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Monitoring Water Quality and Sanitation Practices in Semi-Arid Rural Areas in Namibia

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Abstract:
Farming communities in the rural regions of Namibia, struggle to obtain clean water and are challenged to keep water safe for human consumption. Namibia has one of the lowest sanitation coverage in Eastern and Southern Africa, therefore the main focus of the study was to analyze and improve water quality and sanitation by testing the groundwater quality and providing recommendations to improve sanitation. This was done through interviews, infrastructural observations and water quality tests on eight farms settlements in the Karas region. Groundwater was tested for nitrate, Enterococcus, total coliform and Escherichia coli (E. coli.) Water results were compared to the guidelines for safe drinking water used by Nam Water and WHO. One farm was graded as having water unfit for human consumption (Grade D), three of them had water that has a moderate risk factor (Grade C) to human health, which requires rectification, while four of the farms had very safe water (Grade A).

Keywords: *Groundwater quality, pollution; contamination, rural settlement, Karas region, Namibia*

1. Introduction

In an arid country such as Namibia, water is a scarce and vulnerable resource. Therefore it is important to prioritize the use of water to protect it from contamination. Pollution of water resources is currently the most important issue that faces millions, in Namibia and the rest of the world. Nearly all fresh water bodies are under enormous pressure from expansion of the human population and developmental activities in and around most water bodies (Bordoloi and Bruah, 2014).

Namibia has one of the lowest sanitation treatments in Eastern and Southern Africa. Nationally, only 33 percent of the population has access to improved sanitation with significantly lower percent (14 percent) of rural population having improved sanitation access. This figure concerns around 1.4 million people living in rural areas and in informal settlements in urban areas which do not have access to improved sanitation facilities. Shortage of improved sanitation facilities, poor knowledge and low practice of basic hygiene or proper environmental sanitation behaviors together with the health challenges associated with high occurrence of HIV are demonstrated by increasingly high levels of diarrheal-related mortality and morbidity (UNICEF, 2010).

In order to sustain life, water is among the most essential resources; contaminated sources pose life threatening health risks to consumers. In the rural regions of Namibia, farming communities find it difficult to obtain water fit for human consumption. Poor sanitation practices, limited education, geographic isolation, and inadequate governmental communication amplify this challenge (Boutin, et al. 2011). The use of open areas that are close to residential land, where urinating and defecating is very common has been identified as a major health hazard (Deffner and Mazambani, 2010).

It is against this background that we chose to study a rural area in southern Namibia, where the residents solely depend on groundwater. Eight farms were selected for this study. The main focus of the study was to analyze and improve water quality and sanitation by testing the groundwater and providing recommendations to improve sanitation. Our focus was mainly on nitrate levels and bacteriological content i.e., Enterococcus, Total coliform and E. coli.

2. Description of Study Area

In April 2016, we sampled borehole water quality on 8 farms on the Noordoewer road (C11) that leads to the Cape Town road.

The principal concern of the inhabitants of these two regions, especially the people living on farms is groundwater pollution. Preliminary reports suspect contamination is a result of open human and livestock defecation (Wall et al., 2008). Often the most common sanitation practice is the bush or bucket system. These sanitation practices in combination with an abundance of livestock contribute to nitrate pollution and increase the risk of bacterial contamination (Boutin et. al. 2011).

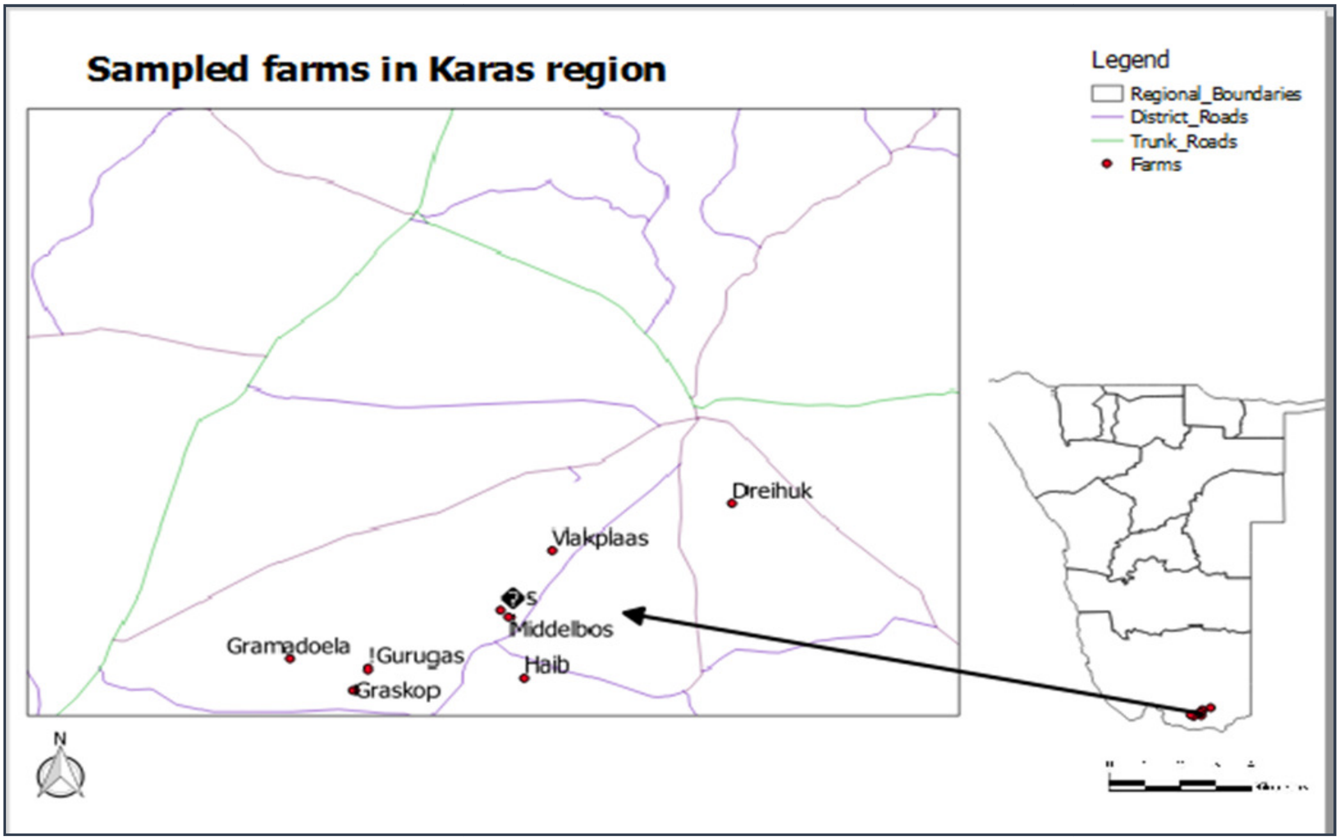

Figure 1: Map of the 8 farms sampled situated along the Noordoewer road (C11)

The majority of people living in Karas region depend on livestock farming and conservancy related tourism. These regions are affected by low rainfall and drought. Southern Namibia receives the least amount of annual rainfall in the country. The southern regions of Namibia receive less than 100 mm of rain per year. The lack of surface water and annual rainfall make water conservation essential for sustainability in rural Namibian communities (U.S. Central Intelligence Agency, 2011).

3. Methods and Materials

To determine the water quality of the boreholes and standard of sanitation we divided the research into three parts. The baseline assessment included testing the nitrate and bacteriological quality (Enterococcus, Total coliform and E. coli) of drinking water. Water was tested at a professional laboratory service. We compared the nitrate and bacteriological water results with the guidelines for safe drinking water used by NamWater, as shown in Figure 2.

Secondly we did a visual evaluation of the farms and the water supply infrastructure. The first component of the profile involved an assessment of the physical landscape and infrastructure. We considered where the houses were situated and livestock were kept in relation to the borehole and how the humans and livestock interacted with the water source. Evaluation of the infrastructure included looking at the conditions of the wind pumps, boreholes, dams, water tanks and water pipes. We assessed the current sanitation technology and practices and their impacts on the water.

Lastly we conducted semi-structured interviews, asking the residents about water supply and sanitation practices. The questions were based on the practices that influence the cleanliness of the existing water system. The interviews also focused on what the residents perceived to be the main concerns about the current state of the water situation. This research enabled us to create a general profile for each farm allowing us to develop specific solutions and compile a list of recommendations for the water quality and sanitation issues for the residents on the farms.

4. Results

4.1. Water Infrastructure and Farm Layout

All of the farms on the Noordoewer road exhibit the same general infrastructure; each consists of a windmill powered borehole, either a 5000L or 10 000L water tank (reservoir), concrete dams, some enclosed with iron sheets. These dams were open on top, except for Dreihuk, that had a closed dam. Some of these dams were not being used due to damage of the concrete walls. Livestock troughs were extremely near to the water sources e.g. reservoir, windmill, borehole and the dam. Visual evaluations of the water sources showed that most of the water infrastructure is functional although occasional maintenance is necessary.

Our objective was to draw conclusions through comparisons of infrastructural evaluations for each farm. We found that the farms had similar geographical conditions, and suffered the same issues e.g. brackish water. Leaking pipes and rusting metal pipes were the most prevalent infrastructural issues. Poor maintenance was the key reason for wear on infrastructure, and this was caused by a lack of funds to maintain the infrastructure. Another common problem was the poor condition of reservoirs, which we found with many holes in their piping systems, and in need of cleaning, problems that we recognized were due to old age and lack of maintenance.

4.2. Water Quality

The final classification for the water on each farm was categorized by chemical and bacteriological quality. Of the eight farms tested, two had acceptable water, four had water of low health risk, and two had water unfit for human consumption. Though several testing parameters were considered, these poor classifications were primarily attributed to high nitrate levels and coliform bacteria.

4.3. Nitrate Results

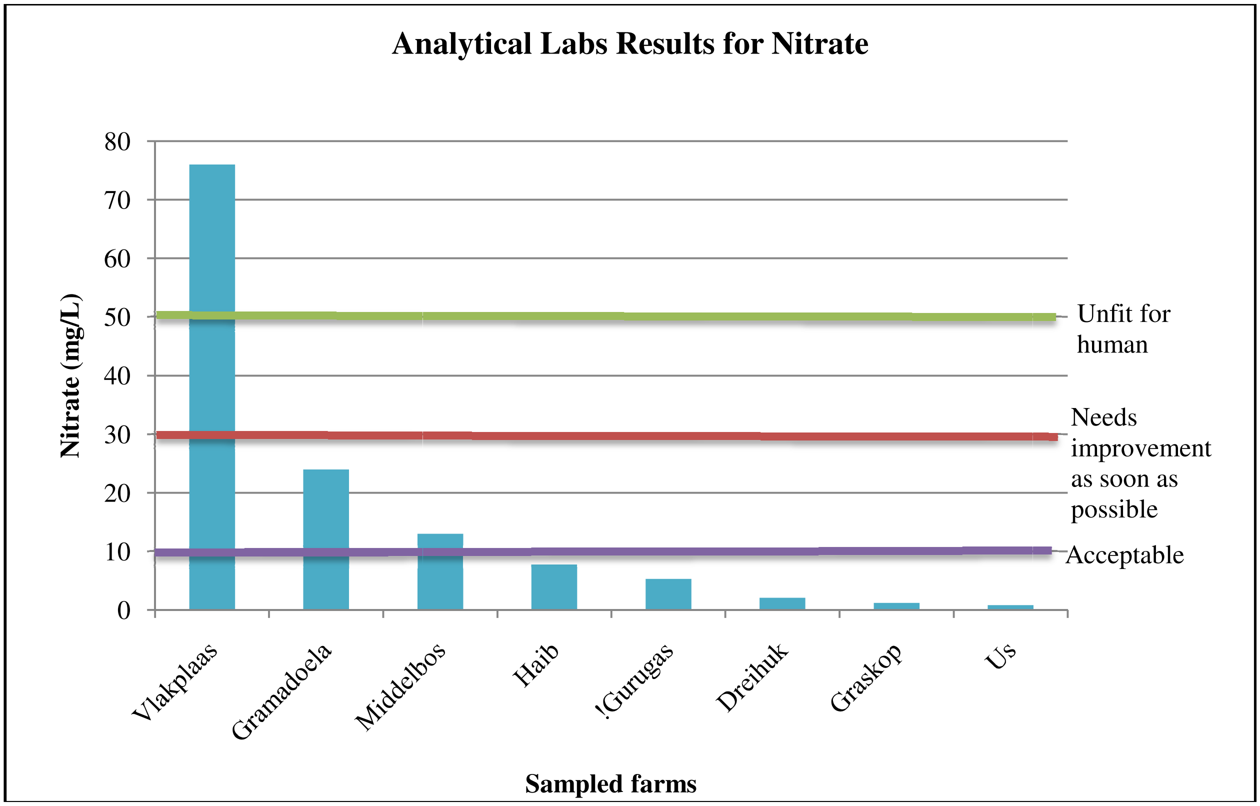

Figure 2: Nitrate results for the 8 sampled farms

Vlakplaas is the only farm where the nitrate concentration is over 70mg/L, making the water unfit for human consumption. The nitrate concentrations for Gramadoela and Middelbos are graded B, although the water on these farms are still suitable for drinking, action needs to be taken to prevent further contamination. Haib! Gurugas, Dreihuk, Graskop and Ús have low levels of nitrate.

4.4. Bacteriological Results

Test Identification	*Enterococcus* count, MPN/100ml	Coliform, MPN/100ml	E. coli MPN/100ml
1. Dreihuk	5	23	9
2. Vlakplaas	<1	2	<1
3. Haib	6	>23	9
4. !Gurugas	<1	<1	<1
5. Graskop	<1	<1	<1
6. Ūs	<1	<1	<1
7. Gramadoela	30	>23	5
8. Middebos	3	<1	<1

Table 1: Test results for Enterococcus, Coliform and E.coli of the 8 sampled farms

Table 1 shows that there is 100% presents of the bacteria in the water sources. Dreihuk and Haib have elevated levels of bacteria. On average the rest of the water sources show that most of the farms have less than 1 most probable number (MPN) per 100 ml.

Farm	Chemical Classification	Bacteriological Classification	Description of Classification
1. Dreihuk	A	C	water with a risk factor which requires rectification
2. Vlakplaas	D	B	Water with high health risk, or water unfit for human consumption
3. Haib	A	C	water with a risk factor which requires rectification
4. !Gurugas	A	A	very safe water
5. Graskop	A	A	very safe water
6. Ūs	A	A	very safe water
7. Gramadoela	B	C	water with a risk factor which requires rectification
8. Middelbos	B	A	very safe water

Table 2: Nitrate and bacteriological graded from A-D and description of classification of the 8 sampled farms

We can observe from Table 2, that the bacteriological and chemical concentrations of the water on average range from Grade A-C, with the exception of the nitrate concentration on Vlakplaas, which is Graded D.! Gurugas, Graskop, Ūs and Middelbos have very safe water. Dreihuk, Haib and Gramadoela have water with a risk factor that requires treatment. Vlakplaas is the only farm where the water is heavily contaminated with nitrates. Although the water at Vlakplaas is bacteriologically safe to drink but because of the high level of nitrates, the water is Graded D, water unfit for human consumption. Such water should be treated immediately.

4.5. Social Baseline

The social baseline was determined from our interviews conducted on the eight farms. All farms sampled said they get their water from a windmill powered borehole. Since Dreihuk is a resettlement area, they use a lot more water than the other farms. Most workers and farmers have to walk long distances or ride with a donkey cart to get water in either 25L or 50L containers. Most farmers complained that they do not have sufficient funds to connect pipes from the water source to their houses.

The primary uses of water on these farms were for human consumption, cooking, bathing, laundry and livestock. Secondary uses of the water were for small gardens on some farms like Ús and Gramadoela. People on these two farms said they throw their used water e.g. after bathing or laundry on the plants in the garden, but the other six farms people just throw the water outside on the ground.

Most people on the farms complained that the water was too brackish, and it gave the children diarrhea, if it was not boiled prior to ingestion. Dreihuk's community council said the water quality has deteriorated drastically. The interviewees suggested that another factor that leads to the brackish water is the lack of rainfall in the region.

Residents complained that the biggest challenge on the farms were on days with minimal wind; their need for water exceeded the amount of water available via the windmill pump. They have insufficient funds to fix leaking and rusted pipes. The water source is too far and plants sometimes die due to a lack of water. Broken windmills are also a big problem, as Gramadoela's residents currently have a water shortage.

All farms sampled have a dunghill, where they collect all their rubbish on and burn it either once in 2 weeks or once a month. Some farms like Middelbos fence off these dunghills, to prevent animals from eating the rubbish.

Of the farms sampled only Dreihuk had a ventilated improved pit-latrine drain (VIPD) toilet. Vlakplaas had a flush toilet in the main house and Gramadoela had a self-built toilet, outside the house in the yard, the rest of the farms did not have any kind of toilet. Gramadoela does not have a lot of trees or shrubs around the farm, therefore the people built the toilet, in order to have some privacy. Most farmers say they would like a toilet, even if it is just a dry toilet, but they do not have the funds to build these toilets.

5. Discussion

Monetary constraints are the main reason for poor water quality and poor sanitation practices, because the majority of people cannot afford any sanitation systems, and have to resort to the bush or bucket method. A lack of repairs of the infrastructure can also be attributed to monetary constraints. The lack of maintenance of the water infrastructures was evident from the leaking and rusting pipes on most farms. These damaged pipes are exposed to contamination and the leaking pipes waste water. The pit latrines at Dreihuk aim to meet the sanitation related target of the Millennium Development Goals (Sibiya & Gumbo, 2013), but are environmentally flawed because the faeces remain in the ground causing further nitrate and bacteriological contamination of groundwater (Graham & Polizzotto, 2013).

Another reason for the high nitrate content might be that the main house has a long drop toilet, and the faeces infiltrate into the groundwater supply or the fact that that the workers on the farm use the bush or bucket method (Ayers & Westcott, 1976). Haib's livestock pen is situated around the dam and the dam is open, flying insects and birds might defecate in the water and increase the bacteriological content of the water (Smith, 1970). ! Gurugas, Graskop and Ús all have excellent water quality, because the dams were not used, only the closed water tanks. Ús had pipes that connected water flow from the water tank to the house allowing less bacteria into the water. No animals were found near the water source at! Gurugas or Ús that could have contributed to the nitrate increase. Gramadoela has a self- built toilet and an open dam that adds to the pollution of the water, making Gramadoela's water to be water with a risk factor which requires rectification. Middelbos also had good quality water, because no animals were sited in close proximity to the borehole on the day of sampling, resulting in low nitrate levels. The livestock pen was 30m away from the water source, which might be the reason for the low bacteriological content, as less faeces is likely to enter the water source.

The geographic location of the borehole also affects the quality of water by either affecting the nitrate concentration or the bacteriological contaminants of the water. Dreihuk and Ús boreholes were situated above the settlement! Gurugas and Middelbos

boreholes were situated at a lower gradient and Vlakplaas, Haib, Graskop and Gramadoela were situated at the same level as the other infrastructures on the farms. The water at Dreihuk and Ús did not exceed the NamWater guidelines for nitrate, as these water points were both situated at a higher level than the settlement, less faeces infiltrate the groundwater supply, as water runs downhill. Ús water also did not exceed the recommended guidelines of Enterococcus, coliforms and E.coli. On the other hand, Dreihuk's bacteriological concentration exceeded the safety mark, therefore the water requires rectification. Gurugas and Middelbos water is very safe to drink, indicating that its nitrate and bacteriological levels are adequate, even though the water points are situated downhill. Vlakplaas' nitrate level far exceeds the recommended guidelines for nitrate by 26g/mL, but its bacteriological classification was acceptable. Haib's, Graskop's and Gramadoela's water did not exceed the NamWater guidelines for nitrate, but Haib and Gramadoela's bacteriological concentration exceeded the safety mark, this could be because they are situated on a flat surface and water doesn't run off, but rather infiltrates into the ground. This indicates that if the borehole is situated on a lower or a level slope it tends to be more vulnerable to groundwater contamination as water pools for a longer period of time, thereby allowing a greater infiltration and hence a greater potential for contamination (Rahman, 2008).
The safe drinking mark for nitrate levels is less than 50mg/L. The results show that nitrate levels at Vlaakplas were well over at 76mg/L, making this water a high health risk. While taking water samples at Vlaakplas we saw 22 cows lying around the water point, indicating that this was common practice. Gramadoela's nitrate levels were second highest, 25mg/L. While this concentration is still considered safe, measures need to be taken to stop the nitrate levels from rising. The other 6 farms had nitrate levels of acceptable proportions, which were less than 10mg/L, although at Middelbos the level was at 12mg/L. Through our observations, we were able to contribute the high levels of nitrate with open defecation of livestock and humans. According to Ayers and Westcott (1976) faeces are mainly composed of nitrates and phosphates, this can lead to pollution in these water systems. Large amounts of livestock faeces were found in close proximity of the water sources at 6 of the farms. Open defecation by the residents was practiced at 6 farms. One farm had a pit latrine, but pit latrines still allow human faeces to come into contact with the environment. Ús had the lowest nitrate concentration (0.8mg/L), no animals were allowed in close proximity of the borehole and the livestock corral was found an appropriate distance from the water source, resulting in low nitrate levels.
The World Health Organization (WHO, 2002) water quality guidelines dictate that water is considered as a very high risk when E. coli most probable number (MPN) is >100/100 mL, which none of the samples were; a high risk when E. coli MPN ranges from >10 to 100/100 mL, which none of the samples were; an intermediate risk when the E. coli MPN is between 1 and 10/100 mL, which 3 samples were; and a low risk when the E. coli MPN is <1/100 mL, which 5 samples were. Based on these guidelines, 37.5% of the water samples collected were at immediate risk and 62.5% of the water samples collected were at low risk.

6. Conclusion

High levels of nitrate and bacterial contamination of groundwater can be attributed to human and livestock defecation in close proximity of the borehole. Shortage of improved sanitation facilities, poor knowledge and low practice of basic hygiene or proper environmental sanitation behaviors are the main factors contributing to water contamination on the farm settlements.
The results from this research provide valuable information on the current conditions and challenges rural communities face in terms of water quality and sanitation and it has also made it possible to provide short and long term recommendations to improve sanitation and decrease groundwater contamination on the farms. The study concluded that a lack of improved sanitation facilities, poor knowledge and low practice of basic hygiene or proper environmental sanitation performances are the main factors contributing to water contamination on the farms.
In conclusion we found that the people on the farms on the Noordoewer road experience a lot of challenges with water quality, infrastructure or infrastructure maintenance and they don't have sufficient funds to fix all these problems. From the interviews we concluded that most farms are in need of a toilet, to address their sanitation situation and ultimately to improve health, especially for children under 5 years of age.

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