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POLICY BRIEF

SASSCAL
Southern African Science Service Centre for Climate Change and Adaptive Land Management
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Issue 7 / January 2025

"Hand-dug Wells in Namibia: An Underestimated Water Source or a Threat to Human Health"

Scientific Evidence of Water Quality and Health Risks in the Cuvelai Etosha Basin

The COVID-19 pandemic has demonstrated the crucial importance of sanitation, hygiene, and adequate access to quality water for preventing and containing diseases. Despite that Namibia has done well in ensuring that its people have access to safe drinking water, significant gaps remain in the provision of improved access to safe drinking and sanitation. Water, sanitation, and hygiene services are necessary for many linked sustainable development goals, including poverty, health, gender and environmental health. Hence, monitoring and maintaining of hand-dug wells can contribute significantly to achieving SDG 6 targets in Namibia, which will culminate in achievement of SDGs 1-hunger reduction and 2 -poverty eradication, hence fostering a healthier and more sustainable environment for its inhabitants.

KEY MESSAGES AND RECOMMENDATIONS

- The entry or access of animals in the vicinity of hand-dug wells should be restricted to prevent defecating near the hand-dug wells.
- Hand-dug wells should be properly reinfored to prevent collapse and sensure long-term stability. Ensure gentle slope or a collection basin around the well to channel surface water into the wellbore. This helps replenish the groundwater and enhance the well's productivity, especially during dry seasons.
- The top part of the hand-dug wells should be elevated from the ground to prevent inflow of surface runoff.
- Disinfectant needs to be added, e.g. chlorination tablets' before drinking. It is also very important that the turbidity first needs to be removed, e.g. with filtration.
- Hand-dug wells should be routinely assessed for water quality and protected against recontamination.

INTRODUCTION

The United Nations highlighted that over 3 billion people worldwide are at risk because the health of their freshwater ecosystems is unknown as they are not monitored regularly UN-Water (2021). In Namibia, more than half of the rural communities in the northern part of Namibia Cuvelai- Etosha Basin (CEB) depend on groundwater as a primary source of domestic water supply and livestock watering (Hamutoko, 2018). Even though most of the population access groundwater with properly constructed boreholes, there is still a significant number of communities that rely on hand-dug wells. Although these hand-dug wells often have visible debris floating in them, they are nevertheless utilized as drinking water without treatment when there

is no alternative source of water. Neither the water quality in these hand-dug wells nor the quantity of water resources in these shallow aquifers that are accessed by hand-dug wells are assessed or monitored. Therefore, groundwater in these aquifers faces pollution, both natural i.e. fluoride and TDS, and anthropogenic for example fertilizers, pesticides, as well as effluents from cattle farming and domestic activities. The lack of a developed water supply system together with the lack of sanitation or waste-water treatment systems in rural areas are also among the factors that increase the risk of water-borne infection. Additionally, the design of hand-dug wells (i.e. unprotected, no lid cover) and human activities around the hand-dug wells (i.e. troughs placed beside the well), have a significant influence on the quality of the groundwater (Figure 2). Water in the hand-dug wells may harbour microorganisms such as viruses, bacteria, fungi, and protozoa which may be pathogenic and induce diseases leading to death in severe cases. In some cases, community members who cannot afford monthly contributions for maintenance and diesel of the boreholes tend to use hand-dug wells even though boreholes exist in their close proximity.

EVIDENT BASED SAMPLING METHODS AND LABORATORY ANALYSIS FROM TWO RESEARCH STUDIES

METHODOLOGY 1: Detection of bacteria

A. Detection of Escherichia coli and Harmful Enteric Bacterial Pathogens in Domestic Hand-Dug Wells

This brief is based on scientific evidence derived from SASSCAL 1.0 research portfolio Task 007. Samples were collected from hand-dug wells in the CEB. A total number of Forty-four (44) hand-dug wells from the Ohangwena and Omusati regions of Namibia were collected and analysed for microbiological water quality during the dry and wet seasons (McBenedict et al. 2018). The water samples were collected directly from hand-dug wells in sterile 200 ml bottles. The bottles were tied to the rope and then lowered into the hand-dug wells. The samples were stored in ice during transportation to the University of Namibia for analysis (Fig 1). The bacterial cultures from each water sample were screened for the presence of; *Citrobacter, Escherichia, Klebsiella, Enterobacter, Proteus, Salmonella, Shigell, and Pseudomonas species* (McBenedict et al. 2018).

Figure 1: On-site parameter measurements in the field

B. 16S rRNA metagenomics analysis

Analysis using 16S rRNA metagenomics was performed as described in McBenedict et al. (2019). Water samples (200 ml each) were centrifuged at 7,000 xg for 1 hour to concentrate bacteria, reducing the volumes to 10 ml by discarding the supernatant. DNA was extracted using the SEEPREP 12 kit and quantified with a NanoDrop-2000. The 16S rRNA gene was amplified via PCR with primers 27F and 1492R, using a Bio-Rad thermocycler. Amplicons were sequenced on an Illumina MiSeq at MR. DNA, and sequence data were processed through a proprietary pipeline. Metagenomic data were cleaned, denoised, and analyzed for taxonomic classification, revealing bacterial community compositions. A phylogenetic tree of zoonotic bacteria was constructed using the Maximum Likelihood Method, with evolutionary analyses conducted in MEGA 7. Seasonal influences on bacterial abundance, diversity, evenness, and richness were evaluated using SPSS, with significant differences assessed via t-tests and Wilcoxon tests.

METHODOLOGY 2: Spatio-temporal variations of hydrochemical and stable isotopes patterns of ground water in the hand-dug wells

Water samples were collected from 48 hand-dug wells in two core study regions over a period of three years (2014–2016) across ten sampling campaigns. Physical parameters, including pH, electrical conductivity (EC), redox potential (Redox), oxygen content (O2), and temperature (T), were measured in the field using Hach portable instruments. Water level measurements were obtained through an electrical contact gauge. Major ions and stable isotopes samples were collected following standard procedures. The hydrochemistry analyses were conducted at both the Analytical Laboratory Services in Windhoek, Namibia, and the hydrochemistry laboratory of the German Federal Institute for Geosciences and Natural Resources (BGR) in Hanover, Germany. Stable isotopes were measured at the University of Namibia (UNAM) and BGR laboratories, using an off-axis integrated cavity output spectroscope (OA-ICOS, Los Gatos DLT-100) and a cavity ring down spectroscope (CRDS, PicarroL2120-i) respectively. Hamutoko et al. (2018) provide detailed discussions about the methods employed at each laboratory.

Figure 2: (a) Shallow Hand-dug well used for domestic purposes in the CEB of Namibia (Source: Hamutoko & McBenedict 2018); (b) examples of Deep hand-dug wells locally known as "Eendungu" (cylindrical-shaped hand-dug wells (Source: SASSCAL Task 007).

FINDINGS DERIVED FROM SAMPLE WATER ANALYSIS

A. Detection of Escherichia coli and Harmful Enteric Bacterial Pathogens in Domestic Hand-Dug Wells

This study recorded total coliform counts ranging from 160 CFU/ml to 297 CFU/ml in the wet season, and 140 CFU/ml to 273 CFU/ml in the dry season (Fig. 3). Bacteriological species of Citrobacter, Escherichia, Klebsiella, Enterobacter, Proteus, Salmonella, Shigella, and Pseudomonas species were detected in hand-dug wells from the CEB (Fig. 4). The detected species in this study signifies a public health threat and emphasizes the need to treat the water prior to consumption. Chi-square showed that there was no significant variation in the presence of Citrobacter ($P > 0.05$), Escherichia ($P > 0.05$), Klebsiella ($P > 0.05$), Enterobacter ($P > 0.05$), Proteus ($P > 0.05$) and Pseudomonas ($P > 0.05$) species between the wet and dry season, and a significant difference in the presence of Salmonella ($P < 0.05$) and Shigella ($P < 0.05$) species between the wet and dry seasons (Source: McBenedict et al. 2018).

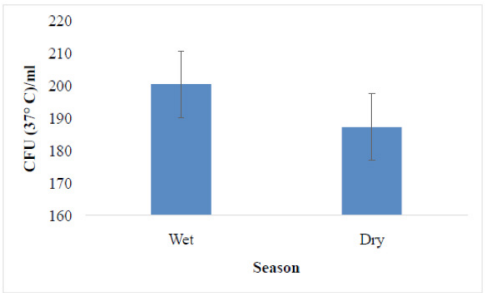

Figure 3: Total coliform counts (CFU's) grown at 37°C from hand-dug well water samples of the CEB in the wet and dry seasons. (Data source: McBenedick 2018)

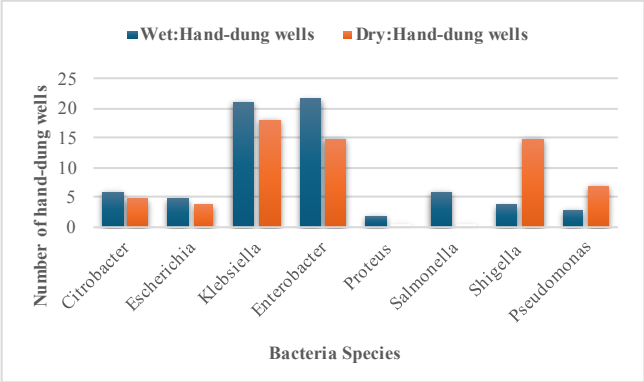

Figure 6: Bacteria Species found in hand-dung wells. (Data source: McBenedict 2018)

Figure 5: (Source: The Namibia 2018)

B. 16S rRNA metagenomics anlysis

A total of 57 zoonotic pathogens were detected and analyzed using a phylogenetic tree (Fig. 6). Clusters formed with significant bootstrap values included: *E. cloacae, Klebsiella sp., Hafnia sp., E. coli, S. enterica, and Vibrio spp. (79% bootstrap); A. faecalis, Alcaligenes sp., and Bordetella sp. (100%); P. aeruginosa and Pseudomonas spp. (96%); Chlamydia spp. and Waddlia sp. (82%); A. butzleri, A. cryaerophilus, and Arcobacter spp. (95%); Anaerorhabdus spp. and Erysipelothrix spp. (97%); P. polymyxa and Paenibacillus spp. (80%); and B. pumilus and B. subtilis (84%). Other clusters included Anabaena spp., Rhodococcus spp., Actinomyces spp., P. acnes, A. viscosus, Mycobacterium spp., N. nova, Corynebacterium spp., C. urealyticum, D. maris, and Dietzia spp. (73%). B. anthracis* served as the outgroup.

The Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that zoonotic pathogen data were not normally distributed ($P < 0.05$). The Wilcoxon rank test showed significant seasonal differences in the abundance of Brucella spp., Bacillus spp., Chlamydia spp., Enterococcus sp., Legionella spp., Leptospira spp., Mycobacterium spp., Salmonella enterica, and Staphylococcus spp. (McBenedict et al. 2019). Higher abundances in the dry season were observed for Brucella spp., Bacillus spp., Chlamydia spp., Enterococcus sp., Legionella spp., and Salmonella enterica, whereas Leptospira spp., Mycobacterium spp., and Staphylococcus spp. were more abundant in the wet season. No significant seasonal difference was found for Escherichia coli, Helicobacter spp., Treponema spp., and Klebsiella sp. Shannon-Wiener diversity indices and species richness data were normally distributed ($P > 0.05$). A Paired sample t-test revealed a significant seasonal difference in Shannon-Wiener diversity (H') indices but not in species richness. Simpson diversity indices and species evenness data were not normally distributed ($P < 0.05$), and the Wilcoxon rank test disclosed significant seasonal differences in Simpson diversity (D) and species evenness.

Figure 6: Phylogenetic tree depicting the evolutionary history of the detected zoonotic bacterial pathogens. Branches corresponding to partitions reproduced in less than 70% bootstrap replicates were collapsed.

Spatial variations in water chemistry and isotopes

According to WHO recommendations, the water quality in most wells is (theoretically) not permissible for drinking and domestic purposes because of high turbidity, microbiological parameters (e.g. bacteria), TDS, potassium, fluoride, sulphate, and nitrate concentrations, which are above acceptable values for drinking water.

The hydrochemical water types imply that pans in Ohangwena are recharge zones while in Omusati they are discharge zones hence the TDS relatively high TDS values are observed in Omusati region compared to the Ohangwena region (Fig 7). High fluoride is observed in the Ohangwena region were fluoride increases with depth, as it has higher concentrations in the boreholes that are tapping the deeper regional aquifer. The spatial heterogeneity as shown in figure 8 can be attributed to lithological, climatic and anthropogenic factors. The water stable isotopes (δ18O and δ2H) signatures suggest that in the ephemeral river, rainwater infiltrates through the soil matrix to recharge the perched aquifer, but it does not reach the regional aquifer. In contrast, the pans/depressions are recharged through mixed processes; i) water that is affected by evaporation either before or after infiltration and ii) water that infiltrates through fast preferential flow paths (Hamutoko, 2018).

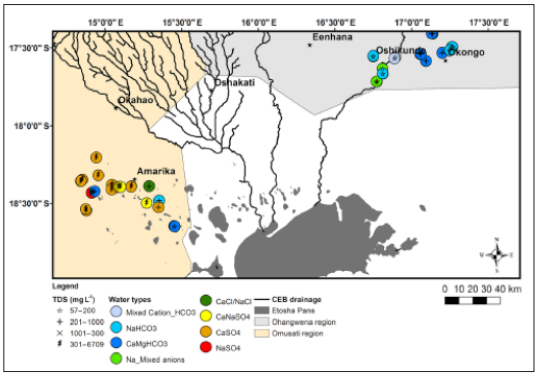

Figure 8: Spatial distribution of TDS and water types in the study area. (Source: Hamutoko 2018)

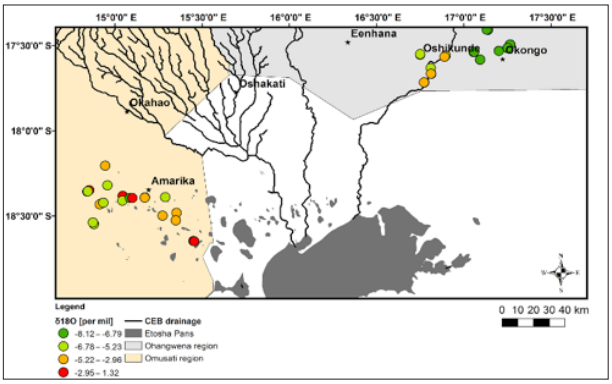

Figure 7: Spatial distribution of TDS and water types in the study area. (Source: Hamutoko 2018)

Figure 9: shallow wells (funnel-shaped hand-dug wells) locally known as "Omifima"

CONCLUSION

The study highlights significant health risks posed by zoonotic bacterial pathogens, revealing their high prevalence and seasonal variations in hand-dug wells. Pathogens such as Brucella, Bacillus, Chlamydia, Enterococcus, Legionella, and Salmonella spp. are more abundant in the dry season, while Leptospira, Mycobacterium, and Staphylococcus spp. peak in the wet season. These variations are influenced by environmental factors like temperature and water scarcity. Poorly constructed wells facilitate pathogen transmission, raising concerns about antimicrobial resistance (AMR) due to inappropriate antibiotic use in livestock. The detection of multidrug-resistant bacteria underscores the need for improved water management, surveillance, and antimicrobial stewardship to mitigate public health risks unless subjected to appropriate disinfection methods. Contaminants include both natural (e.g., fluoride, TDS, potassium, sulfate, etc.) and anthropogenic (e.g., bacteria, nitrate, turbidity) sources. Anthropogenic contaminants are attributed to inappropriate well design, which allows all the dirt, including livestock droppings, to be washed into the wells with surface water, and the transport of dry faeces as wind-blown dust and transport into the aquifer by infiltration. Therefore, these well designs increase the vulnerability of shallow aquifers. The water from the hand-dug wells (Fig 9) is not safe for drinking.

CALL-TO-ACTION

- The hand-dug wells should be assessed for water quality periodically by the Ministry of Health and Social Services and the Ministry of Agriculture Water and Land Reform.
- Solar-pumped boreholes could be an alternative for villages where people cannot afford to pay maintenance and diesel.
- The well owners should be trained on the maintenance of the well thus eliminating resistant bacteria such as cholera bacterium (Vibrio cholerae).
- Differences in the water hydrochemical composition as well as the processes governing perched aquifers must be taken into account when planning groundwater management in the basin.
- Education on basic water usage and protection will also be an advantage i.e. the local communities should be trained/ made aware of the limited resource and how much water can be abstracted sustainably.
- Policies should also advocate for value addition or upscaling of all the traditional hand-dug wells that have been providing water to communities for years.
- Boiling water must become a standard procedure for all drinking water from the boreholes.
- Proper hand-dug well designs and protection zones must be encouraged in the whole basin.

ACKNOWLEDGEMENT:

Southern African Science Service Center for Climate Change and Adaptive Land Management is grateful for the Financial Funding by The German Ministry of Education and Research (BMBF) for supporting Project Task 007 and Task 010 research work through SASSCAL Research Portfolio 1.0. Appreciation also given to SASSCAL Task 007 and Task 010 Project Team for research conducted.

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