integrated water resources management

CUVEwaters

Sanitation and Water Reuse – Implementation Concept

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Abbreviations

ASE	Aqua Services & Engineering
BMBF	Federal Ministry of Education and Research
DME	Deutsche Meerwasserentsalzung e.V.
DRFN	Desert Research Foundation of Namibia
DWSSC	Directorate of Water Supply and Sanitation Coordination (formerly Directorate of Rural Water Supply)
EC	Electrical conductivity
IBEU	Ingenieurbüro für Energie- und Umwelttechnik
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IFAT	Weltleitmesse für Wasser-, Abwasser-, Abfall- und Rohstoffwirtschaft/World‘s Leading Trade Fair for Water, Sewage, Waste and Raw Materials Management
ISE	Institute for Solar Energy Systems, Fraunhofer research organisation
ISOE	Institute for Social-Ecological Research
IWRM	Integrated Water Resources Management
LC	Local caretaker
MAWF	Ministry of Agriculture, Water and Forestry
MD	Membrane distillation
MoF	Ministry of Finance
MSD	Multi-stage desalination
NAD	Namibian Dollar
NamWater	Namibia Water Corporation
O&M	Operation and maintenance
PoN	Polytechnic of Namibia
RO	Reverse osmosis
SEIA	Social-ecological impact assessment
SIJ	Solar-Institut Jülich
TDS	Total dissolved solids
TU Darmstadt	Technische Universität Darmstadt
UNAM	University of Namibia
WPC	Water Point Committee

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Objectives of implementation concept

The implementation concept brings together relevant information for the replication of the proposed sanitation system in other locations. In this context, it is essential to illustrate the benefits of the sanitation system and also the disadvantages of a lack of sanitation. We can see how the CuveWaters sanitation concept can improve living conditions in settlements and how it can be adapted to different framework conditions. Great emphasis is placed on a transparent presentation of financing and tariff options and how communities can achieve a successful implementation. The experiences of Outapi Town Council (OTC) can be used to illustrate the steps and measures taken to fit the sanitation concept into a town council's existing structures. The implementation concept therefore aims to:

- support communication with partners in Germany and Namibia
- ensure strategic planning of sustainable implementation of CuveWaters technologies
- support internal work processes and knowledge management
- refer to associated documents, products and results of technologies

1 Initial situation

1.1 Problem situation

Almost one million people live in the Cuvelai-Etosha Basin in central northern Namibia, which constitutes around half of the Namibian population. The water for human consumption and agricultural purposes originates from the Kunene River on the Angolan-Namibian border, and is transported and distributed via a long-distance water supply system. Some general problems encountered in central northern Namibia are as follows: water scarcity; lack of irrigation water; water losses through evaporation in wastewater ponds; poor access to tap water and sanitation services in informal settlements; poor capacities with regard to health and hygiene, as well as at a technical level.

1.2 Political framework, governance and institutions

The Ministry of Agriculture, Water and Forestry (MAWF) is responsible for the support, development, management and usage of water resources, agriculture and forests. The Department of Water Affairs and Forestry regulates issues regarding water resources management (initially only responsible for rural water supply). The Directorate of Water Supply and Sanitation Coordination under the Department of Water Affairs and Forestry coordinates the efforts of all the ministries and other stakeholders in the area of sanitation. The Ministry of Health and Social Services sets up programmes for hygiene education.

Further key stakeholders in the project region are the Ministry of Urban and Rural Development (MURD, formerly the Ministry of Regional and Local Government, Housing and Rural Development), the Olushandja Basin Management Committee, and Outapi Town Council (OTC). Some external stakeholders might also be relevant, e.g. GIZ for its involvement in (Transboundary) Basin Management Committees.

1.3 Local demand

Population growth and urbanisation are putting pressure on the limited water resources in the Cuvelai-Etosha catchment area. Outapi lies roughly 10 km south of the Angolan border, and had a population of 6,600 inhabitants in 2011 (Namibia Statistics Agency 2014). According to the former CEO of Outapi, the population is currently doubling in number roughly every 3 years. The region is undergoing a process of urbanisation: around 40% of the population in Namibia's urban spaces has no access to improved sanitation facilities (MAWF 2009), and one can assume that the situation in informal settlements is far more drastic. In 2012, the baseline survey in the three pilot settlements in Outapi showed that 97 % of the inhabitants have access to safe water (mostly through communal taps), but almost 50 % practised open defecation (Deffner et al. 2012). There is an acute need for action to improve the sanitary conditions. Moreover, the Namibian Sanitation Strategy (drawn up in 2009) aims to create awareness of sanitary infrastructure as a public commodity incorporating the aspects of "health promotion", "environmental protection" and "energy efficiency" (biogas), along with "food production" (wastewater reuse) (see Footnote 3).

Most food is imported from South Africa. There is obviously a high demand for sanitation and water reuse for agricultural irrigation, and a correspondingly high demand for the supply of food and sanitation infrastructure.

1.4 Analysis of local capacities

At the technical level, there is a clear lack of local capacity. OTC owns and operates a gravity sewer network discharging in a system of ponds with a so-called "evaporation pond" as the final stage. The ponds are overloaded because of population increase and the extension of the sewer system, and have never been maintained since they were built 10 years ago. This leads to an overflow of barely treated wastewater into the surrounding environment and rapid fill-up with sludge. The system that has been introduced (vacuum sewers and reclamation plant) has been brand new to this area, which means there is no experience of it within local authorities and their technical departments. In addition, water operators and technicians are generally lacking in Namibia, and Outapi is no exception. Although management structures regarding water and sanitation exist at OTC level (Technical Department and Environmental Health Department), management skills need further improvement.

Local and regional capacities for small-scale farming – and irrigation agriculture in particular – are limited. Traditional farming is mostly based on rainfed agriculture and the cultivation of pearl millet (mahangu). Only a few commercial farmers practise irrigation agriculture and cultivate crops such as tomatoes, green peppers, cabbage, maize, melons, or other fruits and vegetables. Local markets thus have to be mainly supplied with fresh produce from a greater distance.

The residents know little about water-related diseases and hygiene practices. Initial insights from the community workshop in 2010/2012 showed that there is to some extent a theoretical understanding of the routines that should be practised in order to improve health and hygiene (e.g. washing hands, no open defecation), but daily life differs in conditions characterised by sparse infrastructures; for example, there was no knowledge about infection chains (e.g. faeces-hand-mouth).

1.5 Socio-economic aspects

Insights into socio-economic conditions and the living situation were derived from the participatory planning process at the initial stage (2010) and a baseline survey carried out in 2012:

- Older informal settlement (Onhimbu): a heterogeneous composition of stone houses, corrugated iron huts, and small businesses. Inhabitants mainly collect water from public water taps; few latrines (public and private), very few private water connections, very low household incomes, a high rate of underemployment, and partly temporary residents.
- Newer informal settlement (Tobias Hainyeko, Okayekongwe): corrugated metal huts; the population is predominantly served by public water taps; few public and private toilets, low to very low incomes, an average level of employment (mainly in the informal sector).
- Pre-formalised, self-administered settlement (Shack Dwellers): mainly standardised brick houses; plans for water and wastewater connections; no private water/wastewater infrastructure; few public water taps and latrines; medium to high level of employment in the informal and formal sectors.

On average, household sizes range from 1.4 people in Okayekongwe to 4.8 in Onhimbu; the overall average is 3.4 people. The employment situation of respondents in the survey shows that most are self-employed (38 %) or work full-time (35 %). The highest percentage of unemployed people is found in Onhimbu. Most households have an income of between 500 N$ and 2,000 N$ a month. Especially when it comes to Okayekongwe and the Shack Dwellers' settlement, household incomes tend to be mid-range (N$1,000-2,000). On average, 40 % of households have 500 N$ or less per month. The shares of lower incomes are highest in Tobias Hainyeko (30 %) and Onhimbu (42 %). 79 % live in shacks, and only 22 % in a brick house.

Paying for water and wastewater services represents a big challenge for many residents. It is therefore vital to take account of their willingness (based on understanding) and ability to pay. For instance, it is important to create awareness that water services – although linked to costs – nonetheless bring advantages capable of recouping these costs in the long term through improved living conditions. Pricing thus plays an important role since it is able to steer demand for sanitary infrastructures. The concept foresees a reduced price for water services as well as the cross-financing of toilet utilisation via the utilisation of showers and washing facilities.

2 Approach

2.1 Aim of implementation

The CuveWaters sanitation concept pursues the following objectives:

- To improve capacities with regard to health and hygiene (personal level and community level with Community Health Club (CHC) approach) as well as with regard to technology
- To improve access to water supply and sanitation, as well as offer greater convenience, dignity and safety
- To prevent contamination of surface water during floods (and thus the spread of diseases)
- To increase local production and independence from external supply in terms of food and water
- To create jobs and generate income via the operation and maintenance of all the facilities, as well as on the ag ricultural site

- To determine the necessary steps and preconditions for the implementation of the proposed sanitation concept
- To develop feasible mechanisms for financing and funding (e.g. subsidise water tariffs via agricultural revenues)
- To evaluate the suitability of different sanitation facilities

2.2 Specification of the technology

The proposed infrastructure comprises sanitation facilities, vacuum sewers, a wastewater treatment plant, and agricultural fields for the reuse of the reclaimed water, aiming at a highly efficient usage of water, energy and nutrients (Figure 1). The infrastructure should provide fresh water, adequate sanitation, and resources for agriculture while being economically feasible (in terms of running costs) and minimizing environmental impacts.

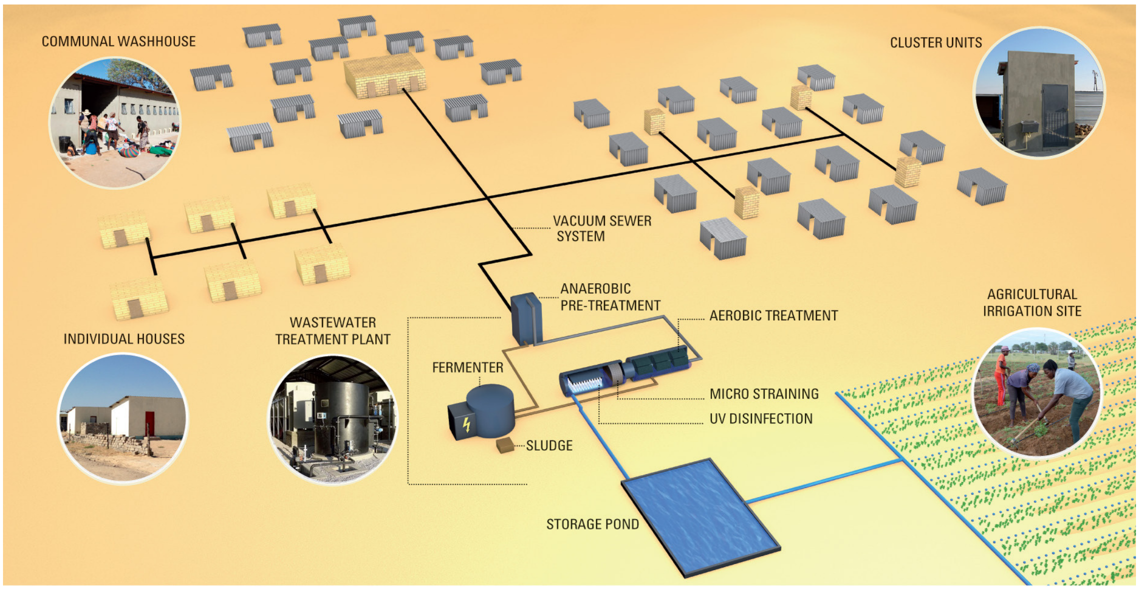

Figure 1: Overview of the CuveWaters sanitation concept

2.2.1 Sanitation facilities

The city of Outapi in northern Namibia is a fast-growing urban area with a very heterogeneous structure which is reflected by differently developed areas. It was clear from the beginning that one single type of sanitation facility could not serve the needs of all the residents and suit all the development stages. The CuveWaters "Sanitation and Water Reuse" sub-project therefore implemented three different types of sanitation facilities in three differently developed areas of Outapi. Roughly 1,300 inhabitants are served by this infrastructure.

A communal washing house in a very young informal area commenced operation in April 2013 and serves around 250 inhabitants. Residents of the settlements as well as people from a nearby marketplace can use the toilets, showers, hand-wash basins, laundry basins and kitchen basins. Security and maintenance staff are provided by the Town Council. 30 small cluster washing houses are shared by four to five families each, in an area with a pre-formal layout. The cluster washing houses are equipped with an indoor shower, toilet and hand-wash basin and an outdoor laundry basin, and are managed by the allocated households. Finally, 66 households in a selfbuild neighbourhood (which already has brick houses) are individually connected to water pipes and sewers.

2.2.2 Sewage collection and conveyance

The water and wastewater management that is currently practised in Outapi is not adapted to flood events; evaporation ponds and pit latrines are located in flood-prone areas. It is therefore reasonable to assume that during floods, rainwater as well as run-off from the Oshanas (shallow ephemeral rivers) and the canal will spread the contents of the evaporation ponds, pit latrines and open defecation to surrounding areas. Pathogens will contaminate stagnant water bodies and the canal water that is used as a source for Outapi's supply of drinking water. The proposed sanitation concept has to ensure that rain and flood water do not mix with sewage and that wastewater is immediately treated to minimize the risk of environmental contamination. These requirements can only be met by a tight sewer system, and a tight vacuum system was chosen because it perfectly fulfils the requirements. The occurrence of floods and waterborne diseases during the rainy season was the main reason for implementing a system of this kind.

A waterborne vacuum sewer system with water-saving flush toilets was therefore chosen for sewage conveyance to a wastewater treatment plant. With regard to construction, cost estimates for Outapi showed that vacuum sewer systems are cheaper than conventional gravity sewer systems, which is mainly due to the flat terrain and excavation costs in sandy soils. Maintenance and operation costs seem to be a little lower than for gravity sewer systems. If one considers the entire lifespan, a vacuum sewer system is expected to be slightly cheaper than a gravity sewer system, including the prevention of rainwater and wastewater mixing during the rainy season.

2.2.3 Wastewater treatment

The wastewater treatment plant in Outapi commenced operation in April 2013, and consists of the following treatment steps:

(1) Anaerobic pre-treatment via upflow anaerobic sludge blanket (UASB) reactors
(2) Aerobic treatment via rotating biological contactors (RBCs)
(3) Lamella clarifiers
(4) Microstrainer (15 µm)
(5) UV disinfection

After the wastewater has been transported to the vacuum station from the washhouses and the individual sanitation facilities, it is first pre-treated in the UASB reactors and then further purified in the RBCs (Figure 2). Organic compounds are oxidised while nutrients largely remain in the water for fertigation purposes. Solids and helminth eggs are removed by lamella clarifiers and a 15 µm microstrainer. The effluent is disinfected by UV radiation before being stored in a pond for reuse in irrigation. Rainwater can also be collected in this pond to adjust the desired water quality and to gain additional irrigation water.

The sludge treatment line consists of a thickener, a fermenter (thermophilic digestion) and sludge drying beds. The co-fermentation of agricultural residues in the digester can increase the production of biogas in the fermenter, and the digested and sun-dried sludge can be used as a soil conditioner.

For more detailed reasons behind the choice of the wastewater treatment steps and the vacuum sewer system, see Müller et al. 2013.

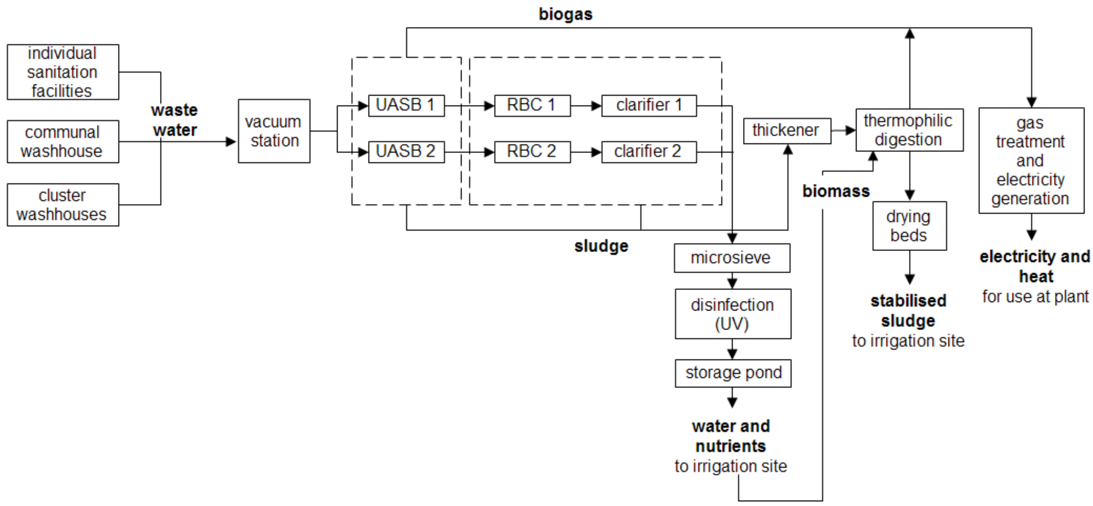

Figure 2: Schematic representation of the sanitation concept for Outapi

2.2.4 Agricultural irrigation area

The net field size of the agricultural irrigation area is 3 ha. Water losses due to evaporation and infiltration can be minimized by using drip irrigation technology. Crops produced include tomatoes, green peppers, maize, water melons and pumpkins. Wastewater is generated daily throughout the year in almost equal quantities. A pond with a capacity of 3,700 m³ is therefore used for irrigation water storage in order to buffer usage fluctuations. The irrigation site produces 32.4 to 42 tonnes of fruit and vegetables per hectare and year, so a turnover of up to 420,000 N$ can be achieved per hectare and year.

2.3 Profitability analysis

An analysis of the system's profitability was conducted, based on the design and assumptions. The analysis comprised capital expenditure, operation and maintenance costs, plus revenues from user fees. Expected costs for the operation and maintenance of the vacuum sewer system and wastewater treatment plant were provided by Bilfinger Water Technologies, and were incorporated into a preliminary tariff system. Actual costs and benefits are presented in Section 4.

2.4 Stakeholders

Besides the institutions mentioned in Section 1.2, relevant stakeholders for the implementation of the sanitation concept and accompanying measures are as follows: Outapi Town Council (OTC); the residents of the informal settlements; the farmers and technicians to be trained (e.g. management skills for the agricultural irrigation site); Development Aid from People to People (DAPP) and – for instance – the Ministry of Health and Social Services.

2.5 Capacity development

The idea was to establish the necessary mechanisms and capacities to operate and maintain the facilities in such a way that no support from CuveWaters is needed after the end of the project. The capacity development focussed on the following aspects:

- Technical capacities: Namibia lacks well-trained water operators, so CuveWaters capacity development measures focused on staff at Outapi Town Council, which operates the wastewater treatment plant. For this reason, CuveWaters initiated operator training in 2011. The German industry partner (Bilfinger Water Technologies) conducted training on vacuum sewers with two representatives from Outapi Town Council in 2012. In addition, a plant manager from Germany was appointed on-site from July 2013 to October 2013, offering day-to-day training to the OTC technicians at the plant. During the subsequent operation and monitoring phase, an engineer and a mechanic from Bilfinger have repeatedly visited the facilities, re-training the operators when needed.
- Management capacities: workshops with OTC as well as constant support from CuveWaters aimed at strengthening the operation of the system at the management level. Establishing collaboration between OTC and experienced operators from a comparable system in Namibia (UJAMS) is a further alternative way towards ensuring a smooth transition to independent operation of the system by OTC.
- Health/hygiene capacities: changing the behaviour of residents has to be addressed from the outset via participatory community workshops. Special attention has been paid to changing hygiene behaviour. Approaches such as Community Health Clubs (CH Clubs) (Waterkeyn 2010; Deffner/Böff 2012) which aim to achieve long-lasting changes to hygiene behaviour have been adapted to the local situation. The objective was to establish a routine in relation to – and a demand for – the use of toilets, showers and washing basins, to communicate the benefits of sanitation facilities so as to embed them in everyday life, and to communicate adequate usage of new facilities.
- Horticulture and farming capacities: once a year, the group of farmers received three-day training sessions on irrigation agriculture. Basic knowledge and skills relating to horticulture and farming were taught in the first year, while refresher training for advanced farmers took place in the second year. The workshops were led by an expert, and also covered managerial topics such as accounting, planning, teamwork, and conflict resolution strategies. In spring 2014, workshops focusing on ecological horticulture and marketing were held in Outapi, Iipopo and Epyeshona in conjunction with the Namibian Organic Association (NOA). Furthermore, additional training on irrigation techniques was conducted in the first half of 2014. Due to an exchange of farmers in 2014, supplementary training was carried out by an expert during the construction of a farm extension in October and November 2014. Furthermore, this expert frequently accompanied and advised the new farmers during his stays in 2015. Apart from this, target-oriented information materials have been provided for consumers as well as farmers and workers at the irrigation site. A factsheet for the general public concerning the water reuse concept in Outapi as well as a training manual on the handling of irrigation water and operational safety were distributed.

2.6 Social embedding

Establishing acceptance and ownership of all the facilities is crucial if one is to prevent misuse and vandalism. This can be achieved by involving all the stakeholders and residents via community workshops, and the local and regional authorities via cooperation and exchange workshops.

In order to reduce the risk of any misunderstandings, social aspects have to be addressed through participatory planning that starts from the very beginning. It should consist of an iterative discussion and adaptation of technological solutions. The specific needs and opinions of users can be considered in community workshops, the aim being to increase acceptance of – and the buy-in to – the new infrastructure before it exists. In a later phase, the embedding will focus on adaptation of social norms, such as changing from open defection to the use of the new facilities. One should select a specific approach that has shown itself to be operational and socially accepted in this field, such as the CHC (see Section 2.5).

2.7 Impact

The impacts of the proposed concept are:

- Improved living conditions thanks to improved capacities with regard to health and hygiene (residents)
- Better access to water and sanitation; convenience, dignity, safety
- Less contamination of surface water bodies and the surrounding environment
- Production of food for the local market
- More efficient use of local resources (water, soil, nutrients)
- Job creation and income generation which strengthen the local and regional economy

3 Implementation

3.1 Work packages and time schedule

Construction of the sanitation commenced in the third quarter of 2011, and the facilities started to operate in April 2013. Subsequent monitoring activities, optimization of the tariff system, operation and maintenance, etc. have been carried out since then. The following table gives a brief overview of the most important implementation steps and phases:

Activity/implementation step	Milestone	Time period
• Demand analysis and demand-responsive approach (community and stakeholder workshops) • Development of the sanitation concept		2009-2010
• Negotiation of cooperation agreement with OTC	• Agreement of collaboration signed with local authorities	01.2011-04.2011
• Final design of sanitary facilities and treatment plant	• Sanitation concept developed	01.2011-05.2011
• Initiation of Community Health Clubs		03.2011-10.2011
• Tendering for the construction of facilities, plant, and vacuum sewers	• Call for tenders for construction published • Local contractor appointed	05.2011-08.2011
• Construction of sanitary facilities, plant, and vacuum sewers • Capacity development	• Beginning of construction • Personnel (plant operators/managers, farmers, etc.) recruited and trained	10.2011-04.2013
• Commencement of operation of sanitary facilities and plant	• First year monitoring and evaluation scheme developed • Commencement of operation of sanitation system	04.2013

Activity/implementation step	Milestone	Time period
• Technical monitoring of the plant, support with O&M	• First year monitoring results evaluated • Financial and cost-benefit analysis completed	04.2013-12.2015

Table 1: Rough timeline for the implementation of the project

Intensive assistance has been given to the operator, especially in the first year of operation; subsequently there has also been ongoing support and monitoring from a technical and managerial perspective.

3.2 Operational concept

Operation and maintenance of the communal washhouse, the vacuum sewer system and the water treatment and recovery plant are the responsibility of Outapi Town Council (OTC), which decided that care and cleaning as well as security are going to be outsourced. All technical works are carried out by OTC personnel.

The cluster units are managed by the participating households, and this process is supported by the Community Health Clubs. In this context, OTC has the role of a mediator and supervisor and is responsible for repairing minor damage.

Management of the agricultural irrigation site is facilitated by a local group of farmers (on behalf of OTC). This management system has been evaluated and modified from 2013 until 2015 in conjunction with OTC and the farmers.

Description	Site	Activities	Workload (hours/week)	Human resource requirements
Head of sanitation	All sites	Surveillance, on-site inspection, personnel management, plant administration, etc.	9	1 person part-time
Technician	Treatment plant	Plant supervision, inspection, maintenance, instructions to skilled help, data analyses and reports, etc.	37	1 person full-time
Skilled help	All sites	Inspection, cleaning, feeding biomass and sludge drying bed, mechanical maintenance, etc.	63	2 people full-time
Caretaker	Community washhouse	Care and cleaning	70	2 people full-time
Security	Community washhouse	Personal security	56	2 people full-time
Back-up technician	Treatment plant	See above		1 person on demand
Back-up skilled help	All sites	See above		1 person on demand
Back-up caretaker	Community washhouse	See above		1 person on demand

Table 2: Overview of personnel required for the operation and maintenance of the CuveWaters sanitation system

3.3 Framing activities

Framing activities of the sanitation concept comprise:

- Planning process: while developing the technical concept, it was adapted step-by-step to meet actual neighbourhood requirements (technically and from the users' perspective). This procedure was known as the "demand-responsive approach" (Deffner/Mazambani 2010), and combined methods of participatory planning as well as social science. It has included three workshops on situation assessment and planning in the three settlements since 2008. During the detailed planning phase and the beginning of construction, further details of the management and operation were discussed during the neighbourhood workshops in order to prepare the end users.
- Capacity development activities were continuously conducted in order to ensure that the Namibian partners and stakeholders will be in a position to keep the project running after the CuveWaters project ends in December 2015. The activities are described in Section 2.5.
- Behaviour change: Community Health Clubs (CHCs) were set up in Outapi in April 2012. The capacity development process via the CHCs lasted for approximately nine months, with weekly/bi-weekly CH Club meetings in the neighbourhoods comprising smaller groups facilitated by students from a local community development school (DAPP). The process ended with the official inauguration of the facilities in 2013, with a graduation ceremony for the club members and the facilitator. The CHCs aim to change norms and values in relation to health and hygiene behaviour (c.f. Section 2.5), and in so doing contribute to better living

conditions. The CHC approach has already been successfully implemented in Rwanda, South Africa, Sierra Leone and Zimbabwe.

- The economic situation and the inhabitants' ability to pay for water and sanitation tariffs were discussed during several community workshops, thereby enabling one to gather and address the inhabitants' expectations. Based on these results, an initial tariff model was developed, one which considers the affordability and practicability of the tariff and payment system.
- Socio-ecological impact assessment (SEIA): the objective of the SEIA was to respond to questions concerning the anticipated impacts of the technologies on nature and society if the local pilot plant were to be scaled up and expanded to create a larger number of similarly sized plants within the region; the Cuvelai-Etosha basin is of particular interest in this context. In this process, the SEIA analysed and assessed potential beneficial or adverse impacts, risks and vulnerabilities, and came up with conditions and requirements relating to how a sustainable dissemination can be ensured.

3.4 Ownership

The main activities to strengthen ownership on the part of the system's operator (OTC) focused on the regular exchange of information between the project and OTC and – as far as possible – the preparation of joint decisions. This process started in the planning phase (cooperation in planning of community activities, joint planning with regard to sites and technical layout), and became more intensive during the construction phase (preparation of technical capacity development, arrangements about supply issues and agreements with the construction firms, final acceptance of works, as-is plans, development of a tariff model, etc.). Ever since operation commenced, the establishment of ownership has focused on regular maintenance processes, spare part and staff management, the adaptation of the tariff structure, and user issues.

The ownership of end users in the individual connected houses, the cluster units and the community washhouse was strengthened by the CHCs and other participation measures. However, further steps have been necessary since operation commenced in order to underpin the responsibilities of end users, especially at the cluster units.

MAWF – in its role as the coordinating body and the chair of the WATSAN Forum – received regular briefings. MURD – as the line ministry responsible for sanitation in urban areas – is also addressed through the forum.

Several measures were necessary to ensure that the sanitation facilities can run successfully after the end of the project and sufficient ownership is created. One element of Phase II of CuveWaters was the development of a contractual agreement between OTC and TU Darmstadt which clearly defined their respective responsibilities as a first measure to trigger OTC's ownership. OTC took over the role as construction principal and assumed responsibility for the maintenance, safety and general conditions of the installations that had been built as well as for their continuous supply with operating resources. It also pledged to operate the facilities after completion. OTC also participated in a number of construction site meetings during the construction phase.

The plant was officially inaugurated during a ceremony on 1 November 2013. Two plant operators are currently engaged in the everyday O&M of the plant, and the Senior Manager of the Technical Department at OTC acts as its operational manager. CuveWaters is supporting the transition process by holding regular meetings with OTC and offering further training on the system as well as giving advice on technical, operational and management issues.

Developing a tariff system and analysing the costs of the sanitation system play a key role in the handover process. Furthermore, all the information necessary to run the facilities has to be collected together with OTC in order to find a way to maintain the capacities developed during the project. In doing so, a detailed strategy for the handing over of the plant has been developed during the final phase of the project.

3.5 Services (products)

The services and products of the sanitation system comprise:

- Sanitation services provided by functioning sanitation infrastructure
- Irrigation water for the agricultural area
- Biogas, electricity and heat through fermentation
- Stabilised sludge which can be used as manure on the agricultural area
- Agricultural products from the irrigation site
- Management structures for all the system components

3.6 Sustainability assessment

The objective of the assessment is to evaluate the CuveWaters sanitation concept in terms of environmental, economic, social, technical, political and institutional sustainability. The system was compared to the local – conventional – infrastructure which uses a separate agricultural irrigation site and to an adapted conventional infrastructure for nutrient-rich water reuse. The so-called analytic hierarchy process (AHP) was used for the evaluation (Saaty 1980); the AHP is a multi-criteria decision analysis tool for dealing with complex decision-making problems. The results indicate that the CuveWaters concept is the most sustainable one (Figure 3). If one looks at specific dimensions, the system scores highest in the social and environmental dimensions. In the economic, institutional, political and technical dimensions, the proposed option is not ranked first even though all three options are very close. Expanding sanitation, wastewater treatment and water reuse for agricultural irrigation is thus a promising step towards a more sustainable sanitation and irrigation infrastructure that uses fewer resources, is economically feasible, institutionally and politically practicable, and technically sound.

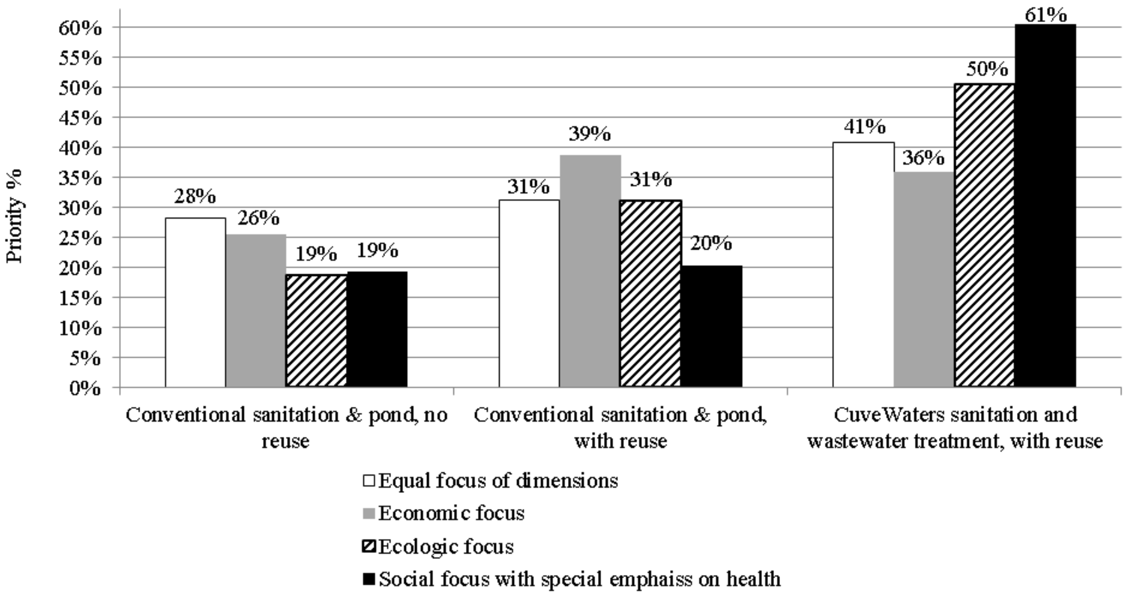

Figure 3: Sustainability assessment of the CuveWaters sanitation concept compared to conventional options (Woltersdorf et al., forthcoming)

3.7 Variance of implementation and challenges

Initial operation of the wastewater treatment plant was scheduled for January 2012. In the end, the waterline in the plant started operation in April 2013, together with the opening of the washhouse. This delay was due to a number of factors:

- Preparation of the contractual agreements between OTC and TU Darmstadt
- Delays in developing the agricultural concept
- Delays in construction activities in Outapi caused by the constructing company (EMS)
- Delays in connecting the facilities to the water supply network and electricity grid
- The vacuum sewerage that was initially installed was made of glued PVC piping from South Africa; it proved to be inappropriate, and was replaced by welded PE piping from Germany

The study concerning the agricultural use of the treated wastewater formed the basis for the technical design of the wastewater treatment plant. A consulting company was commissioned to carry out this study. The anticipated preparation time (including recommendations regarding the required effluent quality and the irrigation system) could not be met by the consultant.

Very heavy rainfall led to delays in the treatment plant's construction works in Outapi. The opening of the community washhouses and cluster units was postponed as a result of the delays to the construction works. One further issue (locks in the cluster units not having keys that could be copied) led to another delay of a few weeks.

During the operation of the water treatment and reuse plant, it has transpired that an unforeseeably large quantity of big fruit seeds arrive at the plant with the sewage. As a result, there is a significant need for manual cleaning of the stone trap, and seeds that have not been separated in the stone trap pass into the downstream rotary lobe pumps, where they cause the rotary lobes to be rapidly worn off. To address this issue, a new concept for the inlet facility of the plant has been developed, including a spiral sieve for the separation of the seeds plus intermediate pumping.

Finally, it is worth mentioning that the fermenter and the CHP facility for the utilisation of the biogas were tested but never fully commissioned. The main reason for this is a lack of sufficient residual biomass from the agricultural fields to support the co-fermentation process in the fermenter.

Other challenges were presented by the dynamic population in the connected settlements. The exact number of inhabitants was not known, and the population changed between the participatory planning process and the commencement of operation, so calculations concerning the anticipated amount of sewage were not very valid, and this affected the operational costs and management model.

Another challenge was the continuation of the CHCs without ongoing input and support from the project and OTC. The effects on health and hygiene behaviour were not as significant as they might have been. Due to project restriction, the initial training phase was carried out in an effective manner, but the further process whereby the clubs sustain themselves as voluntary structures was not achieved. However, OTC included the people who had been trained when decisions had to be taken about the management of the community washhouse.

As for the irrigation site, group dynamics within the first group of farmers led to social conflicts which affected their relationship with the supervising farmer. Training in conflict resolution and group dynamics contributed to solving the problems and thus prevented mismanagement on the farm. Furthermore, the length of the leasehold (two years) might have to be reconsidered because the farmer has to make initial investments and requires adequate time to make a reasonable profit.

A number of technical aspects are currently still being evaluated. It has proved impossible to make a final assessment of whether there are any long-term mineral or nutrient deficiencies in the crops; such aspects have to be scientifically monitored over a longer period in order to optimize additional fertilizer application and liming. Besides this, local conditions – and the availability of materials in particular – naturally have to be considered if the reuse concept is to be replicated. For example, wooden poles to raise the tomato plants are exceptionally expensive in northern Namibia since timber is generally rare here. In addition, plastic sheeting to build a drying unit proved hard to obtain locally.

4 Economic considerations

4.1 Investment

The total capital expenditure for the CuveWaters water treatment and recovery system amounts to approx. 28.9 million N$ (approx. 2.1 million €). The distribution of this investment to different parts of the system is shown in the following table. Approx. 39 % (ca. 11.4 million N$) of the investment can be attributed to machinery, and about 61 % (ca. 17.5 million N$) to construction work.

System component	[N$ million]	[€ million]
Communal washhouse and cluster units	3.17	0.23
Vacuum sewers and pumps	9.07	0.65
Water treatment and recovery plant	9.69	0.69
Biogas and electricity production	6.93	0.50
Total	**28.86**	**2.06**

Table 3: Approximate investment in the CuveWaters sanitation system (1 € = approx. 14 N$)

The capital expenditure shown here mainly applies to implementing a pilot plant in the context of a research project. Costs for the replication of the system (without pilot character and a higher number of users) are expected to be cheaper with regard to *per capita* costs. This is because the CuveWaters pilot plant is provided with additional measurement and control/monitoring technology as well as high-quality equipment. Furthermore, the pilot plant is built on a smaller scale than its economic optimum, and is located in a region with problematic conditions. Nevertheless, the plant has to fulfil international quality standards and tries to cover the entire value chain (from sanitation facilities to arable crops). Apart from this, expenses may also vary depending on local conditions, markets and prices. For the replication of the system shown here, general experience suggests that the above-mentioned capital expenditure can be reduced by about 40 %, which results in approx. 17.3 million N$ (1.2 million €).

4.2 Operation and maintenance costs and revenues

The costs of the CuveWaters sanitation system comprise operation and maintenance costs for the sanitation facilities (washhouse and cluster units), the sewers, the water treatment and reclamation plant, as well as the irrigation site. These costs consist of salaries, water tariffs, electricity costs, fuel, spare parts, maintenance, miscellaneous commodities, consumables and external services. Revenues are generated through water, wastewater and connection fees for users (e.g. in the form of vouchers at the washhouse), the sale of irrigation water to the farmer, as well as the leasehold for the irrigation area.

While a large part of the operation and maintenance costs are fixed costs (e.g. salaries), revenues are highly dependent on the amount of wastewater collected, which in turn depends on the number of users. The amount of wastewater is expected to be 61 m³/d at the end of the research project (December 2015) and after connecting new residential areas, which corresponds to about 900 users in total. In this case, the operation and maintenance costs add up to approx. 1.35 million N$ (about 96,100 €) per year (Table 4). The total revenues amount to approx. 0.68 million N$ (about 48,500 €) per year, which produces an annual deficit of approx. 0.67 million N$ or 47,600 € respectively. This deficit has to be borne by the operator, i.e. OTC.

	Scenario A	Scenario B	Scenario C
Wastewater collected [m³/d]	61	90	150
Estimated number of users	900	1,300	2,200
Annual costs	1.35 million N$ (96,100 €)	1.70 million N$ (121,500 €)	1.93 million N$ (138,100 €)
Annual revenues	0.68 million N$ (48,500 €)	1.24 million N$ (88,300 €)	1.87 million N$ (133,700 €)
Annual deficit	0.67 million N$ (47,600 €)	0.46 million N$ (33,100 €)	0.062 million N$ (4,400 €)

Table 4: Approximate annual costs and revenues, depending on the amount of wastewater collected (1 € = approx. 14 N$)

The plant's capacity has not yet been fully exhausted, so several water use scenarios have been calculated. If 90 m³ of wastewater were to be collected (from about 1,300 users), the annual revenues would increase to approx. 1.24 million N$ (about 88,300 €), thus producing an annual deficit of approx. 0.46 million N$ (about 33,100 €). The revenues could be further increased by connecting even more users to the sanitation system. Up to 150 m³ of wastewater per day (from about 2,200 users) could be treated if peak loads were to be additionally compensated. In so doing, the plant could be continuously operated under full load, which leads to annual revenues of approx. 1.87 million N$ (about 133,700 €). In this case, the annual deficit amounts to approx. 62,000 N$ (about 4,400 €).

4.3 Cost-benefit analysis

A cost-benefit analysis was conducted on the basis of the above-mentioned operation and maintenance costs, as well as the system revenues. In this context, reinvestments were additionally considered in order to calculate a result per cubic metre of water. It was assumed that the initial investment was fully covered by a donor (as is the case with the pilot plant, which is funded by the German Federal Ministry of Research and Education). Furthermore, 10 % *per annum* of the investment was allocated to the amortization or subsequent renewal of machine parts, and 4 % *per annum* to construction work. If there are 61 m³ of wastewater per day, the reinvestments amount to approx. 1.83 million N$ (about 131,000 €) per year, which leads to a negative result of 112.09 N$/m³ (8.01 €/m³) (Table 5). If 90 m³ of wastewater are collected every day, the reinvestments amount to approx. 1.90 million N$ (about 136,000 €) per year, leading to a negative result of 71.99 N$/m³ (5.14 €/m³). If 150 m³ of wastewater are treated, the costs per cubic metre add up to 38.73 N$/m³ (2.77 €/m³).

		Scenario A	Scenario B	Scenario C
Wastewater collected [m^3/d]		61	90	150
Estimated number of users		900	1,300	2,200
Full costs (reinvestments: 10 % machine parts, 4 % construction work)	**Annual reinvestments**	1.83 million N$ (130,700 €)	1.90 million N$ (135,800 €)	2.06 million N$ (147,000 €)
	Negative result	112.09 N$/$m^3$ (8.01 €/m^3)	71.99 N$/$m^3$ (5.14 €/m^3)	38.73 N$/$m^3$ (2.77 €/m^3)
Minimized operating expenditure (reinvestments: 4 % machine parts, 0 % construction work)	**Annual reinvestments**	0.57 million N$ (40,500 €)	0.59 million N$ (42,000 €)	0.63 million N$ (45,300 €)
	Negative result	55.40 N$/$m^3$ (3.96 €/m^3)	32.06 N$/$m^3$ (2.29 €/m^3)	12.71 N$/$m^3$ (0.91 €/m^3)

Table 5: Approximate costs per cubic metre of wastewater, depending on reinvestment rates (1 € = approx. 14 N$)

Apart from this, additional scenarios have been calculated which are based on minimized operating expenditure rather than full costs. This means that 0 % per year of the investment was considered for reinvestment in construction work, and 4 % for machinery. These kinds of minimized operating costs can be maintained so long as the system's asset erosion does not lead to functional defects that in the long run completely compromise the system's functionality. According to experts, it should take about three to eight years for this time to be reached, assuming that minimized operating expenditure leads to a negative result of 55.40 N$/$m^3$ (3.96 €/m^3) in the case of 61 m^3 of wastewater per day, 32.06 N$/$m^3$ (2.29 €/m^3) in the case of 90 m^3 of wastewater per day, or 12.71 N$/$m^3$ (0.91 €/m^3) in the case of 150 m^3 of wastewater per day.

The costs can be reduced even further by considering capital expenditure which applies to the replication of the system (as previously explained). This in turn leads to reduced reinvestment and thus to lower costs per cubic metre of wastewater.

4.4 Financing options

As the cost-benefit analysis shows, the operation of the pilot plant does not cover its costs, so it must duly be subsidised. This not only applies to operation and maintenance, but also to technical support as well as investment in general. The operator of the system (i.e. OTC in the case of the pilot plant) would be the borrower of external financial budget support, which primarily comes from the Namibian Ministry of Urban and Rural Development since it is the body that is responsible for municipal budgets. Expenditure on extending the system could under certain circumstances be financed by the Development Bank of Namibia.

In terms of the system's replication, its set-up could be adjusted to local conditions in order to improve its economic performance, for instance by making exclusive use of cost-efficient system components. In so doing, the fundamental functions of providing sanitary facilities and reclaiming water could still be realised. Nevertheless, grants from the Ministry or loans are required for initial investment, and these could be paid off in subsequent years. Definite prerequisites for the granting of credit are cost-covering management of the sanitation system and corresponding subsidy commitments from the Ministry.

Other potential financing instruments might be international funds, e.g. the United Nations Green Climate Fund. Furthermore, microfinance could cover the construction costs of cluster units or pay for the connection of individual households to the sanitation system. Other potential financing partners not mentioned so far include the Namibian Ministry of Agriculture, Water, and Forestry, the Namibian Agribank, FIDES Bank Namibia, Rural Development Centres, the Namibia Development Trust, and international development cooperation institutions.

5 Transfer/dissemination

The CuveWaters sanitation system offers a great deal of potential when it comes to future transfer and implementation. The proposed infrastructure provides fresh water, adequate sanitation, and resources for agriculture while minimizing environmental impacts. There is a great demand for functioning adapted sanitation concepts in northern Namibia and Sub-Saharan Africa. Namibia is highly dependent on food imported from South Africa and Angola. The CuveWaters sanitation concept links sanitation and food production in a given area with an enormous demand in both fields.

5.1 Initial transfer projects

No transfer projects have been initiated yet. However, following the successful implementation of the sanitation concept one can see potential for dissemination in other cities of Namibia as well as the SADC region. The experience gained with CuveWaters might offer a strong incentive to initiate follow-up projects.

5.2 Demand analysis

A set of criteria have been developed to assess the potential to transfer the sanitation and water reuse system to other regions (Juschak 2014), and these criteria have been used to assess the extent to which countries and areas in southern Africa are suitable for receiving a system such as the one in Outapi. At a national level, Botswana, Namibia and South Africa were identified as the most suitable countries for transferring the CuveWaters sanitation system. The three countries were awarded some of the highest scores in terms of indicators such as literacy rate, ability to pay, government effectiveness, and ease of doing business. The results were then refined by assessing population density, the occurrence of floods, and the suitability of soil and climate for agriculture at a local level (grid of 5 or 10 km). As a result, regions that are potentially suitable for the transfer of the CuveWaters sanitation system include several towns in Namibia (Windhoek, Okahandja, Rundu), a few regions in southern Botswana (Ramatlabama, Gaborone), and substantial sections of the eastern coast of South Africa, as well as several areas in the country’s interior (e.g. regions around Johannesburg and Pretoria).

5.3 Marketing

The sanitation concept was (for example) marketed during the IWA Conference on Water Reuse in Windhoek (October 2013) and at the IFAT Environmental Technology Forum Africa 2015 in Johannesburg. Research findings were also presented during an excursion to the pilot plant in Outapi in 2015; several Namibian municipalities took part in this event. Furthermore, trade fairs (for example, in Ongwediva) and the Olufuko Festival in Outapi provided opportunities to promote the sanitation project. The industry partner (Bilfinger Water Technologies) also visited the pilot plant.

5.4 Networks and partners for dissemination

Regular meetings between TU DARMSTADT, ISOE and Bilfinger Water Technologies ensured ongoing discussions about transfer options. Furthermore, regular exchanges between Cuve-Waters and Namibian partners (MAWF, MURD, OTC) enabled rapid action with regard to changes that arose during the work process.

The main focus was on MAWF and MURD since they are responsible for sanitation in Namibia. However, the considerable effort required for communication and coordination might make it difficult to implement sanitation projects, so CuveWaters invited the respective decision-makers to exchange ideas and discuss ways of improving sanitation in Namibia by using the experience gained with the CuveWaters pilot plant in Outapi.

Platforms for promoting the sanitation concept are at a national level (e.g. Basin Management Committees, WATSAN Forum) and an international level (e.g. Global Water Partnership, SADC Water Division, Sustainable Sanitation Alliance/SuSanA, African Sanitation Knowledge Network/ASKNet, Water Supply & Sanitation Collaborative Council, South African Toilet Organisation/SATO). Moreover, the GIZ Transboundary Basin Management Committees are a good network for approaching neighbouring countries.

5.5 Intellectual property rights management

The industry partner (Bilfinger Water Technologies) holds the intellectual property rights to the plant components.

5.6 Success factors

Opportunities for a successful transfer lie in the tariff system. As long as it is well balanced, the plant's operation and maintenance costs can be directly covered by revenues, and indirectly by selling agricultural products. Apart from this, the project fills the knowledge gap between agriculture and engineering. Furthermore, the vacuum system is flexible and allows for future extensions so that it can grow with the town.

Key success factors for the implementation and dissemination of the proposed system are:

- Clear allocation of responsibilities (e.g. within the operator) and set-up of contracts (e.g. with farmers) as well as institutional structures
- Set-up and design of monitoring and controlling structures by the operator
- Participation of users in the planning process
- Creating an understanding and acceptance among users of the facilities as well as the payment structures
- Discussing and learning about hygiene prepares users for the benefits and costs of the new facilities
- The frequent and regular use of facilities is affected by their maintenance and level of cleanliness

6 References

Deffner, Jutta/Johannes Böff (2012): Participatory sanitation marketing approaches for altering hygiene behaviour. A review of Community Health Club and community-led total sanitation. CuveWaters Papers No. 9. Institute for Social-Ecological Research (ISOE). Frankfurt am Main

Deffner, Jutta/Clarence Mazambani (2010): Participatory empirical research on water and sanitation demand in central northern Namibia: a method for technology development with a user perspective. CuveWaters Papers No. 7. Frankfurt am Main

Deffner, Jutta/Sylke Reisenauer/Karoline Storch (2012): Baseline household inventory survey on water and sanitation situation at the three implementation settlements in Outapi. CuveWaters internal project report/Chartbook

Juschak, Maxim (2014): Development of criteria for the assessment of the transferability of the IWRM project "CuveWaters" in southern Africa. Master's Thesis, TU Darmstadt, IWAR Institute (in German)

Ministry of Agriculture, Water and Forestry – MAWF (2009): Namibia National Sanitation Strategy 2010/11–2014/15. Windhoek

Müller, Katharina/Jutta Deffner/Peter Cornel (2013): A sanitation concept adapted to the preconditions in low-density urban areas of semi-arid environments – an example from North Namibia. Paper presented at the 9th IWA International Conference on Water Reuse, Windhoek, Namibia

Namibia Statistics Agency (2014): Namibia – Namibia Population and Housing Census 2011. Government of the Republic of Namibia. http://www.nsa.org.na/microdata1/index.php

Saaty, Thomas L. (1980): The Analytic Hierarchy Process. McGraw-Hill, New York

Waterkeyn, Juliet (2010): Hygiene behaviour change through the community health club approach. A cost-effective strategy to achieve the Millennium Development Goals for improved sanitation in Africa. Lambert Academic Publishing, Saarbrücken

Woltersdorf, Laura/Martin Zimmerman/Jutta Deffner/Markus Gerlach/Stefan Liehr (forth-coming): Evaluating sanitation, wastewater treatment and nutrient-rich water reuse for urban agriculture in Namibia

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