with the water was attributed to its unpleasant taste. Many participants indicated that the water has a very unpleasant taste, which may be attributed to the high content of minerals such as magnesium and calcium, which are responsible for the tangy taste of water (Harris, 2017). Many of the participants have also described the water to have a "lime" taste. These findings agree with the study undertaken in Thakhinyang, Thailand by Harris (2017). In the study it was found that all households have access to piped water, but people refuse to drink from their piped sources due to the smell and taste of the piped water.

On the parameter of colour, 21.3% of the participants in Bethanie and 29.7% in Grünau revealed they strongly disagree the colour of the water is good. Some of the participants described the water to appear unclear/whitish. Hence, their selection of strongly disagreed. 28.1% of Bethanie and 35.9% of Grünau disagreed that the colour of their water is good. A total of 33.1% selected 'strongly agree' and 'agree' that the colour of their water is good in Bethanie while in Grünau, a combined total of 25% of the respondents strongly agreed and agreed that the colour of the water is good. In Bethanie, 17.5% while 9.4% in Grünau were undecided about the colour of their water. The responses indicate that colour affects how the participants perceive the water. The measures of turbidity, which is a determinant of the colour of water indicates very low levels, which in this case does not correspond to the perception of the respondents. However, temporarily cloudy water may be caused by tiny air bubbles in the water, which are completely harmless.

On the smell indicator, 55% of the respondents in Bethanie strongly agreed, 27.2% agreed, 0.6% disagreed and 1.9% strongly disagreed that the smell of their water was good while 15.3% were undecided. In Grünau, 59.4% strongly agreed, 32.8% agreed, 1.6% disagreed that the smell of their water was good, while 6.3% were undecided. None of the participants strongly disagreed that the smell of their water was good. In comparison to the other two parameters (taste and colour), the participants were more satisfied with the smell of the water. The findings revealed that most residents understood the quality of their water and can relate it to aspects such as taste, clarity and smell.

4.2.4 Public satisfaction with drinking water quality

Table 4.3: Degree of public satisfaction of drinking water quality

	Bethanie		Grünau	
	Frequency	**Percent**	**Frequency**	**Percent**
Are you satisfied with the water you consume?				
Highly satisfied	29	9.1	8	13
Satisfied	58	18.1	9	14
Undecided	37	11.6	6	9
Dissatisfied	119	37.2	18	28
Highly dissatisfied	77	24.1	23	36
Total	320	100	64	100

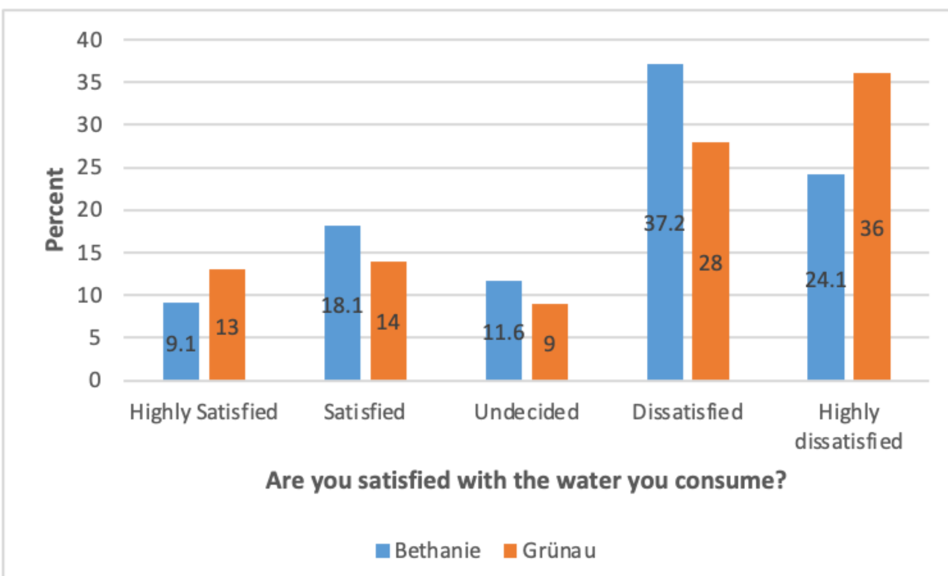

Figure 4.7: Degree of consumer satisfaction of drinking water quality.

Many factors, mostly organoleptic factors (flavour, colour, and smell), availability of water, its safety as well as feelings towards chemicals found in drinking water have mainly been found to be associated with the public perception of drinking water quality in the study area. Responses from the questionnaire regarding the level of public satisfaction with their drinking water quality are presented in Table 4.4 and Figure 4.8. Only 9.1% of respondents in Bethanie were highly satisfied with the quality of their drinking water, 18.1% were just satisfied, 37.2% of them were dissatisfied and 24.1% were highly dissatisfied with their current drinking water. In Grünau, only 13% were highly satisfied with their water, 14% were just satisfied, 28% dissatisfied and 36% felt highly dissatisfied with their current drinking water. In addition, 11.6% and 9% of the participants in Bethanie and Grünau respectively, were unsure (undecided) about how they generally felt towards their water. The main reasons why respondents were dissatisfied with their water was due to sensory properties such as the colour, unpleasant taste, and scale-forming properties of the water on appliances.

The results of participants' length of stay in the study area and level of public satisfaction showed that people who lived in the area longer (more than 10 years) were more satisfied with their water. This can be attributed to the belief that the longer one is exposed to the look and taste of the water, the more one gets used to it and may feel less bothered by the water. Therefore, people who lived in the area for a shorter period (less than 5 years and between 5-10 years) were more dissatisfied with the water, as they have not adapted to the water.

4.2.5 Water treatment

Table 4.4: Boiling of water before drinking.

	Bethanie		Grünau	
	Frequency	**Percent**	**Frequency**	**Percent**
Boiling of water before drinking				
Yes	107	33	11	17
No	213	67	53	83
Total	**320**	**100**	**64**	**100**

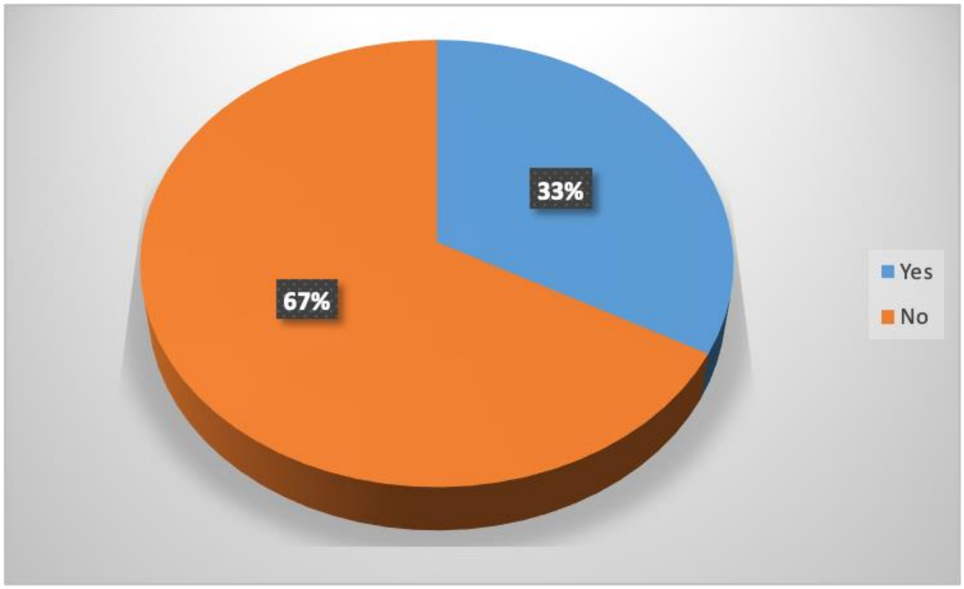

Figure 4.8: Boiling of water before drinking (Bethanie).

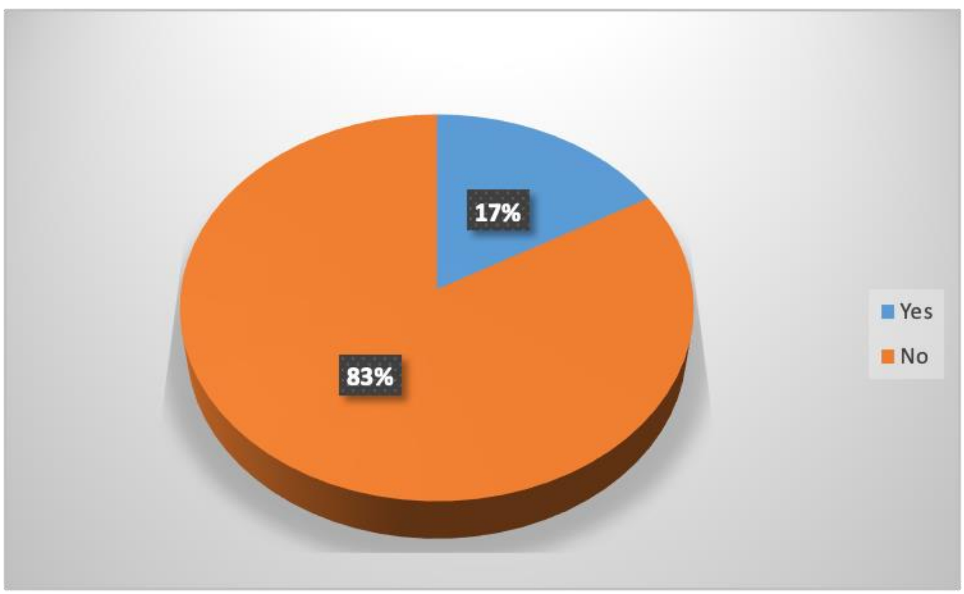

Figure 4.9: Boiling of water before drinking (Grünau).

Question eight (8) of section A was based on whether participants boil their water prior to drinking. The responses indicate that 67% of the participants in Bethanie do not boil their water, while 33% boil their water prior consumption. In Grünau, 83% of the participants do not boil their water while 17% boil their water before consumption. Some participants indicated they prefer to boil water prior consumption because they experience diarrhoeal if they drink water directly from the tap. The practice is common worldwide in areas where poor water quality is found.

4.3 Water quality of the Bethanie and Grünau villages

4.3.1 Physicochemical water analysis

The physicochemical parameters that were analysed are pH, Colour, Turbidity, Total Dissolved Solids (TDS), Free chlorine, Electric Conductivity (EC), Sodium (Na), Potassium (K), Calcium Carbonate ($CaCO_3$) Magnesium (Mg), Sulphate ion (SO_4), Nitrate (NO_3), Fluoride (F), Manganese (Mn), Iron (Fe), Copper (Cu), Lead (Pb), Zinc (Zn) and Cadmium (Cd). The results of the water analysis are presented in table 4.6.

Table 4.5: Physico-chemical water quality analysis

Parameter	Concentration (mg/l)		WHO Max Permissible limit (2008)	Namibia's Max Permissible limits
	Bethanie	Grünau		
PH	7.8	7.6	6,5-8,5	6.0-9.0
EC mS/M	111.7	127	400 mS/m	150 mS/m
Turbidity (NTU)	0.972	0.187	5	1
TDS	748.39	850.9	>1200 mg/l	>1200 mg/l
Calcium as CaCO3	237.5	242.5	180 mg/l	300 mg/l
Nitrate	2	8.01	10 mg/l	10 mg/l
Sulphate	164	75	500 mg/l	200 mg/l
Fluoride	2.9	1.7	1,5 mg/l	1,5 mg/l
Iron	0.02	0.02	2mg/l	0.1 mg/l
Manganese	<0,01	<0,01	0,1 mg/l	0.05 mg/l
Cu	0.01	0.04	2 mg/l	0.5 mg/l
Zn	0.01	0.02	5 mg/l	1 mg/l
Cd	<0,01	<0,01	0,003 mg/l	0.01 mg/l
Pb	<0,02	<0,02	0,05 mg/l	0.05 mg/l
Na	130	114	No Recommended Limit	100 mg/l
K	5	6	No Recommended Limit	200 mg/l
Free Cl (mg/l)	0.73	0.4	5	0.1- 5.0

i) pH

pH is used to determine how acidic/basic water is. Pure water has a neutral value of 7 (Environmental Protection Agency, 2019). pH is a good indicator for any chemical changes happening to the water. Carbonates and bicarbonates that are dissolved in the water, silicates, borates, fluorides, and other salts in dissociated forms affect the pH of ground water. A high pH results in a bitter taste of water, while water pipes and most kitchen appliances become scaly, and causes the disinfection with chlorine to become less effective. On the other hand, low pH indicates the presence of free acids, which results in the corrosion of metals (Deshmukh, 2013). This may also lead to the contamination of the water and affect appearance and taste. In the study area, the pH values of Bethanie and Grünau were 7.8 and 7.6, respectively, which are within the WHO as well as the Namibian standards recommended range of 6.0-9.0 and indicates the water to be in good condition.

ii) Electrical conductivity

The conductivity of water refers to the ability of water to conduct an electrical current (WHO, 2003). Electrical Conductivity (EC) is used to determine the amount of dissolved chemicals and solids in water and can, therefore, identify contaminants present in water. A high conductivity value indicates there are more chemicals dissolved in water. Therefore, electrical conductivity measurement makes it possible to obtain information about the extent of mineralisation in the water. Because the electrical current is transported by the ions in the water, the conductivity increases as the concentration of ions increases. The EC for the current study was 111.7 mS/m for Bethanie and 127 mS/m for Grünau, which corresponds with the observed presence of major cations such as Na^+, Ca^{2+}, Mg^{2+} and anions like sulphate and carbonate in the water.

iii) Turbidity

Turbidity is the measure of the clarity of water. Many particles that are generally invisible to the naked eye cause turbidity. It acts as an indication of the number of suspended particles in water. High turbidity in water can guard bacteria or other microorganisms, hindering the effectiveness of chlorine disinfection (WHO, 2011). In addition, most contaminants that affect the clarity of the water also change the odour and taste of the water. Water that has high turbidity may cause staining or even clog pipes over time.

The WHO's turbidity of drinking water should not exceed 5 NTU and should ideally be below 1 NTU, while the Namibian Water Act should not exceed 1 NTU. In this study, Bethanie recorded a turbidity measure of 0.372 NTU, while Grünau recorded 0.187 NTU, indicating that the turbidity was within the WHO permissible levels, which corresponds with the actual appearance of the water, as it appears relatively clear.

iv) Total Dissolved Solids

Total Dissolved Solids (TDS) represent the total concentration of dissolved substances in water – and as such, it shows the general nature of water quality in terms of salinity. TDS is made up of inorganic salts and a small amount of organic matter. The main components are usually "magnesium, calcium, potassium and sodium cations and carbonates, chloride, sulfate and nitrate ions" (WHO, 2003, p. 1). The presence of dissolved solids in water may affect its taste, and the palatability of drinking water has been assessed and rated by panels of tasters in relation to its TDS levels as follows: "Excellent, less than 300 mg/l; good, between 300 and 600 mg/l; fair, between 600 and 900 mg/l; poor, between 900 and 1200 mg/l – and unacceptable, greater than 1200 mg/l" (WHO, 2003, p. 1). Water that has very low TDS will have a flat taste and is regarded as unacceptable (WHO, 2011). In this study, Grünau recorded 850.9 mg/l and Bethanie 748.39 mg/l of TDS. These figures fall in the 'fair' category, indicating that taste is not exactly of best quality but neither it is of the worst quality. The values also act as an indicator for the presence of salts such as magnesium, calcium and sodium as detected in the water.

v) Total Hardness

According to the WHO, (2011), water hardness is a state in which water contains the presence of magnesium and calcium ions in high concentrations. Other ions that can contribute to the hardness of water include manganese and iron, but these are normally present in lower concentrations. Water hardness was traditionally used to measure the ability of the water to lather with soap. The degree of water hardness is vital, as it contributes to the aesthetic acceptability by the consumers. Aesthetically, hard water has a bitter and unpleasant taste, while soft water has flat taste. According to the WHO water quality guidelines of 2008, water containing calcium carbonate ($CaCO_3$) "below 60mg/l is regarded as soft; 60-120 mg/l moderately hard; 120-180 mg/l hard, and more than 180 mg/l very hard". Water with high levels of calcium is unpleasant for washing, laundry and bathing because it requires the use of more detergents. Health effects related to the continuous use of water with high calcium levels include the development of gall bladder stones or kidney stones (Sengupta, 2013). In this study, high values of $CaCO_3$ have been observed in the water of both Bethanie and Grünau, whereby Bethanie recorded values of 237.5 mg/l and Grünau 242.5 mg/l. These figures exceeded the WHO Maximum permissible limits of 180mg/l but fall within the Namibian permissible limits of 300 mg/l.

The results indicates that the water is hard and therefore, corresponds with the perceptions of the study participants, who expressed the bitter and unpleasant taste of the water. This may also be associated with some of the gastrointestinal problems that have been reported by some of the participants. According to Sengupta (2013), a high intake of magnesium salts may lead to bowel disruptions (diarrhoea). The lime taste of the water is influenced by the geophysical characteristic of the area from where water is sourced. The area lies in the Orange River basin, which contains sedimentary rocks such as limestone, which is the source of calcium carbonate that contributes to the hardness of the water.

vi) Nitrate

The main source of nitrate in groundwater is from nitrogen fertilisers, decaying organic matter, sewage runoff and animal dung (Deshmukh, 2013). According to Fecham et al.; Burkart and Kolpin (as cited in Lewis & Claasen, 2018), nitrate concentrations beyond the WHO recommended level (10 mg/l) are risky, especially to expectant women, posing a health risk to infants between three to six months with conditions such as methemoglobinemia (blue-baby syndrome). In this study, Bethanie recorded 2 mg/l of NO_3, which indicates very low levels of nitrate and so considered safe for drinking, while Grünau recorded 8.1 mg/l $NO_{3,}$ which is quite close to the maximum permissible levels. This indicates that care needs to be taken to prevent extreme future pollution of the water sources.

vii) Sulphate

Sulphate normally enters groundwater through rain, sulphur minerals and sulphides of heavy metals from igneous and metamorphic rocks. Sulphate dissolves into groundwater when water moves through soils and rocks, which have sulphate minerals. High sulphate concentration in drinking water can cause diarrhoea and dehydration, especially to people who are not used to such water. Like other minerals, sulphate can cause the build-up of scales in water pipelines and can also cause bitter taste of water (Brian, 2012). The sulphate results for Bethanie were 164 mg/l and 75 mg/l for Grünau. According to NamWater water quality standards, the best water should not exceed more than 200 mg/l of sulphate. Although the sulphate levels were within the WHO guidelines, the sulphate levels of Bethanie were observed to be relatively closer to the WHO maximum limits, indicating that proactive measures be developed to ensure maximum levels are not surpassed and possible sources are identified for mitigation purpose.

viii) Fluoride

Fluoride (F) enters groundwater because of weathering and leaching of fluoride rich minerals from rocks and sediments. In 1984, WHO estimated that globally, more than 260 million people consume water with fluoride concentration above 1 mg/l (WHO, 1984). In this study, Bethanie recorded 2.9 mg/l of fluoride, whereas Grünau recorded 1.7 mg/l. The national standards of Namibia and that of WHO are the same (1.5 mg/l). Hence, both villages exceeded the maximum allowed limits. The consumption of water with fluoride levels above the maximum levels has serious skeletal and dental effects, such as dental and skeletal fluorosis; the long-term effects cause the teeth to become hard and brittle (Brindha & Elango, 2011). 8.1% respondents indicated that their teeth have become yellow/brown (discoloured) from drinking the water. Research has documented that continuous exposure can cause teeth discoloration Brindha & Elango (2011), which may be the case in Bethanie and Grünau.

ix) Iron and Manganese

Iron (Fe) and Manganese (Mn) are required by the body in trace amounts and can be poisonous in large amounts. These heavy metals in drinking water are commonly linked to human poisoning hence, the vitality of assessment. Common sources of iron are anthropogenic sources such as industries and mines (industrial waste and mine drainage). According to WHO (2008), ground water that contains iron levels above 2 mg/l can cause clothes stains and pipelines. It is also associated with unpleasant taste and colour. Iron in excess amounts can cause vomiting and toxicity in the body, damaging body organs (WHO, 2008). However, a lack of sufficient iron in the body may cause anaemia and shortness of breath. Manganese toxicity is infrequent as it is quickly released from the body. The public water supply assessed at both Bethanie and Grünau recorded Fe concentration of 0.02 mg/l while the water Manganese concentration for was <0.01 in both locations. The measured levels of iron in the water were within both WHO drinking water standards and guidelines (2 mg/l) and the Namibia national drinking water standards of (0.1 mg/l). The detected levels for Mn were less than 0.01 mg/l, which are within the WHO maximum permissible limits and Namibia national drinking water standards of 0.1 mg/L and 0.05 mg/l respectively.

x) Copper (Cu), Zinc (Zn), Cadmium (Cd) and Lead (Pb)

Copper in drinking water is usually present due to the corrosive action of copper (WHO, 2017). Small amounts of copper is needed for the body's function, however, excessive amounts can be harmful. Too much copper can cause liver and kidney failure – and eventually, death WHO (2008). The levels of copper recorded in the water was 0.01 mg/l for Bethanie and 0.04 mg/l for Grünau. None of the water samples recorded concentrations above the Namibia national maximum permissible levels of 0.5 mg/l.

The concentrations of cadmium in all the water samples were above the WHO maximum permissible levels (0.003 mg/l) but within the Namibia national drinking water standards. At both Bethanie and Grünau, the water samples recorded Cd level of 0.01 mg/l each. This contamination may have occurred because of natural deposits or as result of the corrosion of some galvanised plumbing and water main pipe plumbing. The Environmental Protection Agency (2018) found cadmium to possibly cause nausea, diarrhoea, vomiting, convulsions, muscle aches, sensory, liver damage and renal failure, hence its regulation.

The findings from this study showed that there was no indication of lead contamination in the drinking water. The concentration of Pb recorded in the samples were <0.02 mg/l in both locations, indicating that the Pb content of the public water supply these areas is within the WHO maximum permissible level (0,05 mg/l) as well as the Namibia national drinking water standard (0.05 mg/l); hence, they do not pose any significant threat to human health.

The presence of zinc in drinking water adds an unpleasant taste to drinking water when present in concentration of about 4mg/l (WHO, 2017). Study findings revealed that the concentration of zinc in the water samples from both Bethanie and Grünau were within the recommended WHO as well as the

Namibian drinking water quality standards of 5 mg/l and 1 mg/l respectively. At Bethanie, the water recorded 0.01 mg/l Zn while at Grünau, it recorded 0.02 mg/l. Therefore, the zinc levels in the water does not pose any threat to the consumers.

xi) Free Chlorine

Free chlorine in the water indicates that an adequate amount of chlorine was added for the disinfection of the water and guarantees that most disease-causing bacteria and viruses are inactivated. It also means the water was free from contamination during transportation and storage. Therefore, free chlorine is used as one measure of the portability of the water. The water analysis for free chlorine recorded was 0.73 mg/l and 0.4 mg/l in Bethanie and Grünau, respectively. The WHO Maximum Permissible Limit is 5 mg/l, while the Namibian standards are 0.1-5.0 mg/l. Water problems associated with too much chlorine includes stomachaches, vomiting and diarrhoea. The two study locations were, therefore, within these values, indicating that most of the disease-causing microorganisms were inactivated at this point. It is also worth mentioning that the WHO recommends minimum free chlorine levels of least 0.2 mg/l to ensure disease-causing microorganisms are killed.

4.3.2 Microbiological water quality analysis

Microbiological water analysis was conducted to detect any microbial contamination of the public water supply in the study area. The microbiological parameters that were analysed include Total Coliforms, Faecal Coliforms and Heterotrophic Plate Count. The results are presented in Table 4.7.

Table 4.6: Microbiological water quality analysis.

Parameter	**Concentration**		**WHO Max Permissible limit (2008)**	**Namibia's Max Permissible limits**
	Bethanie	**Grünau**		
Total Coliforms	Not detected	3	Must not be detectable in 100 ml of treated water	Must not be detectable in 100 ml of treated water
Fecal Coliforms	Not detected	Not detected	Must not be detectable in 100 ml of treated water	Must not be detectable in 100 ml of treated water
Heterotrophic Plate count	1	26	>500 CFU/ml	Must not be detectable in 100 ml of treated water

i) Total Coliforms and Faecal coliforms

The presence of foreign organisms of the coliform group in drinking water is an important indication of pollution. The presence of coliform bacteria in drinking water increases the risk of consumers contracting water-borne diseases. Even though Total Coliforms can come from sources other than faecal matter, it is still important to be considered an indicator of pollution. Faecal Coliforms in water specifically acts as an indicator of faecal pollution.

The results from the study revealed that there was no indication of the presence of Total Coliforms or Faecal Coliforms in the Bethanie water. However, in Grünau, 3 CFU of Total Coliforms were detected in 100 ml of water. This indicates the presence of bacteria, which came from other sources than faecal matter since no faecal coliforms were detected. However, this still indicates the water has become contaminated by foreign matter and care should be taken to identify the source and mitigations carried out.

ii) Heterotrophic Plate Count

The detection of Heterotrophic Plate Count reflects a load of general aerobic and facultative anaerobic bacteria in the water or water system. In this study, 26 CFU/mL of Heterotrophic Plate Count was detected in the water in Grünau, which reflects the presence of general aerobic and facultative anaerobic bacteria. These concentrations exceed the Namibian drinking water quality standards; hence, the water was classified as Group B water (just below Group A water), which is regarded as bacteriological, still suitable for human consumption [The Water Act (Act 54 of 1956)]. Bethanie, on the other hand, recorded only 1 CFU/mL of Heterotrophic Plate Count. Bethanie water is, therefore, classified as Group A water, which is regarded as water with an excellent quality (in terms of bacteriological quality) as stipulated in The Water Act (Act 54 of 1956).

4.4 Problems associated with the drinking water

The most common problems the participants associated with their water supply include diarrhoea, vomiting and headaches. In fact, 30% of the participants in Bethanie and 7.9% from Grünau have indicated they have experienced diarrhoea from drinking the water. 4% participants from Bethanie and

6.3% from Grünau divulged they have at least experienced vomiting because of the water. A total of 2.6% participants have indicated that the water damages their electrical appliances such as kettles; the water is responsible for scale forming in the appliances. 7.8% participants from Bethanie and 9.4% from Grünau of the participants have indicated that their teeth have been discoloured/damaged by the water. The participants, however, indicated that despite all the negative effects, they continue to use the water, as it is their only source of water.

The participants were asked to make recommendations regarding the quality of their drinking water. At Bethanie, the participants expressed that they want cleaner and better-treated water supply. They also recommended that the treatment should be able to remove the lime taste in the water to make it more palatable and drinkable. Similar sentiments were expressed by the participants from Grünau, who commended NamWater Cooperation for improving the water over the past few years. However, they stated that there is still room for improvement, especially with the scaling of appliances and water pipes clogging.

4.5 Summary

This chapter presented the information gathered by the research in graphs and tables. It also discussed these findings and attempt to address the study objectives. The researcher compared the findings with the findings of similar studies that were undertaken prior to this study. The chapter therefore demonstrated the significance of the study.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter concludes and outlines the recommendations with reference to the findings. The recommendations are based on the findings on water quality perception, measured water quality and the effects of using the water. These recommendations are mainly directed to the water utility provider and local authorities.

5.2 Conclusion

The aim of this study was to determine the perception of consumers towards the water and assess the water quality and its impact on Grünau and Bethanie residents. Overall, the findings revealed that organoleptic factors have a strong effect on the perceived water quality. Taste, colour, and appearance were the main influencing factors on perception. The water quality perception is also influenced by the health problems experienced because of the consumption of the water. The most complained about issues regarding the water are taste, colour, stains, and sediments deposits on appliances. Some participants also stated that they wish to purchase bottled water for drinking purposes; however, the 'high cost' of bottled water is the reason most residents continue to drink the tap water.

Consumer perception is observed to be on par with some of the measured water quality parameters such as magnesium and calcium that are responsible for water hardness – and subsequently, the lime taste, which are experienced by the consumers. Fluoride is also present in high concentrations (above the maximum permissible limits). In terms of microbiological parameters, the public water supply in Bethanie is considered safe and potable (group A water) – while in Grünau, the water was classified as water with acceptable quality (group B water).

This study can act as a starting point for future researchers who wish to study the extent to which water can be attributed to self-reported health conditions, e.g., teeth sclerosis, fluorosis, gastrointestinal illnesses, and cardiovascular diseases that are reported to be accelerated by water of this nature.

Furthermore, the study can complement the interventions and projects related to the provision and improvement of water and water quality within Bethanie and Grünau.

5.3 Recommendations

Based on the findings, the study makes the following recommendations:

- Namibia Water Corporation (NamWater) should treat the water more effectively to remove excess minerals and salts, especially magnesium and calcium that mostly contribute to the hardness and lime taste of the water, thereby improving the taste of the water and improve acceptability by the community. To achieve this, reverse osmosis, which is regarded as one of the most efficient technology used to eliminate lime, can be implemented.
- The study further recommends the strengthening of education and public awareness about drinking water safety by the custodian of water provision (NamWater), together with the local authorities and media houses. This can be done by publishing the water quality reports through different media platforms to prevent the misinformation regarding the portability of their water. This will equip consumers with information regarding the quality of their water.
- NamWater should invest more into the deflouridation of the water and reduce it to safe levels. This can be done by dilution of the groundwater. This can be accomplished by artificial recharge, whereby check dams can be constructed on high grounds. Fresh water from the check dams will then flow into the ground, which will dilute any contaminants that are already in the groundwater.

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APPENDICES

Appendix 1: Questionnaire

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Questionnaire

Research topic: Assessment and perception of water quality on the health of Grünau and Bethanie residents, Namibia, 2021.

Section A: Perception

1. What do you think of the quality of your water?

O Very safe	O Safe	O Undecided	O Unsafe	O Highly unsafe

Please elaborate your answer.

____

____

____

2. Do you think the taste of your drinking water is good?

O Strongly Agree	O Agree	O Undecided	O Disagree	O Strongly Disagree

3. Do you think the color of your drinking water is good?

O Strongly Agree	O Agree	O Undecided	O Disagree	O Strongly Disagree

4. Do you think the smell of your drinking water is good?

O Strongly Agree	O Agree	O Undecided	O Disagree	O Strongly Disagree

5. Are you satisfied with the water you consume?

O Highly satisfied	O Satisfied	O Undecided	O Dissatisfied	O Strongly dissatisfied

6. Which of the following parameters are most important to you in terms of water quality?

O Color	O Taste	O Health effects	O Smell	O Undecided

7. Do you know or suspect any of the following pollutants affect the groundwater quality in your area?

More than one answer can be given.

☐ (Pathogens/germs bacteria, viruses)

☐ Septic systems/latrines

☐ Products and waste water from mining

☐ Minerals

8. Do you boil your water before drinking? ☐ Yes ☐ No

- If yes, go to question 9.
- If no, go to question 10.

9. Why do you boil your water?

☐ I think the water is unsafe ☐ To improve taste ☐ It's a tradition

10. Why don't you boil your water?

☐ I think the water is safe

☐ No specific reason

☐ I do not have enough fuel/electricity to prioritize boiling water over other activities such as food preparation.

Section B: Sociodemographic

11. Age_____ years old.

12. Gender

☐ Male ☐ Female

13. Highest level of education

☐ Never attended formal education ☐ Primary ☐ Secondary ☐ Tertiary

14. Employment status

☐ Employed ☐ Unemployed

15. How long have you lived in Grünau/Bethanie?

☐ Less than 5 years ☐ 5-10 years ☐ More than 10 years

16. What is the source of the water you use?

☐ Tap water (Local Authority Borehole) ☐ Tap water (Namwater Borehole) ☐ Directly from borehole ☐ Other…………………………….

17. Do you buy bottled water?

☐ Yes

☐ No

18. What type of sanitation system do you use?

☐ Pit latrine ☐ Flush toilet ☐ Bucket system ☐ Open defecation

<u>Recommendations</u>

19. What are your recommendations to improve the quality of water in the area?

____

____

____

____

____

Appendix 2: Consent form

PARTICIPANT ID: [ ] **DATE: ____________**

<u>Informed consent form</u>

You are invited to participate in a research study regarding the perception of water quality in Bethanie/Grünau. The study aims to understand public opinion, behaviour and attitudes towards water quality in Grünau and Bethanie as well as the impact the water has on those affected.

I understand and agree to participate in this research study: 'Assessment and perception of water quality on the health of Grünau and Bethanie residents, Namibia, 2021'.

My signature on this form means:

- I have read and understood the study information.
- I have been informed about the study's purpose, procedures, possible benefits and risks.
- I have been given the chance to ask questions before I sign.
- I have voluntarily agreed to participate in this study.

______________________ ___/____/___

Participant signature Date