Treated Wastewater as a Resource for Sustainable Water Supply in Windhoek, Namibia: Overview, Drivers and Benefits

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Abstract

For decades, Windhoek, which is situated in arid Namibia, was under chronic water stress due to diminishing water supply and increasing water demand. To enhance sustainable and adequate quantities of potable water for diverse water requirements, the first wastewater recycling plant in Africa was constructed. This paper provides an overview of Windhoek's water resources and shows how treated wastewater makes an invaluable contribution to promoting the security of supply. The paper concludes that the main drivers for implementing wastewater recycling plants are population growth, urbanisation and industrialisation coupled with poor rainfall, drought and climate change coupled with the paucity of alternative freshwater sources within this central area in Namibia. Windhoek's experience shows that treated wastewater does play a key role in the water supply system, but it requires adequate upgrading, comprehensive planning, training and ongoing commitment for its continued success.

Keywords: *Windhoek, treated wastewater, sustainability, water supply, water demand.*

Introduction

Namibia is the driest country in Sub-Saharan Africa, making water an extremely scarce natural resource. The central area, where Windhoek is located, has one of the highest water demands on the available water resources. This poses a major challenge to authorities to secure sufficient water for all user groups, which is further exacerbated by the fact that no adequate permanent surface water bodies exist in the immediate surroundings of the city and that most of the other local and regional water sources within the central area have been developed and are nearing the limit of their potential. The city forms an economic hub that hosts most of the successful, commercial companies in the country as well as the international airport, and is also host to the central government and

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all of the ministries. Windhoek's surface water availability is closely linked to the rainfall patterns that are extremely inconsistent in both time and space. High population growth rate, urbanisation and industrialisation, coupled with repeated periods of erratic rainfall and drought over the past decades, have placed tremendous pressure on Windhoek's water supply. Therefore, the water authorities had to develop unconventional but sustainable ways to augment the dwindling freshwater supply (Du Pisani, 2006). This is how water treated to drinking quality was introduced in Africa during the late 1960s.

Literature Review

Establishment of Wastewater Reclamation Plant in Windhoek

Wastewater reuse involves the collection and treatment of wastewater so that it may be re-used for further applications. Water reuse can also provide an alternative water supply for many activities that do not require drinking water quality, and, as such, allows for the saved drinking water to be used elsewhere (Tortajada & Van Rensburg, 2020). Windhoek is the first city in Africa to produce drinking water directly from domestic wastewater, capable of producing high-quality effluent to supplement the potable water supply to the city.

In 1968, after yet another dry spell, the local authorities decided to build a wastewater reclamation plant at Goreangab with a capacity of 4,800 m^3/d (Haarhoff & Van Der Merwe, 1996). Since then, the scheme has been successfully operated, undergoing several modifications to the original design made possible by ongoing water demand and by research and improvements in technology. Investigations conducted in 1991 recommended that with minor changes to the reclamation facilities at that time, the capacity could be extended and the final water quality could also be improved (Haarhoff, 1991). During the drought in 1992, where state supplies could not deliver the required quantity, the plant was upgraded and extended to an interim capacity of 14,000 m3/d to ultimately reclaim 21,000 m^3/d. During the mid-1990s, all the components of the reclamation system were reviewed, re-analysed and incorporated into the design of a new reclamation plant. After another severe drought in 1997, it was decided to build a new reclamation plant at a site adjacent to the Old Goreangab Reclamation Plant.

In September 2002, the New Goreangab Reclamation Plant (NGRP) was commissioned. The plant was initially designed to produce 27,000 m^3/d, but, because of continuous demand increases, has been upgraded from time to time and currently yields around 21,000 m^3/d (Gross, 2016). The system went through a series of modifications and improvements over the years and consistently produced water of acceptable quality. The upgrade was to promote the security of the potable water supply, helping to mitigate future water stresses in the region due to climate change.

Approximately 7% of the water used is partially treated and supplied for the irrigation of sports fields, parks and cemeteries (Lahnsteiner & Lempert, 2007). To date, the initial wastewater recycling plant is still being used to produce lower-quality effluent, providing irrigation water for numerous public parks, gardens and sports fields throughout the city. The carbon columns were decommissioned, but the rest of the process remains the same. On average some 3.600, m^3/day are currently treated for irrigation water. The demand varies seasonally and also in accordance with the rainfall amounts (Menge, 2010). This non-potable reuse process has enabled the city to maintain the recreational facilities to a reasonable standard despite the numerous water supply challenges. Irrigation water, which costs 50% less than potable water, is popular and allows public institutions to maintain their facilities during periods of limited supply. During the 2014-2016 drought, the water reclamation plant was expanded and now provides 20% of the city's total water supply (Van Rensburg, 2018).

Table 1. *Comparison of technologies*

Windhoek 1968	**Windhoek 2002**
Secondary treatment followed by: • Algae flotation • Foam fractionation • Chemical clarification • Sand filtration • Granulated activated carbon • Chlorination	Improved secondary treatment by: • Pre-ozonation (for iron (**Fe**) and manganese (**Mn**)) • Dissolved air flotation • Sand filtration • Ozonation • Granulated activated carbon • Membrane filtration (Ultrafiltration) (UF) • Chlorination
Reclaimed water flow: 4.8 Mℓ/day Reclaimed water contribution: 4%	Reclaimed water flow: 21 Mℓ/day Reclaimed water contribution: 25%

(Source: Law, 2003)

Treated Wastewater in Windhoek

In normal conditions, reclaimed water makes up about 20% of Windhoek's water supply, groundwater (20%) and NamWater (the country's bulk water supplier) (60%), drawing supply from a network of dams ranging from 70 km to 160 km from the city (Scott et al., 2018). Windhoek generates an average of about 12.8 Mm^3/year of domestic wastewater, which is a significant amount when compared to the second largest city of Walvis Bay, which produces an average of about 0.66 Mm^3/year. The domestic wastewater in Windhoek is treated through primary, secondary and tertiary treatment processes to attain a high quality of effluent that can be reclaimed to potable standards.

Currently, three reclamation plants are being operated by the City of Windhoek (CoW) for the purpose of providing: (i) treated water for potable use; (ii) treated water for irrigation and non-potable use; (iii) treated water for commercial irrigation projects (City of Windhoek, 2019). This approach falls in line with the Water Supply and Sanitation Policy (WASSP) principles, which priority is the provision of water for domestic use

(Government of Namibia. Ministry of Agriculture, Water and Forestry, 2008). Today, treated wastewater is considered a secure part of the water supply. Moreover, wastewater has become an indispensable resource for the survival and sustainable growth of the City, especially during drought periods. For example, during the 2015–2016 drought, the capacity of reclaimed wastewater was nearly doubled to increase the quantity of water supplied to Windhoek (Figure 2).

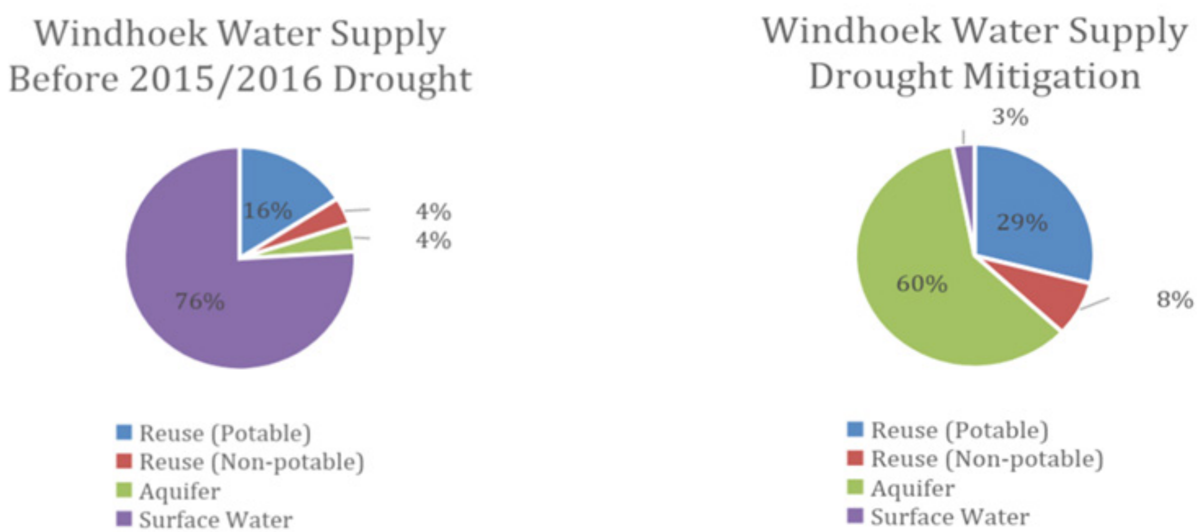

Figure 2. *Potable water reuse as a component of Windhoek's water supply*
(Source: City of Windhoek, 2019)

Current Water Yield and Requirements

Windhoek's main supply is from the Von Bach-Swakoppoort-Omatako Dam scheme (59,600 m^3/d) and the New Goreangab Reclamation Plant (41,000 m^3/d). When the three dams are operated on an individual basis, the 95% safe yield is only 13 Mm^3/a, mainly due to the huge evaporation losses from the Omatako and Swakoppoort dams. Through the conjunctive use of the three dams, water is transferred and stored in the Von Bach dam, which has the lowest evaporation rate due to the dam basin characteristics. This operating procedure improves the 95% safe yield from the three-dam system by approximately 7.0 Mm^3/a to a total of 20.0 Mm^3/a (Christelis, 2010). For water security purposes, the objective is to have a volume of water stored in Von Bach Dam that can supply Windhoek over a two year period (Menge et al., 2009).

Windhoek also receives drinking water from about 80 production boreholes. The total amount of water abstracted from the boreholes per annum ranges between 0.5 and 11.5 Mm^3. The water from the boreholes is not treated separately and is only chlorinated before it is pumped to storage reservoirs (Christelis, 2010). The distribution system is served by 17 reservoirs in 17 pressure zones. There are three wastewater treatment plants, two for domestic and one for industrial effluent. The final treated effluents from domestic sources are either reclaimed for drinking water or reused for irrigation (Menge et al., 2009).

Future Water Requirements

According to the projections in Namibia Statistics Agency's (2014) report, the City's population has increased to roughly 430,000. Due to the influx of people from the rural areas that increase the urban population at a higher rate than normal births and deaths over a short period, the City of Windhoek (CoW) has come under tremendous pressure to supply sufficient water. The CoW's limited financial resources combined with the size of the urban population constrain the development of adequate urban infrastructure, particularly the water supply (Lewis et al., 2018).

The increase in the number of people living in Windhoek is not only due to urban migration but also because of the natural growth of the existing population. Population growth and urbanisation are forcing rapid changes, leading to a dramatic increase in the demand for drinking water. According to a CoW report from 2016, Windhoek's annual population growth rate is currently 4.4%, implying a population doubling time of 16 years.

As the population and economic activity has grown apace since independence, water resources and the established water supply infrastructure have reached their limitations. In 2003, water planning studies for the central areas of Namibia and Windhoek predicted that demand would utilise all of the available water by 2013—which almost happened by the end of that year (Van Rensburg, 2018).

Windhoek's water demand alone is expected to nearly double by 2050—from the current 27 Mm^3/a to approximately 50 Mm^3/a. The City's population is expected to reach 790,000 by 2050 (Murray et al., 2018). Estimates place Windhoek's water deficit at almost 40 million m^3 by 2050. While city officials are aware of these risks and are busy considering mitigating steps, they must evaluate the rainfall patterns that are changing significantly from the norm, for instance during the record 2016 drought.

To mitigate the future water demands, two possible schemes are in the pipeline. Since there are no feasible long-term supply options within a 300km radius of Windhoek, two long-distance supply options are being investigated with cost feasibility studies. The first option involves linking the existing supply system for the central areas and Windhoek to the Kavango River, which is located to the north of Windhoek at the country's border with Angola. This scheme cover means a 250km transmission pipeline with high infrastructure and upgrading costs.

The second option proposes to construct a seawater desalination plant at the coast and will transfer water over a 365 km distance over an altitude of 1650 m. The exceptional altitude challenge complicates this long-distance water transfer scheme in terms of operational cost (Van Rensburg, 2018). According to Remmert (2017), these alternative augmentation schemes are not feasible at the moment, due to the extensive infrastructure required to transfer water over large distances and due to the huge capital that is needed. This would result in an uneconomic cost of water for all users. To ensure a long-term sustainable water supply and to expand the current water supply schemes, CoW is investigating the possibility of building an additional wastewater treatment facility to meet the mid-term water demand of this rapidly growing city (Lahnsteiner & Lempert, 2007).

Drivers for Upgrading and Increasing Treated Wastewater Infrastructure

Climate

Windhoek's water supply is predominantly dependent on climatic conditions. Similar regions to Namibia are likely to face longer and more intense periods of drought as a result of climate change. According to vulnerability assessments for Namibia, climate change will increase the temperatures by 1 to 4 degrees and rainfall will decrease by about 20%, with an increase in rainfall intensity. In 2016 for the first time, the Von Bach dam system serving as the main source of water for Windhoek received no inflows (Van Rensburg, 2018).

The most probable long term effect of climate change concerning water supply is the increased maximum temperatures, with accompanying higher evaporation rates from the surface reservoir, and more frequent droughts with an estimated decline of 20% in average rainfall in the central area of Namibia (Midgley et al., 2005; Turpie et al., 2006).

Growing Water Demands: Population Growth, Urbanisation and Industrialisation

Even without the impact of climate change taken into account, Windhoek could face absolute water scarcity, which means lack of access to adequate quantities of water to satisfy total demand after all feasible options to enhance the supply and manage demand have been implemented in the short to medium term. Population growth, urbanisation and industrialisation are also significantly increasing the water demand every year. Because of the rapid population growth, the per capita water resources have decreased steadily. In Namibia, urbanisation occurred rapidly after independence, when the racially-motivated mobility restrictions of apartheid were abolished and people could move freely. According to the 1991 Namibia, Population and Housing Census, the urban population of Namibia was 28% (413,280) of the total population (1,476,000). Subsequently, this increased to 33% (711,810) in 2001 (total population – 2,157,000) (Namibia Statistics Agency, 2012). Although there has been an overall increase in the urban population in Namibia, Windhoek has been by far the major focal point of urbanisation. Besides urbanisation and population growth, steady economic growth in Namibia since independence has significantly added to the water demand in Windhoek (Remmert, 2016).

Distance from Source

As was previously mentioned, Windhoek's sustainable supply capacity from the existing sources has been exceeded and the nearest perennial river source is 700 km away. Groundwater resources are vulnerable to the effects of pollution and Windhoek cannot risk over-exploitation. On the other hand, the quantity of treated wastewater has increased with mounted demand, which needs to be controlled by mitigation measures.

Conclusion

For 52 years, Windhoek's experience has been a notable example of augmenting drinking water supplies through direct reclaimed water in a safe, sustainable and responsible way. Wastewater reuse has formed an essential security component of Windhoek's water supply. This innovative approach has supported Windhoek to withstand a changing climate and growing population for over half a century.

At the time, this innovative approach to water augmentation has allowed for a paradigm shift, with water providers considering wastewater as a renewable unconventional source within the water system and the concept of including treated wastewater in Windhoek's water supply system has become an indispensable resource for the continued growth and the survival of the city.

Current trends indicate that increasing population growth, urbanisation and industrialisation are unavoidable; therefore, one of the major challenges facing the City is meeting the future growing water demand.

The practical experience in Windhoek demonstrates that using treated wastewater together with other water management strategies such as Water Demand Management, is a practical and sustainable way of augmenting potable unconventional water supplies in arid regions, but it requires continuous upgrading, comprehensive planning, training and an on-going commitment to ensuring its continued success.

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