WaReNam – Multi-Scale Water Reuse Strategy for Namibia: Technology, Governance and Capacity Development

Final Report, Part II

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1 Background and scope

1.1 Scope and task

Many countries worldwide are threatened by or already face water scarcity. Compared to other regions of the world, people of Sub-Saharan Africa have the least access to safe water resources. The expected impact of climate change with increasing droughts will further threaten water security. To establish technologies for stable water treatment, further research is required in order to provide safe water in sufficient quantity and quality. The German Federal Ministry for Education and Research (BMBF) is funding projects worldwide with the scope of mitigating this global water crisis by supporting research and development of innovative technologies, new forms of organisation and utilisation concepts and adopted management of conflicts of interest. Therefore, the research programme 'Water Security in Africa' (WASA) was launched in 2020 as part of that strategy.

The research project 'Multi-Scale Water Reuse Strategy for Namibia: Technology, Governance and Capacity Development' (WaReNam) is funded within this programme. Namibia is one of many examples in Southern Africa where high population growth and urbanisation along with climate change are big challenges for water supply and security. A promising solution to address water scarcity is the diversification of water resources including water reuse. Although Namibia has decades of experience in water reuse in Windhoek, there is a huge untapped potential for water reuse outside the capital. Namibia's Water Resource Management Act, that was passed in 2013, calls for the protection of water resources and promotes the reuse of treated wastewater but lacks a national water reuse strategy. Therefore, technological innovations in combination with governance and capacity building measures are key to the implementation of a sustainable and successful water reuse strategy.

1.2 Objectives

The main phase of WaReNam aims at supporting the transdisciplinary development of a water reuse strategy for Namibia to increase water security by diversifying the spectrum of available water resources. In its initial phase, WaReNam explored the potentials and risks of using effluent from WWTPs and WSPs for industrial and agricultural reuse. For strategy development, different spatial scales were considered comprising urban and peri-urban areas. The strategy consisted of three main components: (1) technological innovations, accompanied by (2) governance and (3) capacity development measures: In terms of technology (1), existing water infrastructures and water quality requirements for different types of usage were aligned through an integrated concept for water reuse (technology matrix). The project evaluated different technologies and their combinations for further polishing of wastewater treatment plants (WWTP) and waste stabilisation ponds (WSP) effluents to reach water qualities that are safe and applicable for specific reuse options. Research activities on governance (2) involved the revision, differentiation and adaption of national water reuse regulations within a risk management framework as well as the design of corresponding institutional structures. The risk management framework compromised the identification and evaluation of social-ecological risks related to water reuse as well as technical, regulatory and knowledge transfer measures to control and minimise these risks. Therefore, institutional structures must be designed to formalise cooperation among stakeholders and institutions as well as to define responsibilities. Capacity development (3) measures were planned to ensure sustainable management as well as operation and maintenance of water reuse facilities by training plant operators, managers, technicians, and farmers. Close cooperation with local institutions facilitated the corresponding knowledge transfer to increase awareness and acceptance among stakeholders.

1.3 Planning and procedure of the project

The joint project WaReNam was carried out in the period from December 1st, 2021, to February 28th, 2023. The partners were the ISOE - Institute for Social-Ecological Research and the IWAR Institute of the Technical University of Darmstadt. The project work on site was carried out in close cooperation with the Namibian Ministry of Agriculture, Water and Land Reform (MAWLR). Furthermore, several Namibian municipalities and institutions were won as associated partners (cf. Chapter 1.5). ISOE was responsible for coordinating the network.

The initial phase of WaReNam follows a transdisciplinary co-design process (Becker, 2002; Jahn et al., 2012), which includes a problem definition in the context of water reuse and related research gaps and needs. In addition, the scientific and societal actors decide on common research goals through the integrative design of the research process. The overall objective is to design a joint implementation plan for the main phase of WaReNam with relevant Namibian stakeholders from politics, administration, industry and science. Furthermore, the participants will jointly select locations for pilot plant operations as well as industrial partners and corresponding technologies for the main phase. To identify a demand profile for water reuse and innovation potentials of technological options, WaReNam will apply a Demand Responsive Approach (DRA) (Deffner and Mazambanim C., 2010; Zimmermann et al., 2012), which includes a qualitative social-empirical perspective with participatory planning. During the 15 months, the focus is on the planning phase of the DRA. The subsequent implementation phase is foreseen for the main phase of the project. The knowledge gained will be processed to obtain a sustainable target corridor for research and development needs. Literature research, own research experiences and results from previous projects (CuveWaters, EPoNa) will support the process. In addition, expert interviews on the state of wastewater management and on-site explorations will be part of the approach. The aim of the DRA is to lead the transdisciplinary co-design process in developing a common understanding of the problem and needs profiles for technology, governance and capacity building. In this way, key research questions and technology options can be jointly identified, taking into account local needs and perceptions.

The initial phase consists of WP 1 "Stakeholder Dialogues and Needs Assessment" (WP lead: ISOE; WP collaborators: IWAR, CUVECOM, SASSCAL) and WP 2 "Innovative Techniques for Water Reuse" (WP lead: IWAR; WP collaborators: EGLV, ISOE), which together form the DRA and in which the necessary research activities will be carried out. WaReNam will conduct three stakeholder workshops (online and if possible in Namibia, accompanied by field reconnaissance) to implement the DRA. The workshops are mapped to the two WPs and include the following target groups, objectives and expected outcomes (WP 1 includes Stakeholder Workshops 1 and 3; WP 2 includes Stakeholder Workshop 2).

1.4 State of the art in science and technology

Namibia is one of the driest counties in Southern Africa. Water resources are becoming increasingly scarce (Clercq et al., 2018) and climate change is expected to have a particularly strong impact in Africa due to its low adaptive capacity and resilience (Herrfahrdt-Pähle and Stuart-Hill, 2011). A promising solution to overcome water scarcity is the diversification of water resources including water reuse (Lahnsteiner and Lempert, 2007) which saves drinking water and uses nutrients from wastewater as fertiliser (Qadir et al., 2020).

1.4.1 Technologies for wastewater treatment

Waste stabilization ponds (WSP) are the most common wastewater treatment technology in many developing countries, also in Namibia. WSPs are characterized by being low-tech and low-cost, a simple design, low accumulation of sewage sludge and high process stability (Mara, 2009; Sperling, 2007).

Traditional WSPs consist of anaerobic ponds, facultative ponds and maturation ponds. In situations with no receiving water body, an evaporation pond is also required. The main purpose of anaerobic and facultative ponds is the removal and stabilization of the organic matter. Maturation ponds are usually designed for the remove of pathogens via natural UV radiation (Shilton, 2005; Sperling, 2007; Verbyla et al., 2019).

WSPs are a key component in achieving the goal of comprehensive wastewater treatment for small and medium-sized municipalities in Southern Africa including Namibia. However, the effluent quality often does not meet the national or international requirements for safe reuse, especially in regard to chemical oxygen demand (COD) and hygienic parameters (Sinn et al., 2022).

WSP operators face many challenges, in particular an increasing inflow and load to the WSP systems caused by fast growing urban populations, which often leads to overloading and overflowing. However, by increasing the number of ponds to compensate for the additional inflow, evaporation which is contradictory to the aim of water reuse, also increases. Other technical solutions for enhancing COD removal and thereby reducing the load to the exiting ponds can help to a certain extent (Sinn and Lackner, 2020).

In many countries worldwide, it is common to discharged treated wastewater into receiving water bodies, usually river, lakes or the sea. Within Namibia, receiving water bodies do not exists, so the poorly purified wastewater of WSPs is either evaporated unused or discharged unregulated into the environment. This is a risk factor for public health and animals. Regions in Northern Namibia which are flooded by the Oshanas during the rainy season are especially affected by disease outbreaks. Larger towns also aim at building conventional wastewater treatment plants (WWTP) in medium-term. However, the process is hampered by outdated infrastructures, limited technical and human resources and insufficient financial support (Callway, 2004; Kusangaya et al., 2014; Zimmermann et al., 2019).

Treated wastewater is subject to different requirements depending on the reuse purpose (Pescod, 1992). Based on the reuse purpose, a wide range of treatment technologies can be considered. The aim is to achieve low-cost construction, simple and low maintenance adapted to the local conditions, to at the same time create safe water for reuse. For irrigation purposes, the challenge is to find a technology which is able to remove COD and pathogens while keeping the nutrients in the water. Especially in the case of process combinations, there is a need for research and development to investigate what effects the technologies have, especially in relation to different local conditions (Fuhrmann, 2014).

1.4.2 Governance

Governance aspects are considered crucial for implementing reuse or circularity concepts (Breitenmoser et al., 2022; Flynn and Hacking, 2019), however little research is done on the governance of reuse and circular economy in low- and middle-income countries (Ddiba et al., 2020). Ddiba et al. (2020) emphasise “the importance of leadership from the public sector in co-developing visionary strategies for circularity and using their convening power to facilitate crosssectoral collaboration".

In terms of governance, specific regulatory references to water reuse can be found in various sources such as the WHO guidelines on the use of wastewater in agriculture WHO (1989, 2006), ISO 31000, Renn (2005, 2008) and WHO (2005). However, existing national regulations (DWAF, 2012) based on WHO guidelines tend to overlook important microbiological parameters and technological options such as treatment and irrigation techniques. Furthermore, the complexity of institutional arrangements for reuse and corresponding risk management is still insufficiently researched (Beveridge et al., 2017). In the literature, municipal partnerships for wastewater treatment facilities are highlighted as promising for the successful implementation of water reuse (Kjellén, 2018; Reymond et al., 2018), but their success factors, effectiveness, and contribution to capacity development of municipalities, particularly in the Global South, are still not well understood (Moodley, 2019). Sanitation infrastructures in the Global South are often heterogeneous and locally specific configurations of material, cultural and regulatory arrangements (Cirolia et al., 2021), which must be taken into account in the analysis.

In addition, many local authorities rely on technical advice from external consultancies, which reinforces classical sectoral views on the water sector (Beveridge et al., 2017). Recent studies suggest that a cross-sectoral and cross-level approach is required, given the complexity of the governance tasks related to water reuse (Mario et al., 2018; Pahl-Wostl, 2019a). Effective co-productive networks of mutual learning and sharing of synergies depend heavily on multi-level embeddedness and, therefore, on key institutionalisation requirements (Pahl-Wostl, 2019b). In this regard, cooperative arrangements for agricultural water reuse have been successfully developed in planning, implementation, and operation in Germany (Ebert et al., 2020). However, effective institutions responsible for quality monitoring of water reuse and the distribution of irrigation water do not exist in Namibia. Research on reuse governance highlights the importance of policies and guidelines giving detailed guidance on reuse technologies, establishment of effective finance mechanisms that allow cost-recovery for operation and maintenance and institutional and monitoring capacities, as well as the fostering of the acceptance of reuse water (Breitenmoser et al., 2022).

1.4.3 Capacity development

Reusing water at different governance levels requires the development of several capacities and technical expertise among different actors as well as the multi-level knowledge production and cross-sectoral collaboration for the sustainable and just implementation of new technology and practices (Frick-Trzebitzky et al., 2022). Previous findings from research projects on water reuse in Namibia have shown that collaboration on the lowest governance level (town/municipality), such as wastewater treatment plant partnerships and networks can help to address collective problems on wastewater treatment and reuse concerning O&M, procurement, spare parts, etc. (ibid). Still, the formalisation and institutionalisation of such proposed networks are required to successfully implement them as functional governance structures (ibid.). Research on adaptive water governance emphasizes the role of low-level partnerships/networks for bottom-up approaches in multi-level governance (ibid.; cf. Kemerink-Seyoum et al., 2019; Pahl-Wostl, 2019b). Multi-level political alliances for water reuse require further research as well as capacity development (ibid.).

One major issue in the sustainabe implementation of new technology is securing of operation and maintenance (O&M). Poor O&M is one of the major challenges for the long runtime of existing WWTPs and wastewater infrastructure in general in Africa (Wang et al., 2014). Sustainable O&M requires (adaptive) knowledge management and training measures tailored to local conditions (social, ecological, infrastructural, economic) on all governance levels (source).

The management of wastewater through reuse presents a multitude of challenges that require continued knowledge transfer and capacity development. Such capacity development is crucial for the successful implementation of a water reuse strategy, particularly in maintaining the plants. It is therefore essential to identify the types of capacities that need to be developed at various levels, such as universities and vocational training, to realise a national water reuse strategy in Namibia and to ensure sustainable operation and maintenance of technological innovations (Remmert, 2016).

In addition to developing capacities, stakeholder dialogues and engagement are crucial for the practical development and application of a water reuse strategy. Recent studies highlight the importance of promoting effective collaboration through co-production and co-design (Deffner and Mazambanim C., 2010; Ebert et al., 2020; Zimmermann et al., 2012). This necessitates a commitment to engaging stakeholders in the development and implementation of water reuse strategies. By doing so, a comprehensive and sustainable approach to water reuse can be realised in Namibia.

1.5 Cooperation with other parties

The WaReNam consortium structure comprised several Namibian and German institutions (cf. Figure 1). Two German industry partners were involved in the project. Mann+Hummel International GmbH & Co. KG is specialized in membrane technology for wastewater treatment. Fuchs-Enprotec GmbH / Mecana Umwelttechnik GmbH are specialized in filtration technology and low-tech applications for wastewater treatment. Their expertise contributed to the co-designing process of the proposed pilot plants.

The Emschergenossenschaft (EGLV) is the largest water association in Germany and the operator of around 60 wastewater treatment plants of various sizes and more than 700 other water management facilities. Since 2017, EGLV has been involved in a partnership with Outapi to support the operation and maintenance of wastewater facilities. Since 2019, EGLV has been active in a BMZ-funded operator partnership in Zambia. As an associated partner in WaReNam, EGLV mainly focused on advising on technological concepts from the operator's perspective and contributed to the structural improvement of wastewater treatment plant neighbourhoods, capacity development, and standards and norms within the water reuse strategy. Together with NIMT (see below), EGLV identified the need for technical and practical training modules for maintenance and operation.

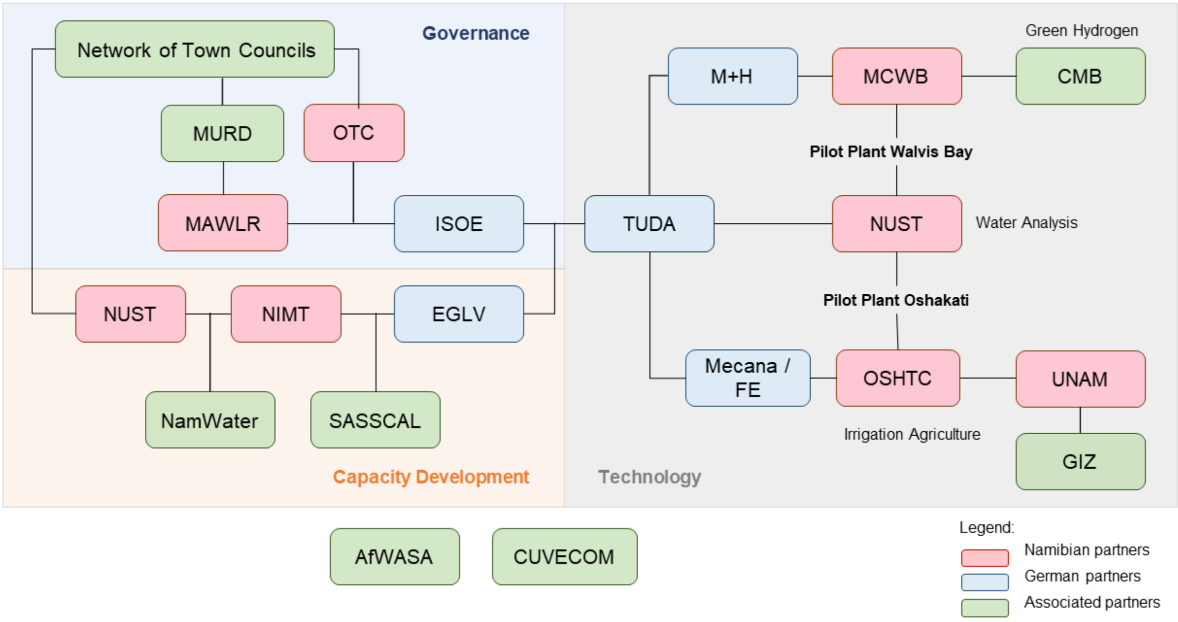

Figure 1: The WaReNam project consortium

Namibian partners from politics, administration, business and academia that were crucial for the initial phase were: The Water Affairs Department in the Namibian Ministry of Agriculture, Water and Land Reform (MAWLR) is tasked with ensuring the sustainable development, management and use of scarce water resources. It plays a key role in the implementation of the Water Reuse Strategy and related regulations. The Cuvelai Watercourse Commission (CUVECOM) is responsible for the transboundary management of water resources in the Cuvelai catchment, which is shared by Angola and Namibia. CUVECOM works with both governments, local and regional authorities and stakeholders to promote water security, water reuse and sanitation in the Cuvelai-Etosha Basin. CUVECOM acted as the Namibian stakeholder coordinator in WaReNam and was a subcontractor. The local authorities involved were potential sites for pilot plants in the main phase. The Outapi Town Council (OTC) in the Omusati region is the operator of an extended WSP and associated agricultural irrigation areas. The OTC has a long history of cooperation with ISOE and IWAR. Other local authorities were the Eenhana Town Council (ETC) with its wastewater treatment plant (Ohangwena region) and the Walvis Bay Town Council with its wastewater treatment plant (located on the coast of Namibia). A crucial Namibian practice partner was the Windhoek Goreangab Operating Company (Wingoc). The operator of the renowned wastewater treatment plant contributes to the development of the water reuse strategy with its expertise and decades of experience. The Omusati Regional Council (ORC) acted as the regional representative of the Ministry of Urban and Spatial Development for the local authorities. The local and regional authorities were interested in industrial, horticultural and agricultural use (urban gardening) and the associated regional/urban development and job creation. They have agreed to provide co-financing and the necessary infrastructure (spaces, equipment, personnel).

WaReNam aimed to work closely with academic partners such as the University of Namibia (UNAM, Faculty of Agriculture and Natural Resources), the Namibian University of Science and Technology (NUST, Faculty of Health and Applied Sciences) and the International University of Management (IUM) on the use perspective of water reuse and academic capacity building.

SASSCAL linked research activities with the Graduate Studies Programmes (SGSP) and the SASSCAL Alumni Network. In addition, contributions were made to the academic demand profile developed during the initial phase. In addition, the Namibian Institute of Mining and Technology (NIMT) offers vocational training programmes in the fields of technology, engineering and building materials. Representatives of development cooperation such as KfW and GIZ were also institutional partners. Close coordination took place in advance with GIZ in particular, especially with regard to water reuse for urban gardening and corresponding training for farmers.

2 Project results and outcomes

The work accomplished in the 15 months of WaReNam's initial phase has produced results at the technology, governance and capacity development levels that lay the groundwork for a water reuse strategy for Namibia. The archived results are presented in detail, their expected benefits are discussed and plans for the near future are elaborated in the following chapters.

2.1 Preliminary clarifications and accompanying studies

2.1.1 Kick-off workshop

As part of the WaReNam project, a comprehensive needs assessment was conducted from January to April 2022. The needs assessment was based on the Demand Responsive Approach (DRA), which combines a qualitative social-empirical perspective with participatory planning. During the 15-month initial phase, the focus was on the planning phase of the DRA. The subsequent implementation phase is planned for the main phase of the project. The lessons learned are processed to obtain a sustainable target corridor for research and development needs.

The needs assessment was initially based on a series of bilateral discussions with relevant Namibian institutions, including the Ministry of Agriculture, Water and Land Reform (MAWLR), the Cuvelai Watercourse Commission (CUVECOM), the Namibia Water Corporation (NamWater), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and various local and regional authorities. The aim of these talks was to get the Namibian stakeholders in the mood for the project, to discuss the project objectives and to prepare for the stakeholder workshop.

A major outcome of these discussions was the official assumption of patronage of WaReNam by the MAWLR. The MAWLR emphasised that the project objectives of WaReNam are in line with the objectives of the Namibian Water Act (Act 54 of 1956) as well as with more recent guidelines (planned Water Resources Management Act No. 13 and IWRM Plan) and thus support the political direction in which Namibia is moving with regard to water.

Another milestone was the holding of the first stakeholder workshop on 21 April 2022. 34 people participated in this online event, including representatives from MAWLR, CUVECOM, NamWater, the Windhoek Goreangab Operating Company (Wingoc) and numerous municipalities. During the workshop, needs profiles were developed in terms of technologies, governance and capacity development.

2.1.1.1 General conclusions

The results of the kick-off workshop clearly showed that a national water reuse strategy should focus on three spatial levels: large cities with conventional treatment plants, large municipalities in northern Namibia with treatment ponds and medium-sized municipalities with treatment ponds. Depending on the quantity and quality of the treatment plant effluent, reuse purposes in agriculture and industry have high priority. In addition, innovative ideas such as a National Implementation Committee for Water Reuse and Operation & Maintenance Units for reuse plants have been developed.

The needs assessment and the resulting measures show a high degree of congruence between the WaReNam project and the objectives of MAWLR and SASSCAL. This underlines the relevance and added value of the project for sustainable water management in Namibia.

The workshop contributed significantly to creating a common understanding of the challenges and requirements of water reuse. A common vision of a strategy based on the needs and requirements of Namibian stakeholders and local authorities emerged.

A needs-based approach was considered very important. WaReNam's activities and objectives should be based on the needs of Namibian stakeholders and local authorities. This approach will ensure that the measures and technologies introduced under the project will meet the specific needs and challenges of the water sector in Namibia.

The importance of capacity development in the context of water reuse was highlighted. This relates in particular to the management, operation and maintenance of water reuse facilities. It was emphasised that capacity development should continue beyond the life of the project to ensure sustainable improvement of water management in Namibia.

Finally, it was noted that institutional structures for water reuse should be developed and implemented in such a way that they are sustainable in the long term. This is crucial to ensure that the benefits of water reuse are sustainable and that the measures and technologies introduced can be effectively managed and maintained.

2.1.1.2 **Conclusions for the water reuse strategy**

The introduction of a national water reuse strategy could address a number of challenges in Namibia and contribute to improving water management and the overall quality of life in the country.

A major problem in northern Namibia is water pollution in the Oshanas due to overflowing sewage ponds. Reuse of pond water could prevent this problem. The strategy could propose water reuse measures and technologies that are specifically tailored to the conditions and challenges in the Oshanas.

Cultural issues and public perceptions regarding water reuse are also important factors to consider. The strategy could propose awareness-raising and public communication measures to raise awareness of the benefits of water reuse and address potential concerns or misconceptions.

Sustainable operation and maintenance are other important aspects that should be considered in the strategy. Appropriate water reuse technologies should be proposed, especially with regard to local and regional requirements and conditions, such as availability of spare parts. This would help to ensure the longevity and effectiveness of water reuse facilities.

The financial challenges of maintaining water infrastructure and implementing water reuse are also a key issue. The strategy could help to improve national financing strategies and open up new (international) financing opportunities.

Finally, there is an urgent need to accelerate the reuse of wastewater for agricultural purposes to ensure food supply in the country as well as water security. The strategy could propose measures and technologies specifically tailored to the conditions and requirements of agriculture in Namibia.

2.1.2 Water scarcity development in the project region

2.1.2.1 Introduction

A study on climate change challenges was contracted by the WaReNam project to the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL). The study primarily aimed to tackle the pressing issue of water scarcity in Namibia, with a particular focus on the Northern and Coastal towns. It underscored the urgent need for a comprehensive water reuse strategy to accommodate the needs of the rapidly growing population. This necessity was especially pronounced in areas such as Walvis Bay, a region that is home to over 52,000 inhabitants.

The study also underscored the importance of aligning with the United Nations Sustainable Development Goals. These goals encompass a range of objectives, including ensuring access to clean water, promoting economic growth, developing sustainable infrastructure, and taking decisive action on climate change.

The study provided an in-depth analysis of the current state of water availability and supply in Walvis Bay. It highlighted the challenges posed by the scarcity of rainfall and the depletion of borehole water, which are the primary sources of water for the region.

The study also outlined the Namibian government's commitment to implementing Integrated Water Resources Management (IWRM). This strategy is designed to promote the development, sustainable utilization, conservation, and protection of water resources in Namibia. However, the study acknowledged that there is a significant gap in human capacity to fully implement IWRM in Namibia.

2.1.2.2 Methodological approach

The methodological approach of the study was centred around a comprehensive analysis of the current water situation in Namibia, particularly in the Northern and Coastal towns. The study examined the existing water resources, the challenges they face, and the potential for water reuse strategies.

The study relied on data from various sources, including reports from the Republic of Namibia and the Water Resources Management Act of 2004. It also considered the impact of climate change on water resources, as well as the government's efforts to implement Integrated Water Resources Management (IWRM). The study also examined the effects of floods on the population, agriculture, livestock rearing, and health facilities. It considered the potential for wastewater reuse as a strategy to mitigate the effects of floods, water scarcity, and water insecurity.

Furthermore, the study took into account the impact of human activities on water resources and the potential for increased stress due to climate change. It emphasised the need for careful water demand management and the implementation of water reuse strategies in the face of these challenges.

In the case of Walvis Bay, the study analysed the town's growing population, the challenges posed by the surrounding mining areas, the increased prices of water desalination plants, and the low average annual rainfall.

Overall, the methodological approach of the study was comprehensive, taking into account a wide range of factors affecting water resources in Namibia and the potential for water reuse strategies to address these challenges.

2.1.2.3 **Results**

The results of the study highlighted several key findings:

- The demand for water in Namibia, which stood at 135 Mm^3/annum in 2008, is expected to more than triple by the year 2030, to 497 Mm^3/annum. If this development is confirmed by this extent, irrigation will use 65% of Namibia's total water demand by 2030.
- The study found that the expected expansion of irrigation farming will be directly impacted by climate change. For example, reduced runoff of the Kunene, Okavango, and Zambezi Rivers will lead to reduced availability of water.
- The study also found that the predicted temperature increases and droughts will result in more severe water scarcity, which in turn may trigger increases in the cost of water (especially piped water) and sanitation provision. This will be mostly felt by poorer sections of the population.
- The study also highlighted the impact of floods on the population, agriculture, and health facilities. In 2009, Namibia and neighbouring Angola received heavy rains which led to localized flooding. It is estimated that around 130,000 people were affected. The flooding also submerged fields, causing extensive damage to crops. Reports from the Ministry of Health indicated 143 suspected cholera cases, of which nine have been confirmed with seven related deaths.
- The study found that due to changes in weather patterns, floods are likely to occur because of heavy downpour or rainfall, upon which the areas become inundated, leading to submerged agricultural land which cannot be cultivated; livestock losses (no grasing) and property damage on homesteads as well as overflowing of wastewater ponds which go on to cause more problems such as waterborne diseases.
- The study also found that the possibility of flood water might not be experienced for some years. This will affect the water runoff in these areas contributing to water scarcity and insecurity. In the face of these uncertainties, a water reuse strategy is just inevitable.

2.1.2.4 **Conclusions**

The study concluded that Namibia, being a water-scarce country where potential evaporation exceeds precipitation, faces significant challenges in managing its water resources. The semi-arid conditions make Namibian water sources vulnerable, where the impact of human activities usually exceeds the natural impacts. Even without human influence, climate variability and climate change will bring about added stress to Namibia's water resources.

Due to the increase in water demand, Namibia has reached its carrying capacity of water in many areas of the country, which might also progressively exceed in the near future. The major responses for the Northern in the case of drought have been so far to particularly ensure water security for drinking, farming, business, and wildlife. Initially, the response of the government has been reactive rather than proactive and long-term due to the absence of early warning information.

In view of added stress on water resources caused by climatic changes, it will become more important to carefully manage demand for water and implement water reuse in the Northern and other regions of Namibia.

The study also concluded that the town of Walvis Bay, with a rapidly growing population, is facing significant water challenges due to the mining areas around the town, increased prices of water desalination plants, and low average annual rainfall. The study emphasized the importance of implementing a water reuse strategy in Walvis Bay and other regions of Namibia to meet the growing demand for water and mitigate the effects of water scarcity and insecurity.

In conclusion, the study underscored the importance of water reuse as a strategy to address the challenges of water scarcity and insecurity in Namibia. It highlighted the need to strengthen the water reuse system in the Northern regions and Namibia at large for water recovery process and mitigation measures to help with water insecurity and reduce the spread of waterborne disease that may arise because of wastewater pond overflow when the flood hits.

2.1.3 **Policy analysis**

Together with the needs assessment, a policy analysis of water-related legal norms in Namibia was conducted. The analysis of laws and regulations shows that there are several regulations that relate to the reuse of water.

The Water Act 54 of 1956 (Republic of South Africa, 1956), which is still the only legally binding water law, gives the ministry the authority to, among other things, study water resources; plan water supply infrastructure; control water pollution; protect, allocate, and conserve water resources; inspect waterworks; collect water charges; and advise on all matters related to the water environment in general. This law was the first to mandate the treatment of wastewater and other effluents from industrial water uses. It addresses the treatment of wastewater or other effluents resulting from industrial purposes. Public wastewater should also undergo treatment to ensure that, after treatment, it is safely returned to the stream from which it was withdrawn. It further states that local authorities that have jurisdiction over wastewater disposal may use the treated wastewater or discharge it into a public stream.

The National Water Policy White Paper of 2000 (MAWRD, 2000) emphasises the need to develop new and alternative sources of water, with particular emphasis on wastewater reuse, water recycling, and rainwater harvesting to promote water use efficiency and ensure that water of the best quality is reserved for human needs.

The Water Resources Management Act No. 11 of 2013 (Office of the Prime Minister, 2013) includes provisions on the quality of wastewater and the reuse of treated wastewater, including industrial wastewater.

Despite these various regulations related to water reuse, the analysis shows that Namibian water legislation needs unification. There are a number of laws and regulations that address different aspects of water use and management but there is a lack of a coherent and comprehensive approach to the issue of water reuse. Such standardization would help improve the efficiency and effectiveness of water use and management in Namibia and ensure that water reuse is promoted in a manner that is both environmentally sound and socially equitable.

2.2 Technology development for water reuse

2.2.1 Mid-term workshops

From July to November 2022, a series of workshops and discussions (according to the proposal Stakeholder Workshop 2 "mid-term workshop") took place on the selection of the pilot sites and the co-design of the pilot plants. The selection of the pilot sites for the WaReNam project was made in close cooperation with the Ministry of Agriculture, Water and Land Reform (MAWLR). After the first stakeholder workshop, it was decided that two pilot sites will be established. The selection of the sites was based on several criteria:

- Local authority willingness to participate: both municipalities showed a strong interest in participating in the project and were willing to provide the necessary resources.
- Local authorities already in the process of improving their wastewater systems: Both Walvis Bay and Oshakati have taken measures to improve their wastewater systems in the past.
- Sufficient technical conditions: Both sites have sufficient water volumes, wastewater treatment capacities and opportunities for reuse.
- Skills and know-how of management and staff: The responsible persons in both municipalities have the necessary knowledge and skills to effectively operate and manage the pilot plants.
- Benefits to the local authority: The establishment of the pilot plants is expected to contribute to job creation and improvement of the local water supply.

2.2.2 Initial considerations for technological applications

Based on the results of the stakeholder workshops and the on-site meetings in Namibia, different challenges regarding the existing circumstances and different reuse purposes were identified. In order to develop and select an innovative and fit-for-purpose technology that can also be scaled-up for a broad application to practice water reuse in Namibia, certain consideration had to be made. Figure 2 conceptually depicts these considerations. The starting point in Namibia is usually an existing WSP (smaller and medium size municipalities), in few cases (large municipalities) there is a more advanced wastewater treatment plant (WWTP), employing either activated sludge or biofilm-based technologies for biological treatment. To be able to safely use the effluent of both of these facilities, WSP or WWTP, further treatment is usually inevitable to reduce pathogens. There are different options, starting with filtration technologies, e.g. rock, sand or cloth filters, followed by disinfection processes, e.g. UV-radiation, chlorination or the addition of other oxidation agents. Depending on the process train that is then realized, the water can be reused for different purposes, either in agriculture or industry. Depending on the aim of water reuse different criteria apply in terms of effluent quality that also affect the choice of technology. Aside from the already mentioned standards, e.g. from the WHO, or the Namibian Code of Practice, a general classification of the desired effluent qualities based on the reuse target have been provided in

Table 1. Water reuse in agriculture always requires the removal of organic matter (C), whereas nutrients such as nitrogen (N) and phosphorous (P) should remain in the water, as they can

serve as fertiliser. The reduction of pathogens greatly depends on the usage. Aside from the irrigation system, the intended use of the products has an impact on the requirements for the reduction of pathogens with stricter values for food vs. fodder crops. Industrial reuse can have a wide range of quality requirements that depend on the intended use. Water for rinsing or flushing might only need a certain degree of water quality, whereas water for production processes often has very high standards on chemical and biological parameters.

For a nationwide concept in Namibia the spatial scale and intended usage are considered in combination and three spatial scales were defined. The different scales. This categorisation was also based on the size and requirements of the towns / cities in Namibia and the demands of the respective town councils.

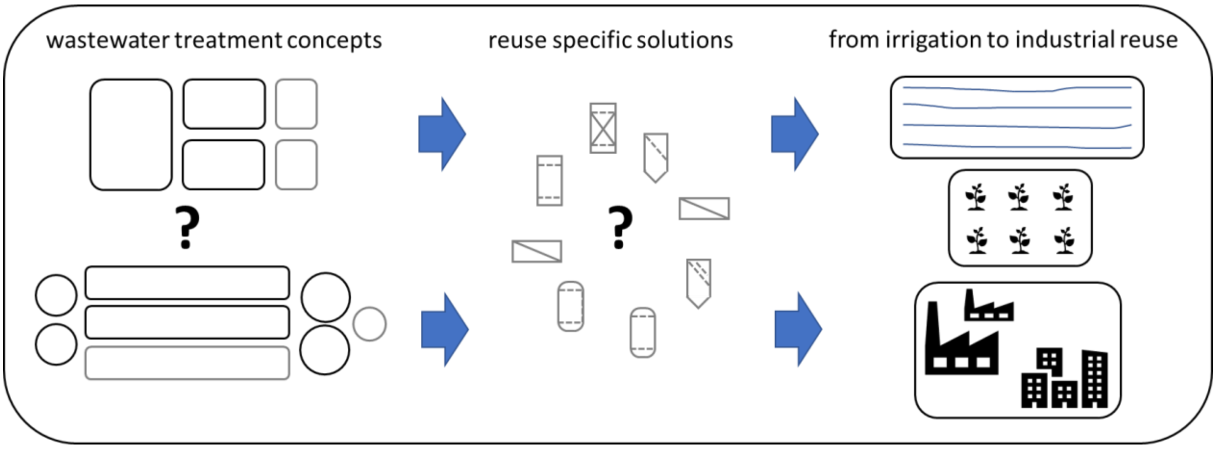

Figure 2: Water reuse with specific technologies for the respective reuse goals

The primary focus for municipalities (level 1) was identified to be industrial water reuse. The challenge for industrial reuse faced by most larger municipalities is to produce constant water quality while dealing with fluctuating wastewater compositions that may contain industrial contaminants with varying composition also over time. This requires the use of technologies that can effectively handle such challenging conditions and still produce highly purified water that meets the quality standards for industrial water reuse.

For large towns (level 2), the identified focus has to be on agricultural reuse. The challenge is to find a balance between water quality and nutrient recovery. Nutrients such as phosphorous and nitrogen can or should even remain in the water and thus be used for irrigation in agriculture. Additionally, the water provided for agricultural reuse has to be safe and free of pathogens to ensure safe contact of humans or animals with the products. Technologies selected for such applications must ensure the right balance between these two factors. and also provide a multi-barrier setting for best possible safety. At the same time the chosen technologies have to be robust and simple in O&M.

Medium-sized and small towns (level 3) also have a need for agricultural reuse, but they may have different constrains in terms of know-how, and human, technical and financial resources. This requires a somewhat different selection of technologies that considers existing infrastructure, including their limitations and provide a feasible solution that can be implemented with the available resources.

Overall, the development of an innovative technology selection for water reuse in different urban levels requires careful consideration of the unique challenges and constraints faced by each level. The technology must be able to handle the specific requirements while ensuring the water is of high quality and suitable for the intended use.

Table 1: Potential applications of water with different qualities

Water Reuse options	C	N	P	Pathogens
irrigation of urban green	x			x
agricultural reuse (fodder)	x			xx
agricultural reuse (food)	x			xxx
industrial reuse	x...x	x...x	x...x	x
service water	x			
drinking water (direct potable reuse)	x	x	x	xxxx

2.2.3 Determined locations and piloting

After contacting various municipalities within Namibia and based on the stakeholder workshop the following municipalities were determined as suitable locations / partner for pilot plants: Walvis Bay Municipality Council and Oshakati Town Council. For both locations, the results from the stakeholder workshops were used to identify possible technological solutions based on existing infrastructure and possible reuse purposes as well as the lessons learned from previous projects in the region (EPoNa). The meeting with each municipality and the site visit provided a better picture of the problem situation. Wishes and suggestions for the future of wastewater treatment in the corresponding area were discussed in detail. The elaborated concepts for both cities were, based on the collected results, the most suitable technologies for the respective applications.

Walvis Bay represents a level 1 municipalities as described in the section above. Walvis Bay is a port city on the west coast of Namibia, has a high share of industry and currently a conventional wastewater treatment plant in a rather poor condition. The plant is too small for the expansion of the town in the recent decades and not suitable for the purification of industrial wastewater. Currently, the partially purified wastewater is used for irrigation of public green spaces or not used at all and therefore discharged into the environment. The high proportion of industrial wastewater and a high salinity of the water in the region were identified as the biggest challenges for the purification and reuse process. The municipality's goal is to promote water reuse in a social and economic sense and to reuse water in industry. Therefore, the production of water with high quality (portable) on a constant level is necessary while wastewater influent is fluctuating in amount and quality. Possible users for the desired purpose might be found in the green hydrogen industry, which started to settle in Walvis Bay recently.

High quality effluent for fit-for-purpose reuse in industry requires a specifically designed treatment train. For Walvis Bay, a new conventional wastewater treatment plant has been in planning and is necessary as basis for further reuse options. The effluent from a conventional activated sludge system does not provide a high enough water quality for high-end industrial reuse. Thus, already the activated sludge process will be supplemented by membrane separation for sludge retention. Additional membrane technologies are required to allow for further reuse options. In order to eliminate micro pollutants and pathogens ultra-filtration will be used, in combination with reverse osmosis to reduce the salinity. The potential set-up for such a process is represented in Figure 3. The additional challenge in Walvis Bay is that industrial wastewater has to be treated which poses additional research questions especially for the membrane technologies and their operation regimes. Data collected from the operators in August 2022 and from measurements during the visit to Walvis Bay in November 2022 are depicted in Table 2 and Table 3. The high solids content and electrical conductivity of the raw wastewater but also the effluent illustrate the challenges a tertiary treatment for reuse will have to cope with. Walvis Bay's representatives, however, see a big opportunity in water reuse. They also pointed out the relevance of a new water act concerning water reclamation, the acceptance of water reuse in general and capacity development on a non-academic level.

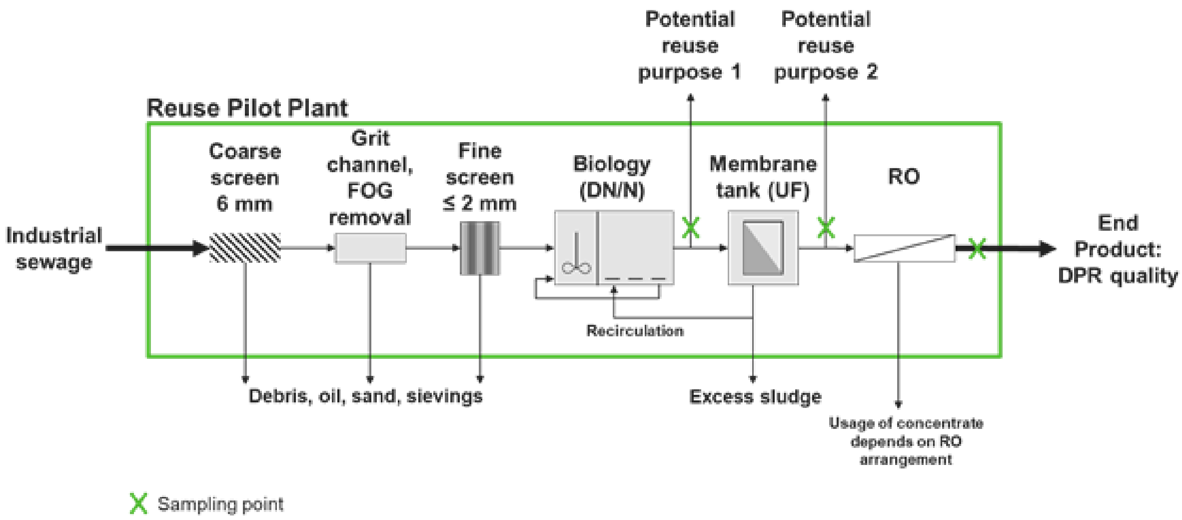

Figure 3: Schematic flow chart of the pilot plant design for Walvis Bay

Table 2: Data from August 2022 for the WWTP in Walvis Bay

Location of sampling point	Description of sampling point	pH	Electrical Conductivity [mS/m]	Total dissolved solids (det.)	COD [mg-O2/l]
Main Plant	raw sewage	6,8	909	5113	7620
Long Beach	raw sewage	7,2	218	1145	572
Main Plant	purified effluent	7,5	914	5556	52
Trickling Filter	purified effluent	7,2	825	4784	610
End User	purified effluent for Irrigation/Landscaping	7,3	901	5630	54

Table 3: Data acquired during the visit in November 2022

Sample (n = 3)	pH ± SD	EC ± SD (mS/cm)	TS ± SD (g/L)
1. WB Pump Station (17.11.2022)	6.99 ± 0.06	21.8 ± 0.1	10.9 ± 92
2. WB Pump Station 18.11.2022 (7:50)	7.24 ± 0.02	20.7 ± 0.1	10.3 ± 61
3. WB Effluent Activated Sludge 18.11.2022 (9:00)	7.78 ± 0.01	8.1 ± 0.0	4.0 ± 21
4. WB Effluent Trickling filter 18.11.2022 (8:30)	7.30 ± 0.01	8.0 ± 0.1	3.9 ± 34

Oshakati is the biggest town in the highly populated region of Northern Namibia. As most municipalities in Namibia, Oshakati is currently using (two) WSP for wastewater treatment. The city has registered a huge population growth within the last years (Figure 4). The WSPs are overflowing on a regular basis, especially in the rainy season. This causes a significant hazard to public health and the environment. Currently, the town is expanding its infrastructure in order to provide living space for the new population that has moved in and to enable a higher living standard for informal settlements by building new districts which are connected to the sewer system. The OSHTC has developed a strong need to improve its wastewater treatment in order to deal with the increasing amount of produced wastewater to prevent the ponds from overflowing and the accompanied health risks.

The Town Council already discussed an improvement of its wastewater treatment and water reuse concepts already before the WaReNam project got involved. Also, the research project EPoNa in a smaller town in the north, Outapi, already provided insights into the impact of several options for extensions before WSPs or upgrades that can also be installed inside the ponds (Sinn et al., 2023; Sinn and Lackner, 2020). Such extensions and enhancements of the WSPs were also discussed for Oshakati, but the risk of overflowing in the rainy season may not be prevented with this approach. Thus, other alternatives for suitable treatment technologies were determined. Based on experiences in the region and an informed decision-making process, a trickling filter system followed by a filtration system and disinfection were determined as the most suitable solution for the town. This treatment train, after piloting to optimise design and operational parameters, will provide the necessary water quality for irrigation. It is thus planned to use the purified water as irrigation water in agriculture for the production of food or fodder crops. There is plenty of unused land in the surrounding area of the WPSs and the planned pilot plant will serve as first stage to conduct agriculture on a larger scale. The research focus is set on the technology combination and agricultural reuse. The agricultural section will be supported by UNAM.

For both locations, water sampling and analysis will be supported and partially carried out by NUST.

Figure 4: Impressions of the Waste Stabilisation ponds (WSP) in Oshakati, top: WSP East; bottom: WSP West

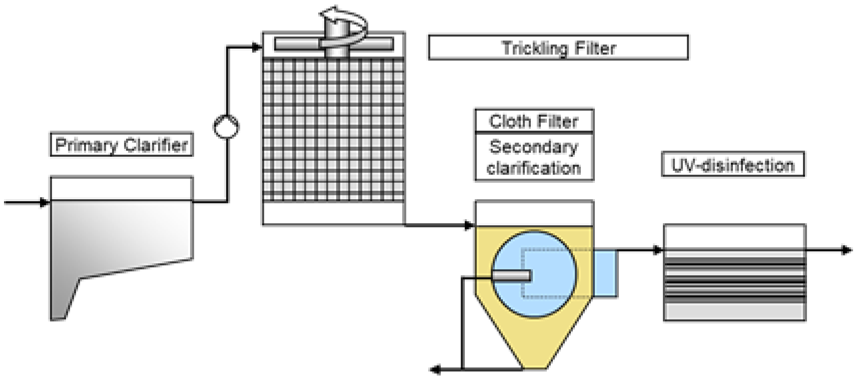

Figure 5: Concept for the WWT in Oshakati

2.2.4 Operational phases and sampling

For O&M as well as quality control, regular sampling and water analyses are essential. It is planned that both pilot plants are accompanied by scientific assistance in addition to local technicians, most favourably from a Namibian and German student at the same time at both locations. In order to monitor the operation of the plants a routine sampling schedule has to be carried out. In addition, intensive sampling phases will be carried out for specific research or operational questions, where a wider range of parameters will be investigated or the sampling intervals are adjusted.

A first routine sampling schedule was developed on the basis of various water reuse regulations. Four regulations have been identified as most relevant for the purpose of this project: *Guidelines for the safe use of wastewater, excreta and greywater* by the World Health Organization, *User's Manual for Irrigation with Treated Wastewater* by the Food and Agriculture Organization of the UN, the *Guidelines for Water Reuse* by the Environmental Protection Agency and Namibian's *Code of Practice: Volume 6 - Wastewater Reuse*. An overview of defined limit values for reuse of water based on the mentioned regulations is shown in Table 4.

Table 4: Water reuse guidelines overview. (EC: electrical conductivity; DO: dissolved oxygen; TSS: total suspended solids; TDS: total dissolved solids; COD: chemical oxygen demand; BOD: biochemical oxygen demand; N: nitrogen; P: phosphorous)

Parameter	**Defined limit values for reuse**			
	WHO	FAO	US EPA	CoP 6 (Namibia)
pH		x	x	x
Turbidity			x	x
EC				x
Temperature				x
DO		x		x
TSS		x	x	x
TDS		x		x
COD total				x
BOD			x	x

Parameter	Defined limit values for reuse			
	WHO	FAO	US EPA	CoP 6 (Namibia)
Otho-P				x
N total		x		x
Ammonia				x
Nitrite				x
Nitrate		x		x
Chloride				x
Sodium				x
Sulphate				x
Sulphide				x
Fluoride				x
Cyanide (free)				x
Cyanide (recoverable)				x
Zinc				x
Total heavy metals				x
Total coliforms				
E. Coli	x		x	
Enterococci				

For routine sampling, the parameters were prioritised according to the intended technologies and the reuse purpose. Samples have to be taken in sufficiently short intervals to be representative and to deliver scientifically significant data. At the same time sampling faces limited financial and human resources which have to be met. Therefore, two schedules were drawn: one that represents the ideal situation (see Table 5) and one that is cut down to a minimum for a proper operation of the pilot plants. The schedules consist of the standard chemical-physical and microbiological wastewater parameters.

Table 5: Ideal laboratory schedule for pilot plant monitoring

sampling frequency:	
daily	▫
twice a week	■
once a week	Δ
once a month	□

line		Oshakati							
parameter	unit	inflow	pretreatment	trickling filter	secoundary clarifier	pile cloth filter	effluent	storage tank	process water of pile cloth fitration
pH	-	■	Δ	Δ	■	■	■	Δ	□
turbidity	FNU	■	Δ	Δ	■	■	■	Δ	□
EC	µS/cm or mS/cm	■	Δ	Δ	■	■	■	Δ	□
temperature	°C	■	Δ	Δ	■	■	■	Δ	□
DO	mg/l o %	■	Δ	Δ			■	Δ	
TS	mg/l	■	Δ	Δ	■	■	■		□
TSS	mg/l	■	Δ	Δ	■	■	■	Δ	□
TDS	mg/l	■	Δ	Δ	■	■	■		□
TVS	mg/l	□							□
VSS	mg/l	□							□
TFS	mg/l	□							□
COD total	mg COD/l	■	Δ	Δ	■	■	■	Δ	□
dissolved COD	mg COD/l	■	Δ	Δ	■	■	■	Δ	□
BOD	mg BOD/l	Δ	Δ	Δ			Δ		
P total	mg PO4-3-P/l	■	Δ	Δ	■	■	■		
otho-P	mg PO4-3-P/l	■			■	■	■		
N total	mg TN/l	■	Δ	Δ	□	□	■		
Ammonia	mg NH4+-N/l	■					■		
Nitrit	mg NO2-N/l	Δ					Δ		
Nitrat	mg NO3-N	Δ					Δ		
Potassium	mg K+/l						□		
Chloride	mg Cl/l	□					□		
total heavy metals	µg/l	□					□		
far, oil & grease	mg/l								
trace elements	µg/l	□					□		
total coliforms	MPN/100ml	■	□	Δ	Δ	Δ	■	Δ	
E. Coli	MPN/100ml	■	□	Δ	Δ	Δ	■	Δ	
enterococci	MPN/100ml	□			□	□	□	□	
Cholorphyll-a	µg/l				□	□	□	□	

line		Walvis Bay					
parameter	unit	inflow	pretreatment	biology	membrane	RO	effluent
pH	-	■	□	Δ	■	■	■
turbidity	FNU	■	□	Δ	■	■	■
EC	µS/cm or mS/cm	■	□	Δ	■	■	■
temperature	°C	■	□	Δ	■	■	■
DO	mg/l o %	□					□
TS	mg/l	■	□	Δ	■	■	■
TSS	mg/l	■	□	Δ	■	■	■
TDS	mg/l	■	□	Δ	■	■	■
TVS	mg/l	□					□
VSS	mg/l	□					□
TFS	mg/l	□					□
COD total	mg COD/l	■	□	Δ	■	■	■
dissolved COD	mg COD/l	□	□	Δ			
BOD	mg BOD/l	□	□	Δ			
P total	mg PO4-3-P/l	■	□	Δ	■	■	■
otho-P	mg PO4-3-P/l	■			■	■	■
N total	mg TN/l	■	□	Δ	■	■	■
Ammonia	mg NH4+-N/l	Δ					Δ
Nitrit	mg NO2-N/l	Δ					Δ
Nitrat	mg NO3-N	Δ					Δ
Potassium	mg K+/l	□					□
Chloride	mg Cl/l	□					□
total heavy metals	µg/l	Δ					Δ
far, oil & grease	mg/l	□					□
trace elements	µg/l						
total coliforms	MPN/100ml	■	□	Δ	■	■	■
E. Coli	MPN/100ml	■	□	Δ	■	■	■
enterococci	MPN/100ml	□			□	□	□
Cholorphyll-a	µg/l						

It was also emphasised that local communities and governments should hold meetings and jointly present their challenges, requirements and actions to the national government to improve the chances of success. In addition, it was emphasised that city councils, regional councils, traditional authorities, leading ministries and leading institutions in the sector (such as NamWater) need to be involved.

A basic multi-level institutional structure to ensure sustainable and equitable development and implementation of a national water reuse strategy is the National Implementation Committee. In terms of the design of the Implementation Committee, various stakeholders have been identified to be involved, including local authorities, regional councils, NamWater, MAWLR, the Ministry of Environment and Tourism (MEFT), the Ministry of Finance, the Ministry of Urban and Rural Development (MURD) and the National Planning Commission (NPC). The tasks and functions of the committee include preparing operational and resource plans, addressing financial issues and exploring funding opportunities.

Two levels have been proposed: a smaller steering group (executive committee) and a larger roundtable. Possible funding sources could be the Green Climate Fund, the African Development Bank and KfW.

2.2.5 Needs profile: Code of Practice for water reuse

Amending the Code of Practice (CoP) on water reuse for water management in Namibia is a complex process that requires several steps and a number of stakeholders. The first step in this process is to engage the government in the renewal of the legislation. This is crucial to ensure that the changes in the CoP are in line with national laws and regulations and are supported by the relevant authorities.

An important aspect of the changes in the CoP is the recognition of new limits for bottled water. This is an area that is not sufficiently addressed in the current version of the CoP and needs to be updated given the increasing importance of bottled water in Namibia.

In addition, it is suggested that more specifications be added in the CoP in terms of limits and parameters. This would help to improve the clarity and precision of the CoP and ensure that it adequately addresses the specific needs and challenges of the water sector in Namibia.

Another important aspect of the amendments is the adaptation of the CoP to different forms of water use and specific requirements. This could include, for example, adapting the CoP limits in relation to transboundary water resources, such as the Kavango.

A particular focus is on standards for the quality of drinking water and wastewater. These standards are crucial to ensure the health and safety of the population and to minimise the environmental impact of wastewater.

It is also proposed to develop specific standards that take into account the requirements of neighbouring countries. This is particularly important in a context where water resources are often transboundary and water quality in one country can have an impact on other countries.

The amendment of the water quality standards could be coordinated with the amendment of the CoP. This would help to ensure a coherent and comprehensive approach to improving water quality and management in Namibia.

Finally, it should be noted that the Water Resources Management Act is currently being enacted. This could complicate the amendment of the CoP, as it will be necessary to ensure that the amendments to the CoP are in line with the provisions of this new Act.

2.2.6 **Final workshop**

As part of the WaReNam project, a stakeholder workshop (Stakeholder Workshop 3 "Final Workshop") on the project's governance approach was held in February 2023. The objective of WaReNam's governance approach was to support the development and implementation of a national water reuse strategy for Namibia, including appropriate institutional structures. The central research question was: What institutional structures are needed to implement a national water reuse strategy?

The final stakeholder workshop took place online, together with MAWLR and ISOE. Its objective was to co-design an implementation plan and a research approach for the main phase of WaReNam. Focus was set on designing governance arrangement and processes in Namibia to support the development of a national water reuse strategy.

During the workshop, various aspects of the governance approach were discussed. These included revising and differentiating national regulations (Code of Practice for Water Reuse), aligning different national policies, establishing a National Implementation Committee to expand communication and collaboration at different levels (including ministries, NPC, academia, industry, agriculture, etc.), developing and consolidating governance structures for sustainable operations, developing risk management plans, and establishing an implementation office to strengthen and support decision makers for future implementation of research results.

As the final product, the WaReNam governance approach was finalized and an institutional structure for a National Implementation Committee (NIC) was co-designed by MAWLR and the project consortium. The NIC structure is outlined below.

2.2.7 National implementation committee

The findings from the stakeholder workshops showed that a multi-level institutional structure for water reuse is crucial for the sustainable development and implementation of a multi-scale National Water Reuse Strategy. They can help to ensure the long-term benefits of water reuse in Namibia and that the measures and technologies introduced can be effectively managed and maintained. Additionally, an adapted research governance approach for the main phase of the WaReNam project can support such an institutional structure in its work in the strategy.

Therefore, both the WaReNam research governance approach and an institutional structure, the National Implementation Committee (NIC; see Figure 6) was co-designed by MAWLR and the project consortium within the final stakeholder workshop. The design will be constantly adapted and improved within to meet the Namibian demands. Various stakeholders were identified to be involved, including local authorities, regional councils, NamWater, MAWLR, the Ministry of Environment and Tourism (MEFT), the Ministry of Finance, the Ministry of Urban and Rural Development (MURD), and the National Planning Commission (NPC). The committee's duties and functions include preparing operational and resource plans, addressing financial issues, and developing funding opportunities.

Establishing the NIC as a multi-level institutional structure is key to develop and oversee the implementation of the national water reuse strategy brings stakeholders and interest groups from different sectors together in a multi-body institutional structure, facilitating cross-level communication and cooperation between these various actors.

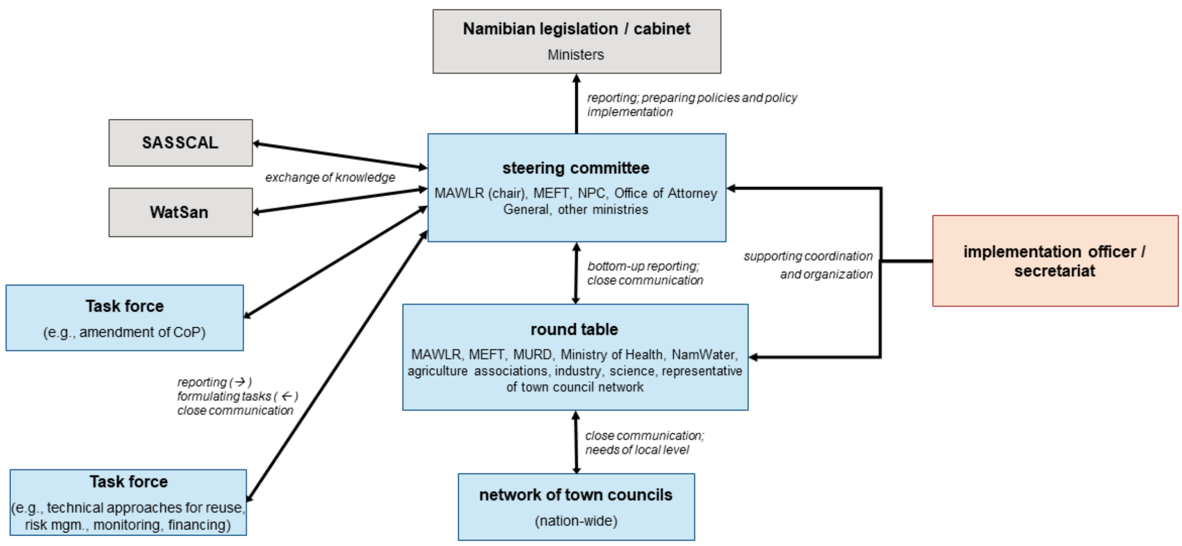

Figure 6: The approached structure of the National Implementation Committee (NIC) as co-designed by the project consortium and MAWLR

The proposed NIC contains a multi-level institutional structure comprising different sectors facilitating cross-level communication and cooperation between various stakeholders. The proposed institutional bodies and their tasks are envisaged as follows:

The Steering Committee at national level consists of most important stakeholders for developing and implementing the reuse strategy. The MAWLR will have the chair and will be joined by one member each of the Ministry of Environment, Forestry and Tourism (MEFT), National Planning Commission (NPC), Office of Attorney General and optional the Ministry of Health. The Steering Committee has the mandate to develop and oversee the development and implementation of the national water reuse strategy. Therefore, it will prepare policy decisions for the water reuse strategy and risk management plans as well as amendment suggestions for existing legal/policy documents related to water reuse and hand them over to the Namibian cabinet and legislation bodies. The Steering Committee functions as a platform to connect the development process on the national water reuse strategy to the WatSan Forum and SASSCAL to ensure a coordinated and integrated approach. This involves the development and consolidation of governance structures that support sustainable operation and decision-making. The Steering Committee is also responsible for multi-level communication finance within the NIC, and initiating, mandating and guiding specialised Task Forces.

The Task Forces consist of experts in chief who work on specific topics for developing the strategy such as the amendment of the Code of Practice, monitoring, financing, responsibilities, risk management plans, strategy objectives, etc. In line with an adaptive governance approach, some task forces could be installed as permanent institutional working groups while some could be temporarily or ad-hoc formed according to demand. The Task Forces inform the work of the Steering Committee.

A further institutional level depicts the Round Table, which advises the Task Forces and the Steering Committee and functions as a platform for exchange of views, information and interests of various stakeholders from different levels. It is an important body to link the different governance levels of the local, the medium and national level and the multiple sectors. It brings the relevant stakeholders of different sectors and ministries (e.g. Ministry of Health, Ministry of Urban and Rural Development (MURD), MAWLR (chair), NamWater, associations (agriculture associations), industry, science, and interest groups related to the topic of water reuse etc., communal actors (town councils, wastewater operators) together to integrate their needs and knowledge in the strategy development process. A further stakeholder representing the local level, is the nation-wide Network of Town Councils (lowest/local level), which consists of representatives of the town councils (CEOs, senior managers) and traditional authorities and is based on the existing wastewater treatment plant partnership established in the EPoNa project (BMBF) (WWTPP). The Network of Town Councils integrates the local perspective into the reuse strategy development by sending (regularly changing) representatives to the working meetings of the round table.

Finally, an Implementation Officer at the MAWLR, supported by SASSCAL and CUVECOM will be established to provide the decision-makers and the Steering Committee with the support they need to effectively develop the strategy as well as implement the research results on all governance levels and ensure the success of the national water reuse strategy. In particular, the Implementation Officer will coordinate the work and organise the meetings between the NIC levels and function as a connecting point between the WaReNam project and the NIC. After completion of WaReNam the officer will ensure the continuation of the work regarding adapting and implementing the water reuse strategy.

This crucial structure overarches governance of the diverse, singular water reuse activities in Namibia. Its task includes networking and encouraging the exchange of water reuse knowledge and experience, setting up operational and resource plans and the addressing of financial issues including open doors for future funding. It may regulate and control the technologies to be implemented. Relevant tasks of the NIC include the revision and differentiation of national regulations to ensure that different national policies are aligned and working towards the same goal. The first step is the revision and differentiation of national regulations especially the Code of Practice for Water Reuse which is outdated and no longer meets the requirements for long-term sustainable water reuse.

2.3 Multi-level capacity development for water reuse

2.3.1 Needs profile: capacity development

Capacity development has a high relevance for sound operation and maintenance (O&M) of water reuse facilities as well as on management level. Within the Kick-off workshop, German and Namibian partners identified key issues and demands of capacity development, especially O&M as the most important factor for sustainable wastewater treatment and reuse.

Capacity development depends heavily on the technical standard of each individual wastewater treatment plant or project site (high-tech vs. low-tech) and the surrounding infrastructure. It is therefore important that capacity development follows a multi-level approach, involving the local community as well as decision-makers on all governance levels. This is critical to ensure that the measures and technologies introduced by the project meet the needs and capabilities of local communities.

Feasibility in terms of distance (travel time, fuel), organization, and other practicalities marks a key factor of capacity development measures and establishing an O&M unit, especially in countries like Namibia, which is large and geographically diverse. Technologies to be implemented should to be able to be maintained by Namibian operators including the availability of spare parts in Namibia.

Adaptation to local conditions and feasibility can be supported by establishing an operations and maintenance (O&M) unit. The O&M unit networks municipalities regionally and supra-regionally to address common wastewater treatment challenges collectively and by sharing expertise and materials. The O&M unit could also improve the procurement of spare parts, which would lead to better alignment of technologies with available spare parts. In addition, the unit could provide support on financial issues. It is also suggested that O&M training should be integrated into educational structures at the local level. This would help strengthen the skills and knowledge of the local population and promote sustainable capacity development.

O&M is considered as the most important factor for sustainable wastewater treatment and use and should therefore be integrated into educational and training structures. It is therefore suggested that O&M should be under the responsibility of local ministries/agencies. This would help improve accountability and effectiveness of the unit. Additionally, the Ministry of Works and Transport (MWT) should play a central role in capacity development.

One way to fund capacity development measures could be to fund students through project funds. These students could later join the authorities to strengthen capacity development. This would be an investment in the future of water management in Namibia and would help ensure sustainable and effective capacity development.

2.3.2 Multi-level capacity development approach

As elaborated in the stakeholder workshops, Namibia demands to ensure the sustainable implementation of the water reuse strategy and practice in Namibia across all levels. To address this challenge, WaReNam suggests a co-design of a combined and networked capacity development approach with Namibian partners, such as the Namibian Institute of Mining and Technology (NIMT), Emschergenossenschaft (EGLV), and the Namibia University of Science and Technology (NUST).

For the main phase of the WaReNam project, it is suggested that the partners will collaborate in providing continuous training program components, processes of mutual learning, as well as workshops and seminars for decision-makers at national, regional, and municipal levels. The approach consists of a dual vocational training system involving seminars and on-the-job training, supported by EGLV, NUST and NIMT in collecting and analysing operational data, as well as planning and controlling maintenance work. This approach is in response to the skill gaps in wastewater treatment identified during stakeholder dialogues, which highlighted the need for targeted education and training.

The envisaged multi-level capacity development approach can be visualised in Figure 7.

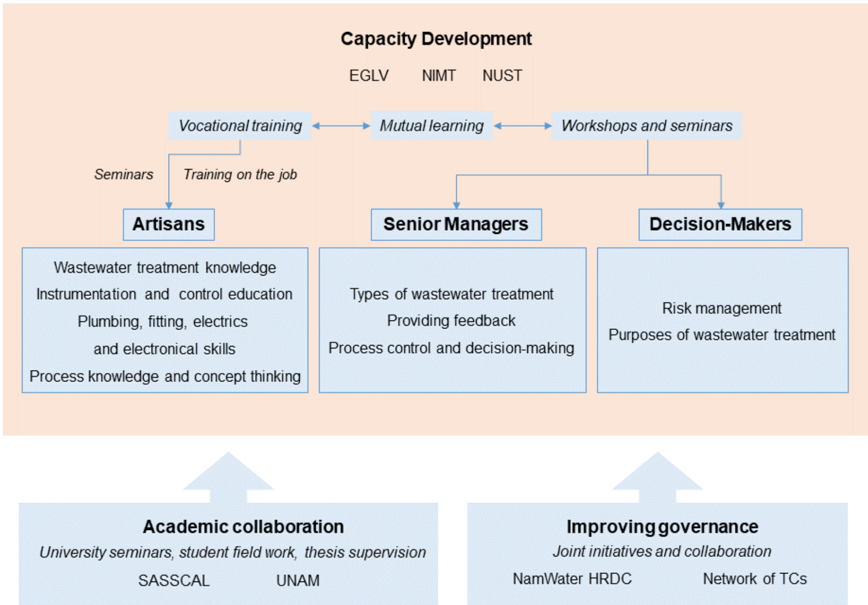

Figure 7: Scheme of WaReNams capacity development approach

The training components and stakeholder groups targeted in the project include technicians and artisans, who will receive training to improve microbiology and chemistry knowledge, enhance plumbing, fitting, and electronics skills, develop instrumentation education, and encourage concept thinking and in-depth process knowledge. Senior managers in local authorities will be trained in process control, decision-making, and providing feedback, as well as understanding different types of wastewater treatment. Decision-makers of ministries and regional/national authorities will participate in seminars on risk management in various wastewater treatment contexts, focusing on different purposes of wastewater treatment, such as irrigation, animal fodder, and human consumption.

Emphasising the importance of different levels of stakeholders and specialised personnel in knowledge transfer and capacity building, the WaReNam main phase will be able to produce a trained and skilled workforce for the effective operation and optimisation of wastewater treatment plants, informed decision-makers at various levels of governance promoting sustainable water reuse strategies, and strengthened academic collaboration, facilitating knowledge exchange and capacity building.

Academic collaboration is also suggested to be a key aspect of the project's main phase, partnering with the SASSCAL PhD graduate school and UNAM for joint seminar series, student fieldwork at pilot plants, and thesis supervision. Furthermore, the main phase should focus on improving governance through initiatives such as clearing up NamWater HRDC and wastewater treatment plant partnerships. This comprehensive capacity development approach, supported by the expertise of NIMT, EGLV, and NUST, is expected to contribute to the overall success of the WaReNam main phase.

3 Project evaluation and impact

3.1 Main items of the financial statement

As outlined in the respective reports on expenditure of funds, the project could be implemented within the overall budget without any significant deviations. A large part of the financial resources was used for personnel. In addition to material and administrative costs, other direct project costs (item 0850) and travel costs (0838; especially travel to non-European countries) should be mentioned. The other direct project costs included travel funds for EGLV, Mann+Hummel, Mecana and MAWLR as well as subcontracts for ConSyn Africa, SASSCAL and Thomas Kluge. The services to be provided included the facilitation of the first stakeholder workshop, a hydrological report and consultancy services. Details can be found in the ISOE's and TUDa's proof of use.

3.2 Necessity and appropriateness of the project work carried out

The WaReNam research project was both necessary and appropriate in addressing the critical issues of water security in Namibia. The project's objectives, as outlined in the application, have been successfully achieved through the execution of the work programme. This was made possible through the collaborative efforts of project and practice partners, resulting in enduring and widely disseminated products. Without the financial support provided for this project, these accomplishments would not have been possible.

The initial phase of WaReNam was designed to establish the groundwork for a transdisciplinary development of a national water reuse strategy for Namibia. This strategy aims to enhance water security within the country, a critical issue given the region's arid conditions and growing population. The project facilitated mutual learning processes between scientific and practical stakeholders on various levels, including technology, governance, and capacity development.

Stakeholders from science, politics, administration, and industry in both Germany and Namibia were engaged in a knowledge and experience exchange. This collaborative approach was instrumental in fully exploiting the potentials of water reuse and developing solutions tailored to local conditions. A particular emphasis was placed on ensuring the sustainable operation of wastewater reuse facilities. This was achieved through a focus on education and vocational training, as well as the establishment of effective management structures.

The work conducted within the framework of the funding and the initial phase of the WaReNam project was both necessary and appropriate. It has laid a solid foundation for the development and implementation of a national water reuse strategy for Namibia, contributing significantly to the country's water security and the Sustainable Development Goals.

3.3 Expected benefits and usability of the results

Within the WaReNam project, a concept for the development of a national water reuse strategy for Namibia was developed as a central product. This concept was developed in close cooperation with Namibian stakeholders and serves as the basis for the application of the follow-up project in the WASA main phase. The strategy concept includes needs profiles and preliminary considerations in relation to the dimensions of technology, governance and capacity development.

The technological dimension includes technical concepts for reuse pilot plants in Walvis Bay and Oshakati. These pilot plants serve as a blueprint for future water reuse projects and contribute to the sustainable use of water resources in Namibia. The governance dimension comprises institutional structures for the implementation of the water reuse strategy. The involvement of various stakeholders at different levels ensures broad acceptance and effective implementation of the strategy. The capacity development dimension includes a concept to support the implementation of the strategy. Through targeted training and further education, the skills and competences of the stakeholders involved are strengthened, which contributes to a sustainable and effective implementation of the water reuse strategy.

The joint development of this concept (co-design, co-creation) has several advantages for the Namibian stakeholders. They were actively involved in the design of the strategy and were able to contribute their specific needs and requirements. This promotes co-ownership and increases the likelihood of successful implementation. Furthermore, the concept contributes to sustainable water resource management in Namibia by promoting the reuse of water, thus contributing to the conservation of valuable water resources.

3.3.1 Economic prospects for success after the end of the project

The ISOE - Institute for Social-Ecological Research GmbH and the Institute IWAR of the Technical University of Darmstadt do not pursue their own economic profit expectations or their own economic secondary uses with the WaReNam project. The knowledge gained through the project will flow into the research lines and topics being worked on at ISOE and TUDa and will be introduced into societal discourses.

The prospects for success after the end of the project lie in particular in the deepening and development of new thematic fields. Due to the transdisciplinary and practice-oriented approach of the project, spill-over effects on the participating actors, especially the municipalities, regional councils and ministries, can be expected. The project results can support innovation processes at the participating companies and other practical actors and contribute to a more sustainable resource management in water management, agriculture and industry.

The active involvement of stakeholders not only generates robust knowledge, but also promotes the willingness of state actors to implement the recommendations for action developed in WaReNam. The participation of companies from the German water sector can expand the export potential of the sector and utilise the results in the economy. The growing urban areas and states in Africa represent a market potential for German companies.

In the short term, the exploitation perspectives of the participating German companies include networking with municipalities in the region, transfer opportunities to comparable locations and, in general, market entry for public measures in the water sector in Namibia. In the medium and long term, the expansion of technical knowledge regarding water reuse under African conditions as well as competitive advantages for the export-oriented German water sector are to be seen.

3.3.2 Scientific and/or technical prospects for success after the end of the project

The overall objective of the WaReNam project is to initiate the implementation of a water reuse strategy for Namibia based on the scientific results of the project in the WASA main phase. The corresponding scientific results for the initial and main phases are diverse and forward-looking.

In the initial phase, the focus was on documenting and evaluating experiences related to technological options for the multi-scale approach to water reuse in Namibia. Societal and scientific needs were identified and options for technology, governance and capacity development prioritised. The results of this phase were documented and fed into the preparation of the research proposal for the main phase of the WASA call. The stakeholder workshops were also documented to guide future research options.

The WaReNam main phase will focus on the development of a national water reuse strategy, including innovative technological options for water reuse facilities. In addition, regulatory (norms and standards in addition to the Namibian Code of Practice) and institutional frameworks for water reuse will be developed in the context of risk management. Furthermore, guidelines for decision-makers and institutions for the implementation of the transformation process will be developed and conclusions for the generalisation and transfer of the strategy to other countries in Southern Africa will be derived. The outputs of the main phase will include publications, policy briefs, technological innovations and training materials, in addition to the actual national water reuse strategy (Table 6).

Table 6: Expected scientific exploitation of results of the main phase by ISOE and IWAR

Project partner	Type of exploitation	Time horizon
ISOE, IWAR, UNAM, NUST, IUM	Technical publications: Informing practitioners about project results	short term
ISOE, IWAR, UNAM, NUST, IUM	Presentations at conferences: Informing practitioners about project results	short term
ISOE, IWAR, UNAM, NUST, IUM	Scientific publications: Science Information	short/ medium term
ISOE, IWAR, UNAM, NUST, IUM	Conference papers international: Information of science	short term
ISOE, IWAR	Counselling: Use of project results in own counselling activities	medium/ long term
ISOE	Policy Paper: Informing decision-makers in business and politics	short term
ISOE, IWAR, UNAM, NUST, IUM	Teaching: Integration of the project results into university teaching	short/ medium term
ISOE, IWAR, UNAM, NUST, IUM	Student theses: Issue of topics for Bachelor's and Master's theses	short/ medium term
ISOE, IWAR	Work in standards committees: Development of technical-scientific standards and rules	medium/ long term

The transdisciplinary composition of the collaborative project and the integrative research approach make a relevant contribution to social-ecological sustainability research. Through the generation of practice-relevant knowledge, not only recommendations for action for the participating economic actors are developed, but also concrete proposals for the design of legal framework conditions are made. The transfer of knowledge makes it possible for the project results to flow into political processes. This represents an important basis for future cooperation with other institutions, companies, networks and research centres.

3.3.3 Scientific and economic transferability

The results of the initial phase of WaReNam have laid the foundation for the development of solutions in the main phase that are transferable to regions with comparable climatic and socio-economic conditions. These contribute to the promotion of sustainable resource management, climate change adaptation and socio-economic development. The assessment of different technical and regionally adapted options and strategies that are robust and low-maintenance has laid the foundation for a country-wide transferability as well as transferability to neighbouring countries such as Angola, Zambia and Botswana.

Considerations of institutional structures and collaborations have enabled continuous mutual learning, ensuring ongoing development and innovation. This has been accompanied by the preparation of appropriate non-academic (e.g. vocational training) and academic (curriculum and teaching at UNAM, NUST and IUM, SASSCAL PhD IWRM programme) capacity building.

The WaReNam initial phase was able to draw on an already existing network of key actors in Namibia and Southern Africa. Large cities such as Windhoek and Walvis Bay have shown interest in further expanding water reuse as it is more energy and cost efficient than seawater desalination (depending on the level of treatment required).

Despite the current difficult budgetary situation in Namibia, additional funding in the water sector can usually be realised through the African Development Bank or, in the case of German investments, through KfW. Other international funding opportunities include the Green Climate Fund, the SADC Water Fund or individual programmes of the World Bank.

For market access, German industrial partners have to get in touch with local actors, which is facilitated by the existing networks and the cooperation within WaReNam. These aspects contribute to the scientific and economic connectivity of the project and provide a solid basis for the WaReNam main phase to successfully implement the results.

3.4 Known progress in the field of the project

The field of water reuse, particularly in the context of Namibia, is a rapidly evolving area of research and development. However, due to the relatively short duration of the WaReNam project, no new results from other projects have emerged that are critical for the main phase of WaReNam. This is not to say that the field has remained static. On the contrary, there are ongoing efforts globally to improve water reuse technologies, governance structures, and capacity development strategies.

One project of note is the BMBF-Project "Implementation-Office Amman". The project builds on the BMBF projects SMART and SMART-MOVE (Sustainable Management of Available Water

Resources with Innovative Technologies for integrated water resources management in the Lower Jordan Rift Valley). In this context, the inter-ministerial and cross-sectoral committee NICE ("National Implementation Committee for Effective Integrated Wastewater Management in Jordan") was established. In the process, the NICE Implementation Office was also established in the Jordanian Ministry of Water and Irrigation. The Jordanian Cabinet approved the NICE regulations "National Framework for Decentralised Wastewater Management in Jordan" and the "Policy for Decentralised Wastewater Management in Jordan". NICE's recommendations include hotspots of groundwater pollution from domestic wastewater, proposals for municipal wastewater, a methodology for site and technology selection, wastewater standards for treatment plants with less than 5,000 population equivalents, and a national approach to plant operation and maintenance.

This provides some parallels to the objectives of WaReNam, which will be examined to see if certain experiences can be transferred in terms of processes of planning and implementation. In general, it can be said that Jordan, on the one hand, is estimated to have more than four times the population of Namibia. On the other hand, Namibia is more than nine times larger than Jordan in terms of area, resulting in a population density that is almost 40 times higher in Jordan compared to Namibia. Apart from this, however, the two nations are comparable in terms of natural, climatic and hydrological conditions as well as socio-economic factors (including GDP per capita both nominally and in purchasing power parities, Human Development Index).

Within the framework of the project "Implementation-Office Amman", a study on the nationwide assessment of the reuse of treated wastewater and biosolids in Jordan was prepared. The study results will serve as a basis for the preparation of a national inventory, especially for decentralised wastewater treatment and reuse systems, in order to facilitate the coordination of permitting procedures and regulatory measures in Jordan. Even though decentralised treatment and reuse will play no or only a minor role in WaReNam (at household or micro level), a national inventory of the reuse potential of larger systems in Namibia can make a relevant contribution to the development of a reuse strategy.

However, the greatest potential for transferring experience from NICE lies in the process of adopting wastewater-related regulations in Jordan and in the institutional anchoring of the inter-ministerial and inter-sectoral committee. In addition, the function and organisation of the NICE implementation office can provide clues to support the implementation of a Namibian water reuse strategy. Accordingly, an exchange between NICE and WaReNam took place at the beginning of the initial phase.

While no new results have emerged that directly impact the main phase of WaReNam, the project team remains vigilant in monitoring progress in the field. This ensures that the project remains at the forefront of water reuse research and development, and that the strategies developed are informed by the most recent and relevant findings in the field.

3.5 Published or planned publications of the findings

The WaReNam project has generated insights that have been, and will continue to be, disseminated through various publications. The main product of the initial phase of WaReNam is the proposal outline for the WaReNam main phase. This document provides a comprehensive overview of the project's objectives, methodology, and expected outcomes. It serves as a roadmap for the project's continuation and is a testament to the collaborative efforts of the project team.

In addition to the proposal outline, the project has also resulted in a joint agreement on pilot sites for the project's main phase. This agreement, co-designed by Namibian and German partners, outlines the technical approach of the pilot sites and sets the stage for the project's practical implementation. Furthermore, the project has led to the co-design of a governance approach for the main phase, known as the National Implementation Committee. This approach, which involves a multi-level institutional structure and various sectors, is a significant step towards the implementation of a national water reuse strategy. The project has also resulted in the co-design of a capacity development approach for the main phase. This approach focuses on enhancing the skills and knowledge of stakeholders involved in the project, ensuring that they are equipped to contribute effectively to the project's objectives.

Lastly, the project has facilitated exploratory talks and joint findings/co-designs of the further research process by Namibian and German partners. These discussions have been instrumental in shaping the project's direction and have resulted in a number of valuable insights. The project team is committed to ensuring that the knowledge generated by the WaReNam project is widely disseminated and accessible to all relevant stakeholders.

Table 7: Overview of the co-design process of the WaReNam initial phase including products

Date	Name of event	Participants	Product
December 15th 2021	Project kick-off (online)	ISOE, TUDA	Presentation
February 10th 2022	Exchange on WaReNam project approach (online)	ISOE, MAWLR	Presentation
March 4th 2022	Exchange on WaReNam project participation of Walvis Bay (online)	Municipality of Walvis Bay, ISOE	Memo
April 21st 2022	Kick-off stakeholder workshop: Developing a joint problem understanding and needs profiles (online)	MAWLR, Municipality of Walvis Bay, Oshakati TC, Omusati RC, Oshikoto RC - Oshivelo Settlement, Ohangwena RC – Omungwelume Settlement, Ondangwa TC, Outapi TC, Eenhana TC, Helao Nafidi TC, Tsandi VC, NamWater, CUVECOM, Wingoc, TUDA, ISOE, ConSyn Africa	Presentations, minutes
July 21st 2022	Exchange on piloting opportunities (online)	Oshakati TC, MAWLR, ISOE, TUDA	Minutes

July 21st 2022	Exchange on piloting opportunities (online)	Municipality of Walvis Bay, MAWLR, ISOE, TUDA	Minutes
September 13th 2022	Exchange on WaReNam project approach (online)	Wingoc, ISOE	Memo
November 14th 2022	Exchange on WaReNam project approach and joint coordination	MAWLR, ISOE, TUDA	Memo
November 14th 2022	Exchange on participation in WaReNam project	NUST, ISOE, TUDA, EGLV	Memo
November 15th 2022	Exchange on participation in WaReNam project	UNAM, ISOE, TUDA	Memo
November 15th 2022	Exchange on participation in WaReNam project	SASSCAL, ISOE, TUDA, EGLV	Memo
November 17th 2022	Mid-term stakeholder workshop 1: Walvis Bay	Municipality of Walvis Bay, MAWLR, ISOE, TUDA, EGLV, Mecana, Mann + Hummel	Presentations, minutes
November 19th 2022	Exchange on participation in WaReNam project	Outapi TC, MAWLR, ISOE, TUDA, EGLV, Mecana	Memo
November 21st 2022	Mid-term stakeholder workshop 2: Oshakati	Oshakati TC, MAWLR, ISOE, TUDA, EGLV, Mecana	Presentations, minutes
November 22nd 2022	Exchange on wastewater and reuse governance in Namibia	MAWLR, ISOE	Memo
November 23rd 2022	Exchange on participation in WaReNam project	GIZ, ISOE, TUDA	Memo
December 19th 2022	Exchange on project approach and strategy	ISOE	Memo
February 13th 2023	Final stakeholder workshop: Co-designing an implementation plan and research approach for the WaReNam main phase (online)	MAWLR, ISOE	Presentation, minutes, governance scheme

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