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Hand dug wells in Namibia: An underestimated water source or a threat to human health?

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ABSTRACT

The rural population of parts of northern and western Namibia uses hand dug wells for their domestic water supply, partly because no other source (e.g., deep tube wells) is available, but also as a substitute for pipeline water that is often perceived as being too expensive. The water quality of these wells is usually not monitored or controlled, thus a study has been carried out in four study areas in Namibia: southern Omusati/Oshana area, Okongo/Ohangwena area, Omatjete/Omaruru area, Okanguati/Kunene area. Hand dug wells have been tested for on-site parameters: electric conductivity, pH and temperature while samples were taken for major inorganic constituents and several minor and trace constituents including fluoride and nitrate. In addition a sampling campaign in 2010 included the determination of coliform bacteria and *Escherichia coli*. Results were classified according to the Namibian Water Guidelines. The constituents making the water unfit for human consumption are fluoride, nitrate, sulphate and total dissolved solids. Contamination by *E. coli* was indicated in nearly all wells that are used for livestock watering. For the Omatjete/Omaruru study area an isotope based study on the source of nitrate has indicated manure as a source. The range of recharge values obtained for the studied villages ranges from 1 mm/a to locally more than 100 mm/a. Overall the water resource in the shallow perched aquifers in the study areas is in many places inappropriate for human consumption. Treatment to improve the quality or introduction of protection measures is necessary to bring this resource to an acceptable quality according to national and/or international standards.

1. Introduction

Namibia is the driest country of sub-Saharan Africa and surface water is only available for short periods during the year. People rely on other sources of water during dry periods, and access to groundwater was a key factor enabling people to settle in northern Namibia many hundreds of years ago (Christelis and Struckmeier, 2001). Traditionally, hand dug wells were used to tap groundwater from shallow perched aquifers but have recently been replaced by boreholes that abstract from deeper regional aquifers where yield and quality allow. In addition, a pipeline system of several hundreds of kilometres that distributes treated surface water from the Kunene River to the densely populated parts of the country is also used. However, in large parts of northern Namibia, the population uses hand dug wells' water for domestic and livestock purposes. This is partly because pipeline water has not reached all regions, but people also use water from hand dug wells as a substitute for pipeline water as the latter is often perceived as too expensive (Klintenberg et al., 2007).

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, in respect to its suitability for a particular purpose (US Geological Survey, 2009). Water is an excellent solvent and interacts with substances as it moves through soils and rocks. For that reason, groundwater will often have more dissolved substances than surface water. Typical diseases resulting from the consumption of water with high total dissolved solids are kidney problems and hypertension; where small children and people with pre-existing health problems are more vulnerable (WHO, 2004).

Water contaminants can be natural or human induced (US Geological Survey, 2009). Naturally occurring contaminants are present in rocks and sediments. Industrial discharges, urban activ-

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ities, agriculture, groundwater pumping, and disposal of waste can all affect groundwater quality. Contaminants from leaking fuel tanks or toxic chemical spills may enter the groundwater and contaminate the aquifer. Pesticides and fertilizers applied to grazing areas and crops can accumulate and migrate to the water table.

Safe water supply is crucial to societal development and growth, and therefore forms part of the United Nations Millennium Development Goals (Agatemor and Agatemor, 2010). Unsafe water is linked to a large number of infectious and life threatening diseases (WHO, 2004). Italtrend (2009) relates diarrheal causing agents in Namibia not only to unhygienic practice but also to the use of contaminated water. Agatemor and Agatemor (2010) in a water quality study in Nigeria, found that the highest faecal contamination levels occurred in hand dug wells. Besides on-site contamination, the quality of the water can be degraded by unhygienic methods of water harvesting. The most common water-quality problem in rural water supplies is bacterial contamination (Takem et al., 2009). The origin of bacterial contamination is likely attributed to result from inappropriate well designs that allow surface run-offs including livestock droppings to enter the well or to the lack of a protection zone (Agatemor and Agatemor, 2010). Studies of water quality of shallow/hand dug wells have been done for several countries in sub-Saharan Africa, e.g., for Malawi (Pritchard et al., 2008), Ghana (Nkansah et al., 2010), Cameroon (Takem et al., 2009), Nigeria (Efe, 2005; Agatemor and Agatemor, 2010) but are missing for Namibia. Although domestic water use accounts for only 9% of the total water consumption in sub-Saharan Africa (World Resources Institute, 1994), the benefits associated with an adequate supply, such as the effects on health, time savings, and greater productivity, are immense (Sharma et al., 1996; Whittington and Swarna, 1994).

The physical properties of an aquifer, such as thickness, rock or sediment type, and location, largely determine whether contaminants from the land surface will reach the groundwater or not. The risk of contamination is greater for unconfined aquifers than for confined aquifers because they lack an overlying confining layer to prevent the movement of contaminants and the vulnerability of aquifers increases with decreasing depth to water table (e.g., Aller et al., 1987).

Hand dug wells are used as a source of drinking water supply in large parts of northern Namibia, e.g., a baseline survey done by the Red Cross (pers. com. Levicki, 2013) in four constituencies in the Ohangwena region indicates that 64% of the households use water from hand dug wells for drinking and cooking; only 50% of them treat this water before drinking it. The study done by the Red Cross also reported that cholera occurred in the last three months in 2% of the 327 households interviewed. The water quality of hand dug wells is usually not monitored or controlled as this is not amongst the responsibilities of national or regional authorities (monitoring is limited to boreholes) nor do the users perceive a benefit of such activities.

As groundwater (including groundwater from shallow perched aquifers tapped by hand dug wells) is the most important water source in Namibia, recharge rates need to be assessed reliably in order to manage groundwater resources sustainably and to prevent over-exploitation. In general the recharge pattern is mainly influenced by the distribution of landscape, soil and vegetation units and shows high inter- and intra-annual variability depending on precipitation. Reviews on groundwater recharge estimation are available e.g., in Lerner et al. (1990), Simmers (1997) and Scalone and Cook (2002).

So far for areas with comparable environmental conditions in Botswana and Namibia, studies were done by e.g., Beekman et al. (1996), Selaolo et al. (1996), Wrabel (1999), Stone and Edmunds (2012), Külls (2000), Klock (2002), but shallow, perched aquifers like in north-central and north-western Namibia have not been included in any of these studies. Thus the work presented here fills that gap in this part of southern Africa. If direct recharge is the most important process, then the chloride mass balance method which is a reliable method can be used and the parameters for this methodology and its determination must be obtained. These parameters are relatively easy to obtain (e.g., Brunner et al., 2004; Wanke et al., 2008).

The first objective of this study is thus to assess the water quality of hand-dug wells in areas of Namibia where these are common. The typical contaminants in hand dug wells in Namibia are to be identified. Furthermore it should be investigated if there is a correlation between the set-up of hand dug wells and the water quality. This study also aims at assessing the available water resource.

2. The study area

Four study areas in different political regions were used in this study to get a regional idea of the water quality in Namibia's shallow perched aquifers: Omusati/Oshana, Okongo/Ohangwena, Okanguati/Kunene and Omatjete/Omaruru (Fig. 1).

North-central Namibia, where studies in the two regions Omusati/Oshana and Okongo/Ohangwena were done, is covered by sediments of the Kalahari Group (possibly up to 600 m thick) (Miller, 2008). Much of the fill of the Owambo Basin has been provided by the upper Kunene river system in the west and the sand-dominated Cubango Megafan further east. The area is characterized by reddish and white sand and sandstones with interbedded calcretes and silcretes overlying up to 300 m of variably cemented sands, clays and gravels. The sediments are flat lying and essentially sandy, not many exposures of rocks occur (Miller, 2008). Most of the knowledge about the sediments of the Kalahari has been derived from boreholes drilled for water supply and to a limited extent from observations around pans and along river cuttings. Hand dug wells in these regions are found in four different geomorphological settings: in flat ephemeral rivers (locally called oshana), in shallow calcrete dominated depressions, in deflation pans and in the slightly undulating flat sand fields (see Fig. 2 for examples).

The Okanguati/Kunene region is located in the north-western Namibia, with the granitic and gneissic rock types covering vast areas in the Kaokoveld (Miller, 1983). Mountain ranges of carbonate rock types related to the Otavi Mountain Land form the eastern edge of the area. The volcanics of the Etendeka are also seen in the area, and build the typical table mountain landscape of the Damaraland. Shale and mudstones of the underlying Dwyka Formation are also present in the Opuwo area. The Omatjete/Omaruru region is located in the Central Zone (CZ) of the Damara Belt, bordered by the Otjohorongo thrust to the north and the Okahandja Lineament to the south (Miller, 1983). The CZ is a high-temperature-low-pressure zone of the orogen and is characterized by sillimanite-cordierite metamorphic assemblages with numerous granitic plutons and fold structures (Miller, 2008). The CZ is divided into the northern Central Zone and the southern Central Zone, separated by the northeast trending Omaruru Lineament along which the lower Swakop Group rocks thickening rapidly northward (Miller, 2008). The southern part of the CZ is characterized by much deeper levels of exposure where pre-Damara basement gneiss, the Nosib and Swakop groups are present (Miller, 2008). In the latter two study areas hand dug wells are mainly found in ephemeral river beds and in local depressions (Fig. 2).

3. Materials and methods

This study has identified areas where hand-dug wells are typically used in Namibia: Omusati/Oshana, Okongo/Ohangwena,