Water Management in Windhoek/Namibia

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ABSTRACT
The City of Windhoek's water management including wastewater reclamation and direct potable reuse is presented. This case study shows that with an integrated approach including proper policy, legislation, education, technical and financial measures even severe water shortages can be managed.

KEY WORDS
Direct potable reuse, wastewater reclamation, water management, Windhoek

INTRODUCTION

Namibia is the most arid country in Southern Africa. More than 80% of the country consists of desert or semi-desert. Windhoek, the capital of Namibia, is located in the Central Highlands approx. 1,600 m above sea level. The annual rainfall in Windhoek is approximately 370 mm, while the potential surface evaporation rate is in the range of 3,000 – 3,500 mm/a. The distance to the closest continuously running river, the Okavango River, is ca 700 km and the ocean ca 300 km from Windhoek. The population of Windhoek is about 240,000 with a growth rate of approx. 5% per year (natural population growth approx. 1.5%, migration from rural areas approx. 3.5%).

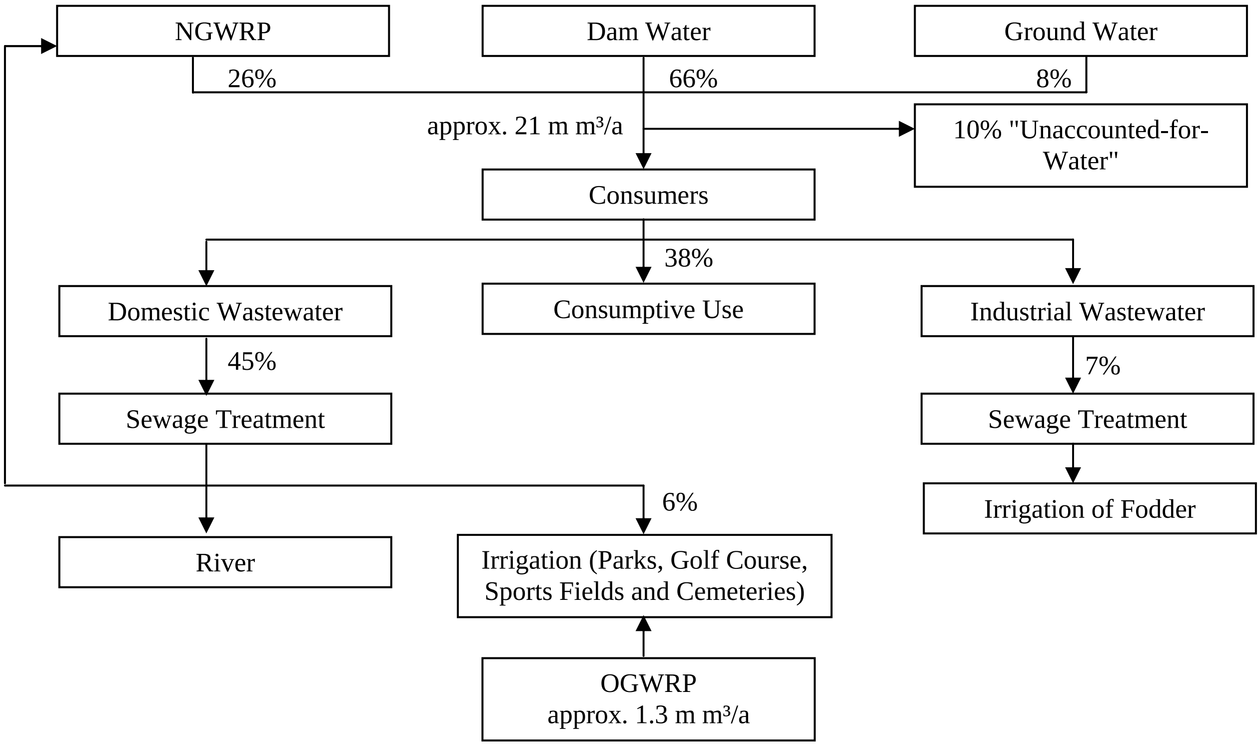
The city's water supply is based on the use of surface water and groundwater. However, as the region is one of the driest in the world, all the potable water resources within a radius of 500 km have now been fully exploited. The rainfall is uncertain and long spells of severe droughts are frequently encountered. Therefore, the supply of water from the central Namibian reservoirs and wells cannot be guaranteed in the near future. In 1994, forced by this prediction the City Council of Windhoek approved an integrated Water Demand Management program including policy matters, legislation, education, technical and financial measures.

WATER DEMAND MANAGEMENT IN WINDHOEK

Today the total water demand of Windhoek is 21 million m³ per year, i.e. an average demand of 57,500 m³/d and depending on the season a range of approx. 40,000 – 75,000 m³/d. There are four main sources of water supply to the central area of Windhoek: dam water (Von Bach Dam), groundwater (50 municipal production boreholes), reclaimed water from both the New Goreangab Water Reclamation Plant (NGWRP) and the Old Goreangab Water Reclamation Plant (OGWRP). Figure 1 shows the water supply scheme including wastewater reclamation and reuse.

Under normal rain conditions water from the Von Bach Dam would be able to supply the entire demand of 21 m m³/a. The boreholes can provide a quantity of 1.7 m m³/a. In emergency situations this water could be abstracted for a period of three consecutive years. One of the options under investigation is groundwater recharge with treated surface water. In times of low water demand it is intended to further treat excess Von Bach Dam water in the City with granular activated carbon and to recharge it into boreholes via the existing groundwater abstraction pipes (reverse direction). The estimated recharge capacity is at least 15 – 25 m m³ and an annual recharge of 6 – 10 m m³ should be possible. The underground storage will be very beneficial as the evaporation of millions of cubic meters from the surface reservoirs can be avoided resulting in higher water availability. Furthermore, the recovery period of the aquifer is shortened substantially by artificial recharge which provides a higher security of water supply. This is especially important after severe droughts when too much water had to be abstracted from the aquifer.

Fig. 1: Water Sources / Water Supply to Windhoek



The capacity of the NGWRP is approx. 7.5 m m^3/a. Currently, the City uses 5.5 m m^3/a of this water, i.e. almost a quarter of the total water demand is supplied by the NGWRP. The water of the OGWRP is unsuitable for human consumption and used for irrigation (5,000 m^3/d mainly for sport fields and a golf course). The OGWRP is treating polluted Goreangab Dam water. The treatment process consists of flocculation, dissolved air flotation, rapid sand filtration, granular activated carbon filtration and chlorine disinfection.

Industrial wastewater (approx. 0.3 m m^3/a) discharged mainly from a small food and beverage industry is treated in anaerobic followed by aerobic ponds and reused for irrigation of pastures.

Municipal wastewater is treated in the Gammams Water Care Works. This is a nutrient removal plant comprising primary treatment (fine screen, coarse screen, grit and grease removal, primary sedimentation), secondary treatment (nitrogen and biological phosphorous removal) with both an activated sludge process and with trickling filters in parallel. Additionally, the secondary effluent (COD approx. 60 mg/l) is polished in maturation ponds with retention time of approximately four days. The outlet (COD approx. 30 – 40 mg/l) of these ponds serves as raw water for the New Goreangab Water Reclamation Plant (NGWRP).

The major policy issues within the integrated Water Demand Management are maximum wastewater reuse and saving of water. Therefore, additionally to wastewater reclamation, the City of Windhoek has introduced special measures by means of municipal by-laws for water savings. During times of severe droughts these measures are rigorously enforced. Table 1 summarizes both the requirements of the water supply regulations and the method of implementation (van der Merwe, 1999).

Table 1: Requirements of the Water Supply Regulations and Method of Implementation

Regulation Requirement	Method of Implementation
Prevention of undue water consumption on private properties	▪ Wastage of water on a private property can be addressed immediately. Windhoek is the only city in Southern Africa with a Water Control Officer in its employ.
Water efficient equipment	As from 16 December 1996 the following is compulsory in new developments in the city: ▪ Metering taps must be used in hostels ▪ Taps outside non-residential buildings must be self-closing or lockable. ▪ Only low flow showers are allowed. ▪ Toilet cisterns must be 6/3 liter dual flush units. ▪ Automatic flushing devices without activation by the user are prohibited. Retrofitting of existing inefficient water devices is compulsory within 3 years.
Groundwater	Groundwater abstraction from private boreholes and groundwater levels are controlled.
Gardens	Watering may not be done during high evaporation times, i.e. between the hours of 10:00 and 16:00.
Swimming pools	Swimming pools must be covered when not in use.
Prevention of water pollution	Regular testing of groundwater fuel tanks is mandatory. All tanks were registered.

Consumption related, progressive water pricing (since 2004: 0 – 0.200 m³ per day = 0.58 €/m³; 0.201 – 1.8 m³ per day = 0.96 €/m³; > 1.8 m³ per day = 1.8 €/m³) has also played an important role towards achieving ambitiously set water saving targets. Nevertheless, these improvements have been more than counterbalanced by population growth and an above average influx of people to the capital due to urbanization (approx. 5% per year). Per capita consumption has already been reduced to a minimum by technical improvements and exemplary public relation activities. The technical measures implemented are mainly with regard to leakage control (lowering of "unaccounted-for-water") and proper watering of gardens. In order to reduce water losses both leakage detection and water audits are being done on a continuous basis. Additionally repair as well as systematic pipe replacement programs have been implemented and a proper management of water meters is done. Due to these measures the water losses in the City of Windhoek are only approx. 10%, which represents the lowest value in Southern Africa and, if compared to cities in highly developed regions such as Western Europe, this is also a very low figure.

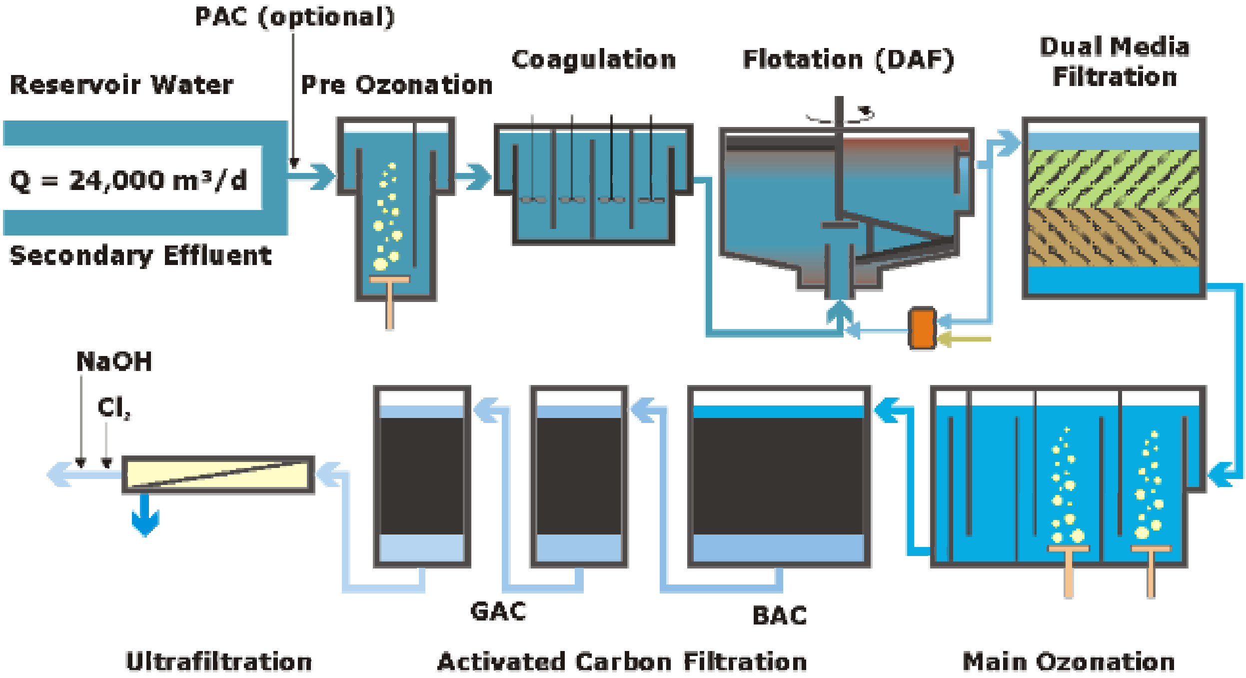
THE NEW GOREANGAB WATER RECLAMATION PLANT (NGWRP)

In the past regular droughts in Namibia and a continuous shortage of potable water supply to Windhoek have necessitated the City of Windhoek to investigate alternative sources of raw water. It was decided to exploit reclaimable water from the Gammams Water Care Works (Municipal Wastewater Treatment Plant) and the Goreangab Dam. This led to building of the Old Goreangab Water Reclamation Plant (OGWRP), which produced drinking water utilizing the mentioned sources as raw water (Lahnsteiner et al, 2004). This plant, after more than 30 years of successful operation, was in the second half of the nineties of the last century at the end of its viable life span. It was therefore decided to build a new, larger reclamation plant next to the old plant.

The NGWRP produces 21,000 m³/d of drinking water safe for human consumption at all times. A "multiple barrier" approach was taken during the final selection of the process technology (Figure 2). The following unit processes have been included in the final plant:

Powdered activated carbon (PAC) dosing, pre-oxidation and pre-ozonation, flash mixing, enhanced coagulation and flocculation, dissolved air flotation (DAF), dual media rapid gravity sand filtration, ozonation, biologically activated carbon (BAC) filtration, granular activated carbon (GAC) filtration, ultra-filtration (UF, Figure 3), disinfection and stabilization.

Fig. 2: Process flow diagram



The treatment processes that were chosen ensure that at least two (in many cases three or more) removal processes are provided for each crucial contaminant that could be harmful to the human body or aesthetically objectionable.

For example, complete and/or partial barriers for one of the most resistant pathogens, *Cryptospiridium*, include ozonation, enhanced coagulation, DAF, dual media filtration, ultrafiltration and chlorination.

Fig. 3: Ultrafiltration process step

Similarly, five barriers have been included for organic substances, viz enhanced coagulation, ozonation, BAC, GAC adsorption and ultrafiltration. This ensures both micro-pollutant removal and degradation and results in a substantial reduction of the THM formation potential (Table 2).

The basis for the guarantee values is provided by the WHO Guidelines, the Rand Water Guidelines (South Africa) and the Namibian Guidelines for Group A water. Water samples are taken for analysis in the water reclamation plant laboratory every four hours. Refrigerated composite samples are taken twice per week and used for a comprehensive analysis of all the water quality constituents.

The process is automated based on a monitoring supervisory control and data acquisition (SCADA) system. The plant operation shows that the requested guarantee parameters can be easily met and a high quality drinking water is provided (Table 2). Additional safety is provided by blending the reclaimed water with treated dam water and/or groundwater. The maximum portion of reclaimed water fed into the distribution system is 50% in times of low water demand (winter season). Originally the maximum percentage of reclaimed water was limited to 35%. The basis for this limit was a DOC value of approx. 5 mg/l produced in the OGWRP and the corresponding THM formation potential in the distribution network after blending. Since the NGWRP constantly achieves DOC values of $\leq$ 1 mg/l, the original limit of 35% for reclaimed water has been increased to 50%.

Table 2: Major Quality Parameters for NGWRP Water

Parameters	Units	Raw water (design value)	Treated water (guarantee value)	WHO Guidelines	EU Directive	Results[1)]
Physical & Chemical						
Turbidity	NTU	53	0.1	0.1[2)]	[3)]	0.08
DOC	mg/l	15	5			1.0
COD (dichromate)	mg/l	43	20			12.6
THM	µg/l	169	20	[4)]	100	11[5)]
Microbiological						
Giardia	per 100 ml	214	0 or log 6 removal			0
Cryptosporidium	per 100 ml	334	0 or log 6 removal			0
E. Coli	per 100 ml	20,347	0		0	0
Heterotrophic Plate Count (37°C)	per 1 ml	332,150	80			8
Elements						
Iron	mg/l	2.8	0.05		0.2	<0.05
Manganese	mg/l	0.9	0.005	0.4	0.05	<0.005

1) Median at Performance Test
2) Recommendation for Effective Disinfection
3) No Abnormal Change
4) Guideline Values: Chloroform 0.2 mg/l, Bromoform 0.1 mg/l, Dibromochloromethane 0.1 mg/l, Bromodichloromethane 0.06 mg/l
5) Currently 4-6 µg/l have been accomplished

The project has been financed by the Kreditanstalt fuer Wiederaufbau (40%), the European Investment Bank (55%) and the City of Windhoek (5%). The consultants were GFJ (South Africa), Multi Consult (Namibia) and Fichtner (Germany). The contractor consisted of a consortium made up of DB Thermal (at that stage representing WABAG technology in Southern Africa) and Stocks Structures. The technology incorporated in the plant is based on WABAG technology.

The New Goreangab Water Reclamation Plant was started up in May 2002, with final hand-over on August 5, 2002. The plant was officially inaugurated on December 2, 2002.

Initially, raw water fed to the New Goreangab Water Reclamation Plant consisted of 50% secondary effluent and 50% surface runoff water from the Goreangab Dam. Currently, the portion of secondary effluent feeding the plant constitutes 100% secondary effluent, because the quality and quantity of Goreangab Dam water has deteriorated to a point where it can not be utilised anymore. As already mentioned this water is currently only abstracted for treatment in the OGWRP and used for irrigation.

A 20-year operation and maintenance (O&M) contract has been concluded between the City of Windhoek and the Windhoek Goreangab Operating Company Ltd. (WINGOC). In order to include as much specialist process and operating know-how, WINGOC is made up of three major international water treatment contractors: Berlinwasser International, VA TECH WABAG and Veolia Water.

The investment costs for the reclamation plant were approx. € 12.5 m: Electrical & mechanical equipment, € 8.3 m; civil works € 4.2 m. Total operating costs are € 0.63/m^3 (capital costs € 0.33/m^3, operational costs € 0.30/m^3). These costs are lower than other options for importing water to Windhoek (e.g. transport from the Okavango River).

There should be a certain cost reduction potential for future plants, as the design will probably become simpler with the experience gained on this plant. Also, other processes could be considered, which could reduce costs further, such as a two-stage membrane process (e.g.

ultrafiltration followed by reverse osmosis) and blending the RO permeate in the distribution network with treated surface water (Von Bach Dam) and/or groundwater. The existing UF in the NGWRP consists of 5 trains and can be extended to 6 trains. An option would be to treat 1/5 (one of five trains) or 2/6 (two of six trains) of the UF permeate with RO and reducing the salinity accordingly. Over time, this would also reverse the currently observed slowly increasing salinity of the potable water supply to the customers. The salinity has shown an approximate 50% increase over the past 50 years.

PUBLIC AWARENESS TO WATER SAVING AND ACCEPTANCE OF DIRECT POTABLE REUSE

In order to increase both the level of awareness to water saving and the acceptance of direct potable reuse the City of Windhoek has arranged adequate education programs in schools, radio and television as well as in printed media. The evaluation of these programs showed that the biggest benefit will be accomplished if water awareness forms part of the normal curriculum in schools.

Reclaiming drinking water from municipal secondary effluent is not generally acceptable to the public and psychological barriers have to be broken down first. However, with persistent and good marketing as done in above-mentioned education programs, this perception can be changed. The people of Windhoek have even derived some pride from the fact that they are the only ones where direct potable reuse is applied worldwide.

A prerequisite for this success was of course that since the beginning of potable reuse in 1968 no outbreak of waterborne disease has been experienced and no negative health effects have been attributed to the use of reclaimed water. An indication for the trust in potable reuse is the fact that only 5% of the population uses additional point source treatment in their homes e.g. with GAC filters (and cooling the filtrate in the fridge). Interviews with people showed that they like to drink tap water (average portion of reclaimed water approx. 25%, max. portion 50%).

CONCLUSION

Summarizing the experience made in Windhoek, it can be said that careful water management including direct potable reuse is required to secure the water supply of the City. With proper process design and quality management, water meeting stringent standards can be produced by reclamation and direct potable reuse can be practiced. The public will accept such schemes if properly informed, despite initial health and aesthetic concerns. The operation of the NGWRP represents a milestone for further similar projects. The Windhoek Water Management policy can be considered as a model for other arid regions.

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