SERPIC

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Deliverable Report
D3.3 Transfer concepts

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1 Introduction to the project SERPIC

The project *Sustainable Electrochemical Reduction of contaminants of emerging concern and Pathogens in WWTP effluent for Irrigation of Crops – SERPIC* will develop an integral technology, based on a multi-barrier approach, to treat the effluents of wastewater treatment plants (WWTPs) to maximise the reduction of contaminants of emerging concern (CECs). The eight partners of the SERPIC consortium are funded by the European Commission and by six national funding agencies from Norway, Germany, Italy, Spain, Portugal and South Africa. The official starting date of the SERPIC project was 1. September 2021. The project had a duration of 40 months and ended 31. December 2024.

The overall aim of the SERPIC project was to investigate and minimise the spread of CECs and antimicrobial resistant bacteria/antibiotic resistance genes (ARB/ARG) within the water cycle from households and industries to WWTPs effluents, and afterwards via irrigation into the food chain, into soil and groundwater and into river basins, estuaries, coastal areas, and oceans with a focus on additional water sources for food production.

A membrane nanofiltration (NF) technology was applied to reduce CECs in its permeate stream by at least 90 % while retaining the nutrients. A residual disinfection using chlorine dioxide produced electrochemically was added to the stream used for crops irrigation (Route A). The CECs in the polluted concentrate (retentate) stream were reduced by at least 80 % by light driven electro-chemical oxidation. When discharged into the aquatic system (route B), it will contribute to the quality improvement of the surface water body.

A prototype treatment plant was set-up and evaluated for irrigation in long-term tests with the help of agricultural test pots. A review investigation of CECs spread was performed at four regional showcases in Europe and Africa. It included a detailed assessment of the individual situation and surrounding condition. Transfer concepts was developed to transfer the results of the treatment technology to other regions, especially in low- and middle-income countries.

2 Report summary

The SERPIC technology presents both significant advantages and some notable challenges for water re-use applications. By leveraging its strengths while addressing weaknesses through strategic planning and community engagement, there is potential to enhance water reuse practices significantly within Africa, Europe and beyond. Continued alignment with regulatory frameworks and stakeholder interests will be essential for successful implementation and sustainability of the technology in addressing water scarcity challenges faced by agriculture sector. Evidence from both planned and existing initiatives indicates that the implementation pace within the water services sector has been hindered by socio-political, technical, and economic challenges. Nevertheless, water supply authorities are increasingly recognizing that water reuse should no longer be viewed merely as an emergency measure; instead, water reclamation and reuse is becoming an alternative water source and it must be integrated into long-term water supply strategies within resource planning.

3 Deliverable description as stated in the Project Description

Transfer concepts will be developed for the transfer of the results to other regions in Europe and beyond with the same needs, especially low- and middle-income countries. The individual boundary conditions of these regions like WWTP effluent quality, water scarcity, needs of farmers, regulatory limits, economic situation and solar radiation will be taken into account.

The task investigates the potential applicability of the tested technology in other cases, on the basis of the local characteristics (climate conditions, fresh water availability, water scarcity, drought periods, water needs, crops types to be irrigated...) and it develops a strategy for improving the adoption of the SERPIC technology, on the basis of the SWOT analysis.

4 Introduction

Climate change, increasing demand for freshwater from various users, population growth, rapid urbanization, and deteriorating water quality have significantly strained freshwater supplies worldwide, especially in third world countries. As a result, there is a growing emphasis on exploring alternative water sources. Among these alternatives, water reclamation and reuse have emerged as strategic options that could help countries achieve their development objectives. The SERPIC technology therefore serves as a potential solution to be especially implemented in low-and middle-income (LMI) countries where water scarcity is a concern as well as the occurrence of CECs in wastewater discharge in the river systems and subsequently in crop irrigation. To improve the scientific quality and societal relevance of the project results in different socio-economic settings, the development of transfer concepts to these regions, provides a rich understanding of the technology and solution impacts in different geographies and socio-economic contexts. Efficient implementation of the SERPIC technology in LMI countries, requires a strategic approach that leverages its strengths, addresses weaknesses, capitalizes on opportunities, and mitigates threats.

5 Results

Transfer concepts were developed with the focus on Southern Africa (South Africa) and West Africa (Nigeria). For the Southern Africa, concepts are focused on centralized approach whereas for West Africa a more decentralized approach, with on-site treatment, was considered.

5.1 Southern Africa (South Africa)

South Africa primarily relies on surface and groundwater resources to satisfy its household, municipal, industrial, and agricultural water needs. With current water demands, the country is projected to face a water deficit of 17 % by 2030. Globally, water scarcity has emerged as a significant driver for the adoption of water reuse practices. Consequently, several water reuse initiatives have already been implemented, with more planned for the future (DWA, 2013). As South Africa grapples with these challenges, diversifying its water sources through innovative methods such as water reclamation and reuse will be crucial for ensuring a sustainable water supply for its growing population. While South Africa is looking into desalination as one of the alternative water sources, it has been demonstrated that water reclamation and reuse is a more cost- and energy-efficient option without a need to address the desalination brine management challenge.

By 2040, South Africa aims to increase its reliance on water reuse from 14% to 18%, aligning with national priorities outlined in the National Water and Sanitation Master Plan (NW&SMP) to expand the number of water reuse schemes and enhance capacity across the country (DWS, 2018). While several additional municipal water reuse projects are currently in the planning stages, there is no guarantee that these initiatives will proceed as intended or that the targets will be met.

Despite the existing operational capacity of wastewater treatment plants and planned reuse schemes, wastewater remains an underutilized resource. South Africa has approximately 824 wastewater collection and treatment facilities with a combined hydraulic design capacity of 6,509 ML/day. Among these, 59 are classified as macro wastewater treatment works (with capacities exceeding 25 ML/day) and account for 65% of the nation's total wastewater capacity. Collectively, these facilities have a hydraulic capacity of around 4,000 ML/day and an estimated potential for water reuse of about 2,500 ML/day. Notably, coastal cities contribute approximately 1,100 ML/day to this capacity, while inland cities account for the remaining 1,400 ML/day (DWS, 2018).

The slow pace of implementing water reuse initiatives in South Africa can be attributed to a complex interplay of technological, economic, and socio-political factors. Research has shown that socio-political issues play a more significant role in hindering widespread adoption of planned water reuse projects compared to technical and economic challenges (DWA, 2013; van Niekerk and Schneider, 2013; Swartz et al., 2015; Muanda et al., 2017; Slabbert and Green, 2019).

To overcome these barriers and enhance water reuse strategies, a coordinated effort involving improved governance, public engagement, and investment in technology is essential. By leveraging these insights and addressing the outlined challenges, South Africa can enhance its agricultural resilience through effective implementation of water reuse practices.

5.2 West Africa (Nigeria)

Nigeria faces significant challenges in water management, despite its abundant water resources. The country is classified as economically water-scarce, with an estimated total annual water demand of approximately 5.93 billion cubic meters in 2021, projected to rise to 16.58 billion cubic meters by 2030. The primary sources of freshwater demand include agriculture, municipal use, and industry, with over half of the abstractions coming from groundwater (Ior & Leo, 2023). Oyetoro (2022) identified several key constraints affecting the transfer of agricultural technologies in Nigeria:

Complexity of Technology

The complexity inherent in agricultural technologies poses significant challenges for uneducated farmers. Many technologies fail not due to their inherent quality but because they are too complicated for farmers to implement effectively. The adoption rate of these innovations is heavily influenced by their characteristics, with many being prohibitively expensive and difficult to access. Often, these technologies are developed in controlled environments tailored to specific conditions, and the necessary operational details are frequently not communicated to farmers. When information is provided, it often does not align with local needs, leading to technical failures that exacerbate existing issues.

Issues with the Technology Transfer System

The procedures involved in technology transfer are predominantly top-down, which complicates adaptation for smallholder farmers. Most technological advancements do not include farmers in the development process, resulting in a disconnect. Additionally, these technologies often arrive too late in the production cycle for farmers to benefit from them. These again underlines the importance of crucial stakeholder’s involvement at the early stages of technology transfer, necessity of adjusting to the local conditions, and bottom-up approaches to increase the uptake of the novel solutions.

Socio-Economic Attributes of Farmers

The personal characteristics and circumstances of farmers significantly influence their willingness to adopt new technologies. Key factors include:

Education: Literacy levels among farmers play a crucial role in technology adoption. Educated farmers are more likely to understand and utilize complex innovations effectively. Kafando et al. 2022 emphasize that educational initiatives must be reassessed to better meet farmers' needs.

Age: Younger farmers tend to be more open to adopting new technologies compared to older farmers, although some technologies may favor older demographics (Ior & Leo, 2023).

Experience: Experienced farmers are generally better equipped to manage risks associated with new technologies than their less experienced counterparts (Donkoh et al. 2019).

Income and Social Status: A farmer's financial situation can greatly affect their ability to adopt new technologies, as those with better financial resources can more readily absorb associated risks.

Culture: Introducing technologies that conflict with traditional societal norms can be counterproductive. For instance, altering gender roles within agricultural tasks may face significant resistance (Ior et al. 2023).

Group Membership: Farmers who belong to various social organizations are more likely to adopt new technologies due to shared experiences and collective decision-making processes. Encouraging the formation of cooperatives can enhance technological adoption rates.

John et al. 2022 also noted that factors such as age, household size, education level, farm size, access to credit, and visits from extension agents significantly impact the transfer of improved technologies. Younger farmers are particularly more inclined to embrace new innovations. Providing adequate educational resources is essential for increasing adoption rates, while access to credit is crucial for enabling farmers to take on new technological risks.

Local Peculiarities and Differences

Rural smallholder farmers often resist abandoning established practices for new technologies unless these innovations have been proven advantageous and compatible with local customs and conditions (Ior et al. 2023).

The effectiveness of technology development and transfer strategies in Nigeria largely hinges on the critical roles played by technology developers, disseminators, and users throughout the value chain. Currently, the potential for technology advancement and transfer in Nigeria is supported by emerging technologies such as precision agriculture, weather tracking systems, satellite imaging, agricultural robotics, and radio frequency identification (Ior et al. 2023). To enhance these efforts, a more pragmatic and results-oriented approach is necessary. This should involve deploying selected experts to collaborate closely with farmers in the field to advice on best practices and address specific challenges over defined periods. Additionally, there should be a push for increased private sector involvement in the multiplication and dissemination of affordable production technologies that meet farmers' needs. Moreover, a pluralistic funding model for agricultural extension activities is essential. This model should involve contributions from federal, state, and local governments, each with clearly defined roles and proportional funding commitments to ensure effective implementation.

5.3 Developing transfer concepts for South Africa and Nigeria

The following strategies were developed considering the results of the SWOT analysis conducted by UNIFE (Table 1) as well as relevant literature.

Table 1. Results from the SWOT analysis of the SERPIC technology.

	Factors	Main reasons for the factor selection
Strengths	Water quality improvement	The SERPIC technology is able to remove most of the residuals of conventional pollutants and a wide spectrum of micropollutants (CECs) not only organic compounds but also microbials (including ARB and ARGs). It provides stable, high quality irrigation water. Route A final effluent can thus be directly reused for agricultural needs.
	Easy to control	The SERPIC technology includes different quality controlling devices (among them: flowrate measurement, pH, and conductivity probes) and it can be automated to be controlled remotely. It also allows for easy integration of additional control systems, e.g., various water quality parameters, if necessary.
	Dedicated treatment for NF concentrate	The SERPIC technology (Route B) includes a photoreactor to remove the CECs in the NF membrane concentrate.
	No chemicals addition	The oxidants necessary in the SERPIC technology (ozone and persulfates) are produced electrochemically on site.
	No waste production	The SERPIC technology does not produce waste streams (for instance NF concentrate) to be disposed of.
Weaknesses	Variability of the SERPIC technology performance	The SERPIC technology performance varies according to different parameters related to the feeding characteristics and the operational conditions
	Safety concerns	Ozone is potentially corrosive, and it enhances fire hazards. For workers, it is irritating and toxic, and may cause respiratory problems at 0.1 ppm peak concentration in 15 minutes
	Operational problems	The prototype requires specific operational procedures (i) periodic cleaning and eventually replacement of NF membrane (due to membrane fouling), (ii) regular monitoring of ozone equipment and (iii) control of the toxicity in the ozonated effluent due to the potential formation of unknown transformation ozonated products
	Complex construction and equipment	SERPIC technology requires specific equipment to generate the oxidants and to promote CEC degradation (photoreactor) and to monitor the processes
	High energy demand	The SERPIC technology has a high energy consumption compared to the common quaternary treatments (based on ozonation and activated carbon).
Opportunities	Customer request (of a promising and valuable low cost (green) technology to be included in a dedicated treatment)	Increased customer interest in integrating conventional treatments with polishing ones able to remove CECs
	European rules encourage water reuse	The reuse practice is in agreement with the European Union (EU) Water Framework Directive (EU Directive, 2000/60/EC) and the recent European minimum requirements for water reuse (EU Regulation, 2020/741).
	European rules require CECs removal during urban wastewater treatment	The revised Directive concerning urban wastewater treatment EU 2024/3019 (UWWTD), in force starting from January 1st 2025, introduces the need for a quaternary treatment to reduce the content of micropollutants in the final effluent to be released in the environment as well as for small wastewater treatment plants placed in an area at risk of accumulation/pollution due to CECs.
	European Green Deal initiatives	The initiatives promote green technologies and solutions with zero pollution discharges and limiting CO_2 emissions. In addition, the new UWWTD, EU 2024/3019, requires actions towards the energy neutralization, asking for the adoption of renewable energy sources (solar/wind/hydraulic) in the wastewater treatment sector.

	Factors	Main reasons for the factor selection
	National policies (Implementation of national policies to reduce CECs in WWTP effluent)	In some countries, national regulations are in force for CEC removal from WWTPs effluents (for instance in Switzerland, Germany, etc.)
	Public (farmers) interest in water reuse	Normally people are aware of environmental issues so they may be willing to contribute to the reuse of treated wastewater as it is a promising solution to address the (fresh) water scarcity and drought events, which are increasing in frequency as a consequence of climate change
Threats	Variation of CECs concentration in secondary effluent	CECs concentration in the secondary effluent may vary according to different factors (namely, countries or region, consumption patterns, level of treatment applied at WWTPs, etc.)
	Attention to aquatic life	Attention to the potential environmental impacts induced by emerging technologies is increasing. Polishing treatments do not have a well-known effect on the reduction of CECs ecotoxicity impacts on freshwater. In general, the formation of transformation products during the polishing treatments (such as ozonation, AOPs, etc.) may increase toxicity
	Other CEC treatment technologies as its main competitors	The SERPIC technology can be compared with others which may be more effective, or consume less energy and be less expensive
	Socio-economic concerns	The most crucial social issues are farmers, retailers, and consumers' acceptance. If their products are not sellable, farmers will not find wastewater reuse viable; consumers will not purchase products where treated wastewater was used unless it has been proven safe

The following strategies were identified:

Leverage Strengths

Water Quality Improvement: Highlight the capability of the SERPIC technology to remove conventional pollutants and a wide spectrum of contaminants of emerging concern (CECs), including antibiotic-resistant bacteria (ARB) and antibiotic resistance genes (ARGs), ensuring water quality suitable for direct agricultural reuse. This aligns with South Africa and West-Africa's policies promoting water reuse in agriculture.

Ease of Control and Automation: Utilize the technology's automated control systems, including flowrate measurement, pH, and conductivity probes, to facilitate remote operation. This is particularly beneficial in South Africa and Nigeria, where technical expertise may be limited in remote rural areas.

On-site Oxidant Production and Zero Waste: Emphasize the environmental benefits of producing oxidants electrochemically on-site and the absence of waste streams, aligning with global trends towards sustainable and green technologies.

Address Weaknesses

Mitigate performance variability: Conduct localized pilot studies to assess and optimize SERPIC technology performance under South African and Nigerian conditions, considering variations in feedwater characteristics and operational parameters. Develop clear guidelines for operation and maintenance to manage performance variability.

Safety concerns: Implement stringent safety protocols and training programs to manage risks associated with technology use. Ensure compliance with both countries' occupational health and safety regulations. Implement rigorous training programs for local operators to safely handle the electrochemically production of oxidants and manage operational risks. Provide detailed but understandable safety protocols and monitoring equipment as part of the technology package.

Operational challenges: Develop comprehensive yet easy to follow maintenance schedules and training for local operators to address issues such as nanofiltration membrane fouling and monitoring of equipment. Establish local support centres to provide technical assistance and spare parts.

Complexity and energy demand: Simplify the system design where possible and ensure the integration of solar power, to offset the technology's high energy consumption and make it viable in regions with unreliable electricity. This approach is feasible given South Africa's abundant solar resources (D3.1) as well as in Nigeria. Create a country, or even local, specific user manual to address the complexity of the technology.

Capitalize on Opportunities

Growing demand for sustainable technologies: Position SERPIC technology as a green and cost-effective solution for removing CECs, appealing to the country's stakeholders interested in sustainable agricultural practices.

Alignment with European and national policies: Leverage the European Union's directives encouraging water reuse and the European Green Deal initiatives to attract funding and support for implementing SERPIC technology in South and West Africa. Collaborate with authorities to align the technology with national water reuse policies.

Public interest in water reuse: Engage with local farmers and communities to raise awareness about the benefits of treated wastewater reuse, addressing water scarcity and promoting acceptance of SERPIC technology. Capitalize on farmers' interest by conducting educational campaigns to demonstrate the environmental and economic benefits of using treated wastewater for irrigation. Use testimonials or case studies from European farms to build trust and acceptance among African farmers and to highlight environmental and economic benefits through case studies from Europe.

Position as a Green Technology: Promote SERPIC technology as part of South Africa's commitment to sustainable development under global frameworks like the Paris Agreement and sustainable development goals. Seek funding under national or international green technology initiatives.

Mitigate Threats

Variability in CEC concentrations: Conduct thorough assessments of local wastewater to understand CEC profiles and adjust technology operations accordingly to ensure consistent treatment efficacy. For example, include robust monitoring and adaptive control systems to handle variations in feed water quality. In parallel, conduct ongoing research to study and mitigate local water quality challenges.

Water quality monitoring: Recent findings from a study funded by the Water Research Commission indicate that South Africa lacks sufficient laboratories capable of conducting routine analyses on emerging contaminants in water (Swartz et al., 2018). To ensure the safety of product water, it is essential to invest in bio-sensors, in addition to the automated water monitoring sensors, mentioned above, that can effectively monitor water quality in real-time and ensuring that polishing treatments do not inadvertently increase toxicity of the water. The absence of water quality regulations specifically addressing water reuse is a significant barrier to building public trust in this practice. Currently, neither the South African Water Quality Guidelines nor SANS 241 (the standard for drinking water quality) nor the Nigerian water quality guidelines sufficiently address emerging contaminants or establishes clear water quality requirements for the various uses of reclaimed water.

Competition from alternative technologies: Differentiate SERPIC technology by emphasizing its unique features, such as on-site/in-situ oxidant production and zero waste generation. Highlight modularity, flexibility in operation and control, and compatibility with renewable energy sources. Demonstrate high effectiveness and cost-effectiveness through pilot projects and case studies.

Socio-economic acceptance: Develop certification programs to assure consumers of the safety of crops irrigated with treated wastewater. Engage with retailers and farmers to build trust and acceptance of SERPIC-treated water in agricultural production. Position the technology as a long-term cost-effective solution by demonstrating savings from reduced waste disposal and chemical use. Implement pilot projects with subsidies or co-funding to reduce initial costs for farmers. Partner with retailers and certification bodies to create a "sustainable farming" label, boosting consumer confidence in products irrigated with treated wastewater.

Risk-sharing agreements: Create agreements to share risks (e.g., economic, operational) between European providers and South African partners.

Contingency planning: Develop robust strategies to address potential challenges like droughts or power outages that could impact system functionality.

Address Financial Constraints

Innovative financing models: Introduce cost-sharing schemes, public-private partnerships (PPPs), or subsidies to encourage adoption.

Tiered implementation: Break the technology transfer into affordable phases to spread out costs.

Attract International Funding: Apply for grants and subsidies from organizations like the African Development Bank, Green Climate Fund, or EU initiatives supporting green technology adoption in Africa.

The proposed roadmap to implement the technology involves the following:

Phase 1 (Year 1):

Identify locations: Conduct feasibility studies and identify regions in South Africa/Nigeria with urgent water scarcity and suitable conditions for SERPIC technology.

Stakeholder Engagement: Initiate dialogues with South African/Nigerian government agencies, agricultural bodies, and local communities to build support for SERPIC implementation. Develop partnerships with local authorities, agricultural cooperatives, and funding bodies.

Host workshops: Introduce SERPIC technology and gather feedback.

Phase 2 (Year 2-3):

Engage local technology providers: Upon sufficient interest during the workshop and from the relevant stakeholder's, engage with local technology providers potentially interested in transfer and implementation of the SERPIC technology.

Pilot projects: Implement localized pilot projects to refine technology performance under South African and Nigerian conditions.

Training: Provide training programs for local operators and technicians to handle the system safely and efficiently to ensure proper operation and maintenance of SERPIC systems.

Policy Integration: Work with policymakers to incorporate SERPIC technology into national water reuse strategies and obtain necessary regulatory approvals.

Phase 3 (Year 4-5):

Scale up successful pilots and expand installations across water-stressed regions.

Establish local manufacturing partnerships to reduce costs and simplify construction.

Ongoing:
Implement continuous monitoring systems to assess performance, environmental impact, and socio-economic acceptance, allowing for iterative improvements. Establish long-term monitoring and evaluation frameworks.

Engage in community outreach to build long-term acceptance and adoption.

Conduct regular training and awareness programs to ensure sustained adoption.

5.4 Conclusion

Water reuse presents a viable solution for addressing Africa's, such as South Africa and Nigeria's, pressing water challenges. By implementing the proposed roadmap in both countries there is potential for successful implementation of the SERPIC technology. While there is potential for significant progress through public awareness, overcoming regulatory, infrastructural, and funding barriers is crucial for successful implementation in both countries and beyond. A coordinated approach involving government, private sector participation, and community engagement will be essential for advancing water reclamation efforts.

6 Literature

Amis, A., Solomon, N. WRC report 2349/1/16 Exploring Green Technology in Agriculture. https://www.wrc.org.za/wp-content/uploads/mdocs/2349-1-16.pdf, (2016).

DWA (Department of Water Affairs) (2013) National Water Resources Strategy. Water for an equitable and sustainable future. Second edition. June 2013. http://www.dwa.gov.za/documents/Other/Strategic%20Plan/NWRS2-Final-email-version.pdf

DWS (Department of Water and Sanitation) (2018) National Water and Sanitation Master Plan Volume 1: Call to Action. https://www.gov.za/sites/default/files/gcis_document/201911/national-water-and-sanitation-master-plandf.pdf

Ior, A.J., Leo, D.S. Agricultural Technology Transfer in Nigeria: A Review of the Challenges and Prospects in the Contemporary Times. Proceedings of the Annual Conference of the Agricultural Extension Society of Nigeria (2023), https://dx.doi.org/10.4314/jae.v28i1.4S

Kafando, B., Pelenguei, E and Gnedeka, K.T. Education and agricultural technology adoption: Evidence from rural India. International Journal of Research in Business Management and Economics, (2022), 1(1), 53-74.

Kalebaila, N., Ncube, E.J., Swartz, C.D., Marias, S., Lubbe, J. Strengthening the Implementation of Water Reuse in South Africa.WRC Report TT 742/1/18, (2018).

Malisa-van der Walt, R., Taigbenu, A. Policy, Laws, and Guidelines of Wastewater Reuse for Agricultural Purposes in Developing Countries. In: Nasr, M., Negm, A.M. (eds) Cost-efficient Wastewater Treatment Technologies. The Handbook of Environmental Chemistry (2022), vol 117. Springer, Cham. https://doi.org/10.1007/698_2022_864

Muanda C, Cousins D, Lagardien A, Owen G and Goldin J (2017) Direct reclamation of municipal wastewater for drinking purposes. Volume 2: Investigation into institutional and social factors influencing public acceptance of reclaimed water for potable uses in South Africa. WRC Project No. TT 734/17.

Oyetoro J. O. Analysis of agricultural technology generating practices in North. Central Nigeria: A Case Study of Nigerian Stored Product Research. Institute, Ilorin. Journal of Xi'an Shiyou University, Natural Science Edition, (2022), 18(12), 1037-1046.

Pesqueira, J.F.J.R., Pereira, M.F.R., Silva, A.M.T. Environmental impact assessment of advanced urban wastewater treatment technologies for the removal of priority substances and contaminants of emerging concern: A review. Journal of Cleaner Production (2020), 261, 121078

SALDIAS, Cecilia; SPEELMAN, Stijn; VAN HUYLENBROECK, Guido and VINK, Nick. Understanding farmers' preferences for wastewater reuse frameworks in agricultural irrigation: Lessons from a choice experiment in the Western Cape, South Africa. Water SA (2016), vol.42, n.1 [cited 2024-12-09], pp.26-37.

Slabbert S., Green, N. Public knowledge of water re-use and other water related aspects. WRC Report No. TT 807/19, (2019).

Stoneham, A. M.; Ramos, M. M. D.; Sutton, A. P.: How do they stick together? The statistics and dynamics of interfaces. In: Philosophical Magazine A (1993), 67, p. 797-811

Swartz CD, Genthe B, Menge JG, Coomans CJ and Offringa G (2015) Direct reclamation of municipal wastewater for drinking purposes. Volume 1: Guidance on Monitoring, Management and Communication of Water Quality. WRC Report No. TT 641/15.

Swartz C.D., Genthe B., Chanier J., Petrik L.F., Tijani J.G., Adeleye A., Coomans C.J., Ohlin A., Falk D., Menge J.G. Emerging contaminants in wastewater treated for direct potable reuse: The human health risk priorities in South Africa. WRC Report TT 742/1/18, (2018).

van Niekerk AM and Schneider B (2013) Implementation plan for direct and indirect water re-use for domestic purposes – Sector Discussion Document. WRC Report No. KV 320/13.

https://unfccc.int/sites/default/files/resource/Nigeria_LTS1.pdf

Wastewater Production, Treatment, and Use in Africa. https://www.ais.unwater.org/ais/pluginfile.php/231/mod_page/content/188/Session3a_CountryReport_Rodda_South%20Africa.pdf?utm_source=chatgpt.com