Nitrate and Bacteriological Assessment of Groundwater in Omaheke Region, Namibia.

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Received: 14th May, 2016. Accepted: 19th September, 2017. Published: 11th November, 2017.

Abstract

In Namibia, a large percentage of the population uses water from sources such as rivers, wells and boreholes. The quality and safety of such water sources is generally considered poor, and therefore is a potential health hazard. Groundwater in boreholes does not go through a treatment process and therefore the cleanliness of water is a major concern. The main objectives of the study were to analyze groundwater for nitrate and bacteriological content, i.e. total coliforms, faecal coliforms, Enterococci and E.coli, as well as evaluate sanitation practices. The study area included 8 farms on the C20 road to Aranos, Omaheke region. The nitrate and bacteriological results were compared with the guidelines for safe drinking water used by NamWater and World Health Organization (WHO). The results showed that Groot Ums was the only farm having water unfit for human consumption (Grade D), Cristiana 1 had water that had a moderate risk factor (Grade C) to human health, while the rest of the 6 farms had very safe drinking water (Grade A and B). Based on the findings, short and long-term recommendations on sanitation practices were made to help farmers with the current water situation.

Keywords: Groundwater; pollution; nitrate; rural settlement; Omaheke region, Namibia

ISTJN 2017; 10:56-67.

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ISSN: 2026-7673

1 Introduction

Water quality is a term used to express the suitability of water for various uses or processes. Water quality assessment provides the base line information on water safety. Since water quality in any source of water and at the point of use, can change with time and other factors, continuous monitoring of water is essential (UNICEF 2015). Water quality can be defined by a variety of variables which limit water use. Any specific use has certain requirements for the physical, chemical or biological characteristics of water (Ayers and Westcott 1976). Namibia is extremely vulnerable to the effects of water pollution, mainly because of the country's limited supply of surface water and high dependence on groundwater sources. Once it has been contaminated, groundwater is virtually impossible to clean up (Italtrend 2009). In the absence of strictly implemented local and transboundary policies, pollution from pesticides, excess fertilizers and other substances is likely to increase in the decades to come.

Namibia has not succeeded to supply all its populations with piped water, which is deemed to be the best method of decreasing water borne related diseases. A large percentage of the population use water from other sources such as rivers, wells and boreholes. The quality and safety of such water sources is generally considered poor, and therefore is a potential health hazard. A huge challenge in water and sanitation in Namibia is limited access to potable water and sanitation services (WHO 2004). Fluoride, nitrate, sulfate and total dissolved solids are the constituents making water unfit for human consumption. In wells used for livestock watering, *E. coli* is present 99% of the time, as *E.coli* is an indicator for contaminated water through feacal pollution (Ishii and Sadowsky, 2008). Groundwater can be used effectively if it is replenished by natural recharges. The availability of groundwater depends on a combination of sufficient precipitation and favorable hydrogeological conditions (Boutin et al. 2011).

It is against this background that the focus of this study was to evaluate and improve water quality and sanitation practices by testing the groundwater and providing recommendations to challenges that farmers may encounter.

2 Study area

Namibia is divided into 14 regions, Omaheke region being one of them. Figure 1 displays the geographical location of Omaheke region and the eight farms that were included in the study. Its capital is Gobabis and it lies on the eastern border of Namibia. It is the Western extension of the Kalahari Desert.

There are about 900 commercial and 3500 communal farmers in the Omaheke region

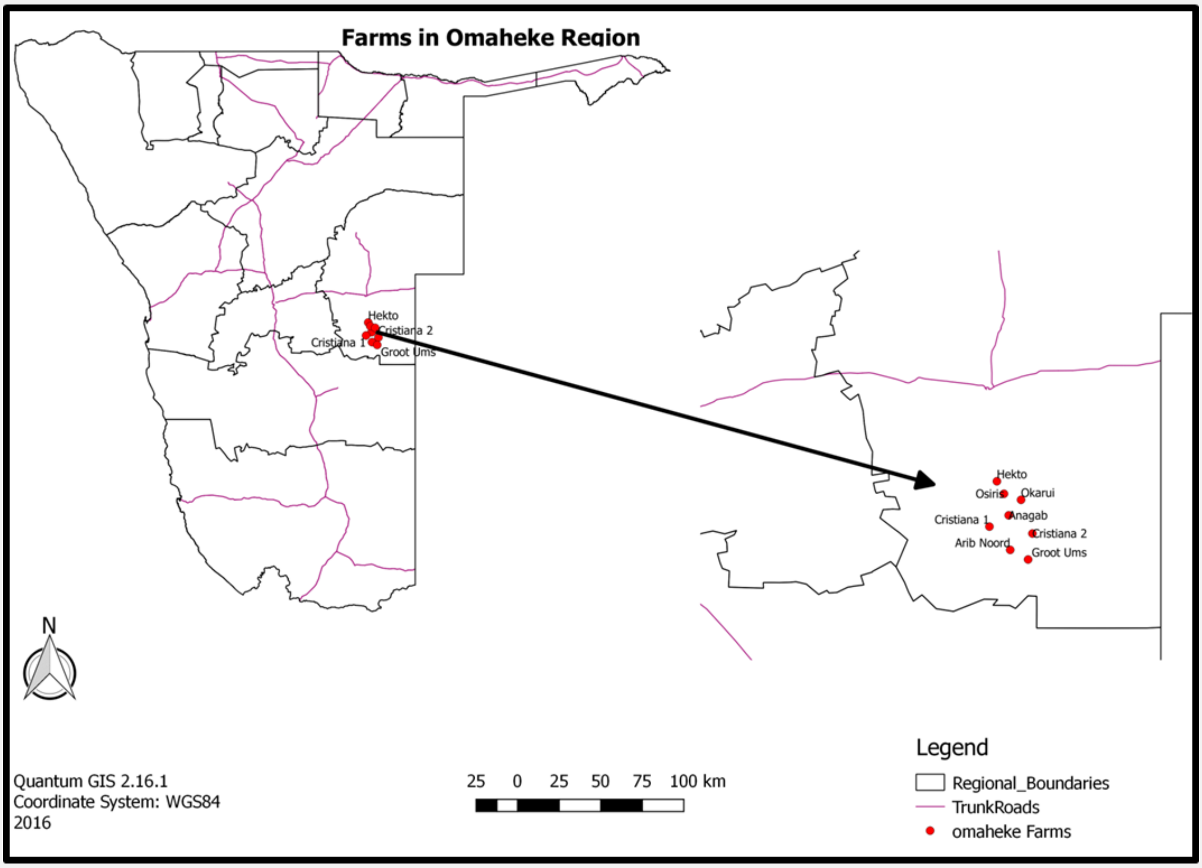

Figure 1: A map of the 8 farms sampled in Omaheke Region.

and most of them are cattle breeders (Stadtler et al. 2005). The low availability of water resources and the lack of infrastructure in Omaheke region, contributes to it being sparsely populated. The total population is about 80,000 (AFRICON 2002).

According to the authors (Stadtler et al. 2005), the success rate of boreholes drilled in the Omaheke region is less than 10%, because groundwater recharge is low due to sporadic rainfall and high evaporation, which are about 400 mm/a and 3,000 mm/a, respectively. Over 70% of the population living in Omaheke region depends on groundwater as their only source of water. This is supported by a study done by Hangara et al. (2011), that showed that respondents indicated that borehole water is their main source of water (92%). Most of them are solely dependent on farming and use the boreholes for livestock watering. The development and improvement of local groundwater resources is challenging because of unfavorable geological conditions.

3 Materials and Methods

Groundwater samples were collected in August 2016 on 8 farms, namely: Anagab, Arib Noord, Cristiana 1, Cristiana 2, Osiris, Okarui, Hektor and Groot Ums, situated on the road from Gobabis to Aranos (C20). The criteria used to select the 8 farms were geography, access and distance between farms. As water may not be used for sampling after 24 hours (APHA 1998), the farms close to one another were chosen to get the samples back to the laboratory within this time frame. A study done by Boutin et al. (2011) on ground water in Hardap region in Namibia, which has similar geological and geographical conditions as Omaheke region (Mendelsohn 2006) displayed that nitrate, total coliform, faecal coliforms and *E.coli* were detected at levels that were dangerous to human health, therefore this study only encompasses those four parameters. The research was divided into three parts:

3.1 Water infrastructure

Visual evaluation of the farms was carried out by evaluating the physical landscape, distance from the houses and corrals and location of livestock in relation to the borehole, and how the residents and livestock interacted with the water source. Conditions of the wind pumps, boreholes, dams, water tanks and water pipes were inspected and the current sanitation systems and practices and their potential impacts on the water were assessed.

3.2 Social baseline

Questionnaires were administered based on the practices that influenced the cleanliness of the existing water system and on what the residents perceived to be the main concerns about the current state of their water situation.

3.3 Nitrate and Microbial parameters

Water was collected in 250ml dark bottles for nitrate determination and in 500ml clear bottles for bacteriological determination. The sampling, preservation and transportation were conducted according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA 1998). The bacterial component encompassed Enterococcus, Coliform and *E. coli* counts. Water samples were transported to a professional laboratory for testing. Both bacterial and chemical properties of water were compared with the guidelines for safe drinking water used by NamWater, (NamWater adopted the existing South African guidelines) (MAWRD) (Table 1) and WHO (Table 2).

Table 1: NamWater water quality group description.

Group	Nitrate (mg/L)	Total coliform counts/100 ml	Faecal coliform counts/100 ml	*E.coli* counts /100 ml	Chemical description	Biological Description
A	10	0	0	0	Water with excellent quality	Water which is bacteriologically very safe
B	20	10	5	0	Water with good quality	Water which is bacteriologically still suitable for human consumption
C	40	100	50	10	Water with low health risk	Water with a bacteriological risk for human consumption which requires immediate action for rectification
D	>40	100	50	10	Water with high health risk, or water unfit for human consumption	Water which is bacteriologically unsuitable for human consumption

Table 2: Health based guidelines by the WHO (2011) value for drinking water.

Parameter	Water Quality Status
Nitrate	50 mg/L
Faecal coliforms	0 in a 100ml sample
Total coliforms	0 in a 100ml sample
E.coli	0 in a 100ml sample

4 Results

4.1 Water infrastructure evaluation

All the farms in Omaheke region exhibited the same general infrastructure; each consisted of a windmill, solar powered generator or a diesel pump borehole, either 10 000L or 20 000L water tanks (reservoir), concrete dams, some enclosed with iron sheets. All dams sampled were open on top. Some of these dams were not being used due to damage of the concrete or the pipes pumping water into the dam. Livestock troughs were extremely near to the water source. Visual evaluations of the water sources showed that most of the water infrastructure is functional although occasional maintenance is necessary, especially where water was leaking from damaged pipes.

4.2 Social baseline

The social baseline was determined from our interviews conducted on the 8 farms. Based on the interviews, all residents said that they get their water from either a windmill, solar or a generator powered borehole. Most workers said that home owners use modern water systems, whereby water is distributed from the water storage tanks to the main house, while workers get their water from a tap with a bucket at the water source; except in Okarui where the workers built a system whereby water flows from the borehole into a tank of an old abandoned truck which they connected to underground pipes to their houses.

The primary uses of water on these farms were for human consumption, cooking, bathing, laundry, and livestock watering, while secondary uses were for gardens. Arib Noord was the only farm that had a garden.

Most people could not estimate how much water was being used daily, as most farms sampled had a lot of livestock e.g. chickens, goats, sheep, cows and horses, and these animals consume a lot of water daily. The people on the farms said they discard used water e.g. after bathing; cooking or laundry, by throwing it outside the yard on the ground. All farms have a rubbish dump where they collect rubbish and burn it, once too much rubbish piles up.

The interviewees claimed that the water quality in Omaheke region is good because it is not brackish. The water did not give the children on the farms diarrhea, if it was not boiled prior to ingestion, therefore the people concluded that the water does not cause any health problems.

Very little rusting of metal and water pipes were observed, but in numerous cases it was found that water was leaking from the infrastructure. All the farms sampled had either a long-drop or a flush toilet in the main house, but the workers resorted to the bush method. None of the farms sampled had a dry toilet system. The residents said that they fix their broken or damaged infrastructure themselves.

4.3 Nitrate and Microbial parameters

4.3.1 Nitrate Composition

Figure 2 shows that none of the farms had extremely high levels of nitrate. The nitrate levels ranged between 6.8mg/L to 22.2mg/L, thus, the water was fit for human consumption. All farms had a nitrate level less than that of the WHO (2011) health based guideline for drinking water which is 50mg/L. According to NamWater's safe drinking water guidelines, Cristiana 1, Cristiana 2, Groot Ums, Okarui, Hektor and Osiris all had water classified as Grade B, which means that the water is of good quality. Arib Noord and Anagab had water classified as Grade A, indicating that the water is very safe to drink at the current nitrate level.

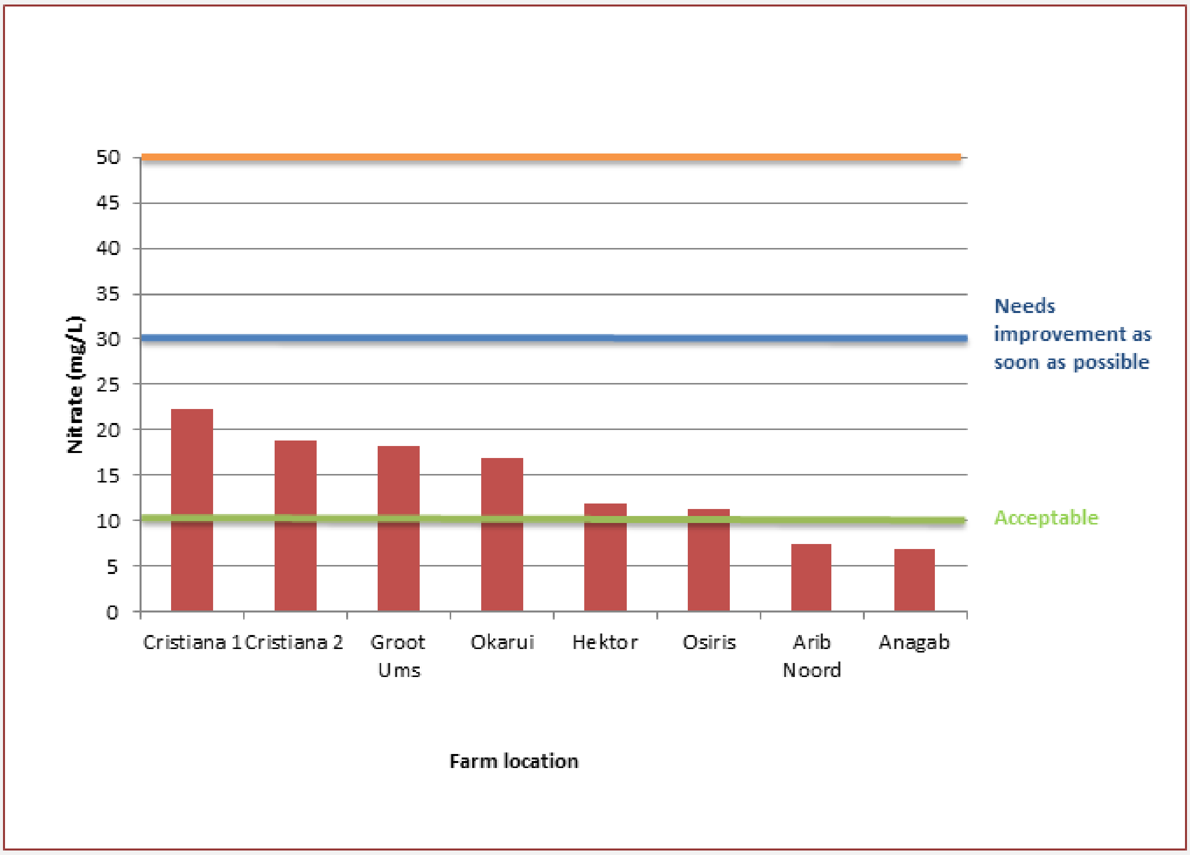

Figure 2: Nitrate results for the 8 sampled farms in Omaheke.

4.3.2 Microbial Composition

Table 3 shows that no faecal coliforms and E.coli were found in any of the farm's water supply, which complies with the WHO (2011) and Namwater's guidelines for safe drinking water. Enterococci were only found in Hektor's and Groot Ums' water supply and total coliforms were present in larger quantities in the water supply of the farms, except for Okarui, Anagab and Arib Noord.

Table 3: Summary of the Microbial composition of the eight farms in Omaheke region.

Location	Total coliforms count/100ml	Faecal coliform count/100ml	*E.coli* count /100ml	Enterococci count/100ml
Hektor	10	0	0	1
Osiris	8	0	0	0
Okarui	0	0	0	0
Anagab	0	0	0	0
Arib Noord	0	0	0	0
Groot Ums	164	0	0	1
Cristiana 1	36	0	0	0
Cristiana 2	8	0	0	0

4.3.3 Nitrate and bacterial grading

On average, the bacterial results show that on most farms the water is of acceptable quality, ranging from Grade A-B, except for Cristiana 1 (Grade C) and Groot Ums (Grade D). According to the nitrate classifications, water on all the farms are fit for human consumption as none of the nitrate levels are above Grade B. From all the farms sampled, only Cristiana 1 and Groot Ums have water that is not classified as safe to drink (Table 4).

5 Discussion

The World Health Organization (2004) in association with UNICEF estimated that 2.5 billion people globally were lacking improved sanitation facilities and as a result they practice open defecation. This statement coincides with the results found on the 8 sampled farms along the Aranos road. All the studied farms had either a flush toilet or a long-drop toilet in the main house, but farm workers did not have any kind of toilet, so they were 'forced' to use the old bush method.

The construction of toilets could help reduce the nitrate level in the water as well as the bacteriological content as there will be fewer faeces on the ground to infiltrate and pollute

Table 4: Nitrate and bacterial grading and classification of the eight sampled farms in Omaheke region.

Farm	Nitrate Classification	Bacteriological Classification	Description of Classification
Hektor	B	B	very safe water
Osiris	B	B	very safe water
Okarui	B	A	very safe water
Anagab	A	A	very safe water
Arib Noord	A	A	very safe water
Groot Ums	B	D	Water with high health risk, or water unfit for human consumption
Cristiana 1	B	C	water with a risk factor which requires rectification
Cristiana 2	B	B	very safe water

the ground water source (Graham and Polizzotto 2013). At Osiris, which was graded B, for both the nitrate level and the bacteriological content could be due to the long drop toilet in the main house as the faeces could potentially infiltrate into the groundwater supply (Ayers and Westcott 1976).

The Grade B nitrate classification at Cristiana 1, Cristiana 2 and Osiris could be attributed to the fact that these farms do not have fences around their water sources to prohibit livestock from defecating near the water sources as well as to prevent the animals from walking on and damaging the water pipes. Defecation near the water source could potentially cause faeces to infiltrate into the ground and contaminate and pollute the groundwater source (Graham and Polizzotto 2013). Damaging of the water pipes can cause faeces, microorganisms and other smaller organisms to enter these water pipes and pollute the water running through the pipes from the water source to the houses. The reason why water at Cristiana 2 and Okarui is very safe to drink could be because livestock were not allowed near the water source.

To reduce the nitrate level as well as the bacteriological content of the water at Groot Ums, Cristiana 1, Cristiana 2 and Okarui, the livestock troughs will have to be moved away from the water source. Where there are a lot of animals and faeces, there are usually more insects. As most farms have open dams and these dams are not fenced off, animals defecate near the dam which attracts insects. These insects whether they are flying or crawling insects can defecate in the water and increase the bacteriological content of the water (Smith 1970).

Our objective was to draw conclusions through comparisons of infrastructural evaluations for each farm. We found that the farms had similar infrastructural and geographical conditions. A lack of repairs of the infrastructure e.g. the broken stopper at Cristiana 2 and the dam's wall at Osiris that farm workers tried to fix but were still leaking can be attributed to monetary constraints, lack of equipment or lack of skilled workers and time. The lack of maintenance of the infrastructure could also be seen from the rust on farm infrastructure on farms like Groot Ums, Osiris, Cristiana 1 and Arib Noord, the cracked cement walls of the dams on Anagab and Osiris and the leaking iron sheets of the dam at Hektor.

Anagab and Arib Noord had very low levels of nitrate in the water (6.8mg/L and 7.4mg/L, respectively). The fact that the water source is fenced off, could be the reason for the low nitrate level and less faeces is found near the water source and so less faeces infiltrate into the ground water source. None of the farm's nitrate levels exceed or even come close to the (dangerous) guidelines for nitrate in drinking water. The NamWater guideline for high nitrate level is 50g/mL and Cristiana 1 had the highest nitrate level of 22.2g/mL. According to the WHO (2002) water quality guidelines, 25% of the water samples collected were a health risk and 75% of them were at low risk i.e. safe drinking water.

Pollution in water systems can be attributed to livestock faeces, because these livestock faeces are partly composed of both nitrates and phosphates (Ayers and Westcott 1976), and this pollution of water can cause ill health. Therefore, a key component to improving access to safe drinking water and sanitation starts with monitoring and maintenance of water systems and infrastructure.

6 Conclusion

Based on infrastructural evaluation we concluded that settlements in Omaheke region had very little rust on the water infrastructure and all farms have either long-drop or flush toilets in the main house. To improve the sanitation facilities and water quality on the farms, farm workers should also get or use flush or long-drop toilets, rather than the bush method.

From the semi-structured interviews, we concluded that farm workers are unaware that their unhygienic practices can cause groundwater contamination. The people also concluded that the water did not give the children on the farms diarrhea, if it was not boiled prior to ingestion and that the water didn't have a brackish taste, which is supported by the results.

The Grade B nitrate classification at Hektor, Osiris, Okarui, Groot Ums, Cristiana 1 and Cristiana 2 can be attributed to livestock defecation near the borehole as well as low basic hygiene practices. Although most farms have very safe drinking water and only two farms have water that requires rectification or that is unfit for consumption, it is crucial to ensure that the water remains in a condition that is safe for human consumption. The two farms, Groot Ums and Cristiana 1, that have water of lower quality, because of the high bacterial content should take measures to treat the water. The best method will be finding an alternative source of water, till the current water quality situation can be improved.

Acknowledgements
The authors express their gratitude to all the interviewees on the farms, who were kind enough to answer questions and allow us to take water for sampling.

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