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Water processing and supply during the load shedding crisis in the O.R. Tambo District Municipality

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Abstract

Understanding the impact of load shedding on the quantity and quality of water is crucial for ensuring reliable water supply systems. This study aimed to identify differences between the quantity and quality of water treated by water treatment facilities during load shedding and under normal electricity supply in the O.R. Tambo District of the Eastern Cape Province. The study made use of a quantitative, retrospective analysis of water quality and quantity data from selected water treatment facilities in the O.R. Tambo District Municipality. Researchers used existing records to compare the volume of water, as well as key water parameters, including pH, turbidity, electrical conductivity, and free chlorine, during periods of load shedding and periods of normal power supply. The data were analysed with R software using a generalised linear model with a negative binomial distribution, since the data were found to be abnormally distributed. The findings revealed no significant differences in the volumes of water treated during load shedding periods compared to non-load shedding periods. Furthermore, three quality parameters (pH, electrical conductivity, and turbidity) remained constant regardless of load shedding. However, chlorine levels differed between the two periods. The O.R. Tambo District Municipality's water treatment facilities maintain their operational efficiency during load shedding, ensuring a steady water supply and maintaining quality. These results have important implications for water resource management and infrastructure development in areas affected by load shedding.

Keywords: *Load shedding; water supply; water quality; water quantity*

Introduction

Access to safe water, sanitation, and hygiene is essential for every individual's dignity, health, and well-being, serving as the foundation for flourishing communities, strong economies, and a healthy environment (Connor, 2015; Economic and Social Commission for Asia and the Pacific, 2016). Despite the global commitment embodied in the United Nations (UN) Sustainable Development Goal (SDG) 6 to provide water and sanitation to everyone, the current situation in many countries is quite different. Insufficient infrastructure, worsened by climate change and inadequate governance, has led to severe water supply shortages in many areas, with developing countries disproportionately impacted. In South Africa, for instance, water security is a significant issue, particularly in rural municipalities where service delivery is often inconsistent (Adom & Simatele, 2024).

South Africa is facing severe water shortages. The nation's freshwater resources are heavily taxed owing to a combination of factors, including rapid population growth, unsustainable usage practices, poor water management, conflicting demands from different sectors such as agriculture and industry, widespread pollution, and the growing occurrence of droughts linked to climate change (Adom et al., 2022; Chitonge, 2020; du Plessis, 2023). Additionally, the country's water supply system relies heavily on electricity, as treatment facilities, pumping stations, and distribution networks require power to operate (Potgieter et al., 2019). The electricity crisis in South Africa, marked by rolling blackouts known as load shedding, has disrupted many vital services, including water supply. Eskom's implementation of load shedding to manage an unstable electricity grid has been a persistent issue (Botha, 2019). However, the increasing severity and frequency of these blackouts have become a significant burden, causing frustration among citizens and hindering economic progress, affecting various aspects of daily life (Banderker, 2022). One of the most critical impacts of load shedding is its threat to the country's water security (South African Local Government Association, 2022) . If this situation persists, it could jeopardise numerous businesses, especially those involved in irrigated agriculture and food production. Furthermore, the decline in water quality poses an immediate threat to both public health and the environment (Gelderblom, 2023).

Until recently, the electrical power supply to water purification and pumping systems was considered reliable, and concerns about power failures were not a significant factor in the design and functioning of drinking water supply and distribution systems (Potgieter et al., 2019; Winter, 2011). However, the water supply sector, particularly in municipalities, is struggling to manage prolonged electrical outages. The effects of load shedding on water supply in the O.R. Tambo District raise important issues regarding service delivery, the resilience of infrastructure, and risks to public health. The South African Local Government Association (SALGA) (2022) noted that without sufficient backup power systems at water processing facilities, residents may face extended water shortages, which can compromise sanitation, hygiene, and economic activities. In addition, municipal solutions such as the use of water tankers to supply neighbourhoods with water are ineffective in the long term, putting vulnerable communities at greater risk.

This study investigates the impact of load shedding on the efficiency of water treatment and distribution systems in the Oliver Reginald Tambo District Municipality (ORTDM). It compares the quality and quantity of water produced and supplied by ORTDM water treatment facilities during periods of load shedding and periods without load shedding. The findings shed light on the effects of load shedding on water processing and supply in the region, ultimately informing policy suggestions that aim to enhance water resilience in the district.

The Importance of Electricity in the Water Sector

South Africa boasts one of the most advanced water and wastewater systems in Africa (Winter., 2011). Understanding the intricacies of the country's water supply chain is crucial for evaluating how power outages affect the water sector. In addition, energy plays a vital role at every stage of water supply, including extraction, processing, distribution, and collection and treatment of wastewater (Paraschiv et al., 2023). Figure 1 gives an overview of the water supply chain in South Africa.

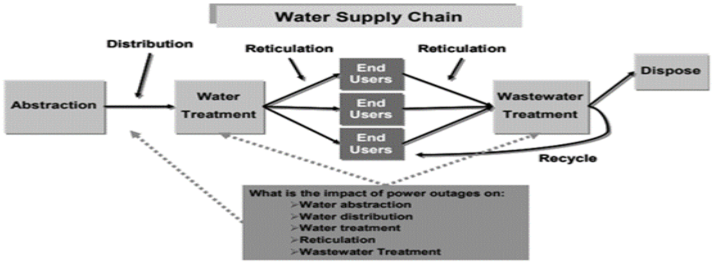

Figure 1: South Africa's water supply chain
Source: Winter (2011)

Energy costs account for approximately 75% of the expenses associated with municipal water processing and distribution, underscoring the critical role of energy in water supply and services (Kotulla et al., 2022). Additionally, water supply operations consume between 30% and 50% of a municipality's overall energy budget (Gulati et al., 2013). The amount of energy used throughout the water supply process is influenced by various factors, including the specific stage in the supply chain, the technology employed, whether pumps or gravity are used to induce flow, and the quality of the water being processed (Winter., 2011). Figure 2 illustrates the ranges of energy consumption for different stages of the water delivery system in South Africa, highlighting the significant variations in energy usage associated with specific treatment processes along the supply chain.

	kWh / ML	
Process	Min	Max
Abstraction	0	100
Distribution	0	350
Water Treatment	150	650
Reticulation	0	350
Wastewater Treatment	200	1800

Figure 2: Energy consumption range for the South African water supply chain
Source: Winter (2011)

Ageing infrastructure, including treatment facilities and collection and distribution networks, along with outdated treatment methods and controls, can lead to unnecessarily high energy consumption in the water sector (Gulati et al., 2013). Issues like leaking distribution systems and water loss force utilities to produce more treated water, which in turn increases energy usage for water extraction, treatment, and distribution (Paraschiv et al., 2023). The energy requirements at each stage of the water-use cycle can vary considerably, based on factors such as the water source, the distance and elevation changes between the source and the destination of the water, and the local topography (Nel et al., 2022). Transporting water over long distances is often the most energy-demanding part of this cycle (Paraschiv et al., 2023).

Abstraction Energy Requirements

The Department of Water Affairs and Forestry (DWAF) is responsible for regulating most water abstraction in South Africa. After considering return flows, the total net water abstraction from surface water sources in the country is approximately 10.2 million annually (Nel et al., 2022). Water is also sourced from groundwater, and in certain cases, local desalination of saltwater is conducted. The volume of water abstracted in each region depends on the availability of surface and groundwater as well as the demand (Winter, 2011). The abstraction phase of the water value chain is the most energy-intensive owing to the pumping required. While gravity is used to move water in catchment systems, high-lift and booster pumps are necessary for areas with topographical challenges to elevate the water to a level where gravity can be used (Nel et al., 2022).

Water Treatment Energy Requirements

In South Africa, water boards are tasked with the treatment, storage, and distribution of bulk water to local municipalities. In areas where a water board is not operational, a water service authority (WSA) such as the Oliver Reginald Tambo District Municipality, steps in to oversee these responsibilities (van der Merwe-Botha & Quilling, 2024). Water boards typically purchase raw water from the Department of Water Affairs and Forestry (DWAF), treat it, and then deliver it to the end consumers (Eales, 2011). Gulati et al. (2013) found that pumping operations are the most energy-intensive activities in water treatment processes, with pumping alone accounting for 85–99% of the energy consumed at water treatment plants. Other important processes, such as chemical dosing and remote telemetry control systems, also require energy. Furthermore, a typical water treatment plant employs various pumping methods, including raw water and well pumps, high-service pumps, filter backwash pumps, and distribution system booster pumps (Winter, 2011). The amount of energy consumed by water treatment facilities can differ significantly based on the plant's location, the extent of pumping needed, and the characteristics of the plant itself (Smith & Liu, 2017).

Water Distribution Energy Requirements

The process of moving water from water boards to water service authorities is known as water distribution (Eales, 2011). This involves the use of complex pipeline systems and pumping stations to deliver water to customers. Water managers encounter significant challenges in ensuring that water is readily available where needed, which can sometimes require transporting it over long distances, even hundreds of kilometres. Pumping is the most energy-consuming aspect of water delivery, and telemetry control systems also require a consistent power supply. The energy consumption associated with pumping is largely determined by the volume needed, in areas where gravity is used, less energy is typically required (Winter, 2011).

Water Services

The Oliver Reginald Tambo District Municipality (ORTDM) is supported by a single significant dam, Mthatha Dam, which yields 145.5 million m³ per year based on a 1-in-50-year assessment. In addition, there are four smaller dams located throughout the district – Corana, Mabheleni, Mhlanga, and Magwa – collectively holding a total of 6.84 million cubic meters of water. The population not covered by these dams receives its water from independent systems, including boreholes, springs, and direct withdrawals from rivers (Nel et al., 2022).
The Oliver Reginald Tambo District Municipality (ORTDM) is responsible for 25 water treatment plants (WTP), 20 of which are operational, while five are not. Additionally, the municipality oversees water quality for five broad borehole schemes, one in each local municipality, as well as numerous independent boreholes and spring schemes. Figure 3 shows the operational status of all the schemes in the district municipality.

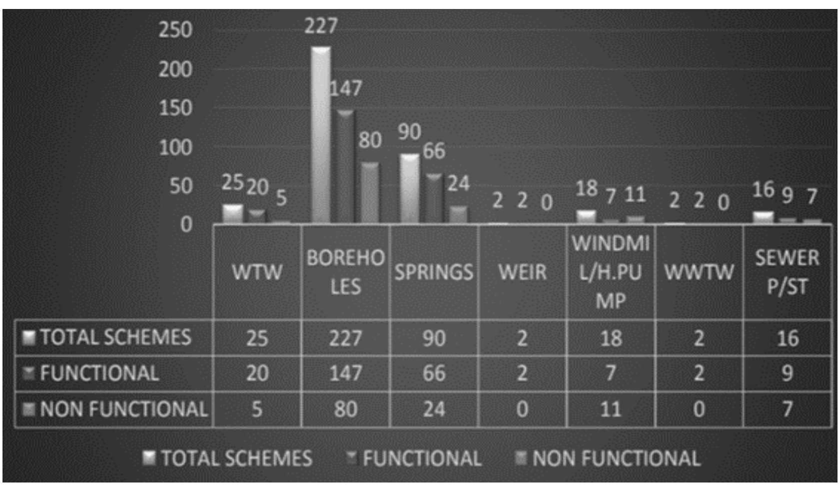

Figure 3: The status of the water and wastewater treatment facilities in Oliver Reginald Tambo District Municipality
Source: (O.R. Tambo District Municipality, 2022/2027)

Materials and Methods

Study Area

The research was conducted in the Oliver Reginald Tambo District Municipality, located at coordinates 32°46'31" S and 21°23'29" E in the Eastern Cape. This large, primarily rural region along the Indian Ocean coastline is categorised as a Category C2 municipality (i.e., a district municipality) and encompasses five local municipalities, covering a total area of 15946.84 km², with Mthatha being the central town. A significant factor in selecting this area for the study was its reliance on electricity-powered piped water.

Figure 4 shows the nine water treatment facilities in this district that were selected for the study. As noted above, there are 25 water treatment facilities in the district, five of which were not operating at the time of the study.

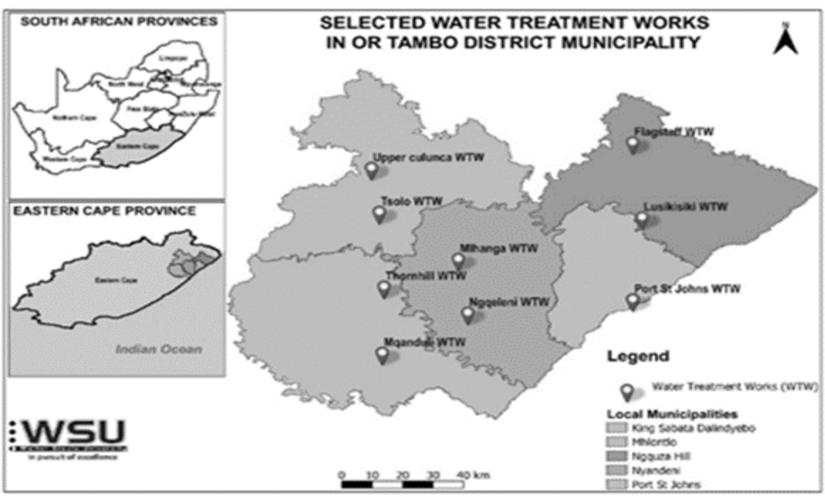

Figure 4: Map of study area showing the nine selected water treatment works in the ORTDM

Data collection

Ethical Considerations

Before the study commenced, an ethical clearance certificate (reference number WSU/FNS-GREC/2024/02/11G8) was obtained from the

Faculty of Natural Science Research Ethics Committee at Walter Sisulu University, and the research was also approved by the Oliver Reginald Tambo district municipal manager. Comprehensive details regarding the study's goals were shared with the area managers of the water treatment works. They were assured that all water quality data would be handled with the utmost confidentiality, ensuring that individual water treatment works sites would not be identifiable in any future analyses or reports, with data presented collectively at the district municipality level.

Sampling Procedure

Nel et al. (2022) state that all water treatment works maintain records of water quality. As a result, the researcher collected water quality and quantity data from nine selected water treatment facilities in the Oliver Reginald Tambo District Municipality in order to analyse the quality and quantity of water delivered to end-users during periods of load shedding and periods of normal power supply. The study relied on existing quantitative data from water treatment facilities owing to the unpredictable nature of load shedding. The challenges of ensuring regular access to facilities during possible power outages, along with the logistical difficulties of performing extensive water tests across the district's large area within limited load shedding windows, made this method necessary. Water volume samples were collected from the ORTDM water treatment facilities, comprising ten readings from each facility, 10 during load shedding, and 10 outside of load shedding times. However, one local municipality encountered meter issues, resulting in a final sample size of eighty readings instead of the intended one hundred.

To evaluate any variations in the quality of water processed and supplied by ORTDM water treatment works during and outside of load shedding periods, measurements for four parameters (pH, turbidity, electrical conductivity (EC), and free chlorine) were taken, aiming at 40 readings per parameter from each local municipality (20 during load shedding and 20 outside of load shedding). This should have yielded a total of 200 samples; however, the actual numbers varied for certain parameters. Specifically, one water treatment works did not test electrical conductivity due to a malfunctioning pH testing machine, and another was unable to conduct tests on some days because of equipment breakdowns.

Statistical Analysis

Data collected from water treatment works were analysed in R. The data for water quality parameters and volume of water treated and distributed were tested for normal distribution using the Shapiro-Wilk test and were found to be abnormally distributed. As a result, a generalised linear model was used to compare the volumes of water treated and distributed, as well as the levels of pH, chlorine, electrical conductivity, and turbidity, for both load-shedding and non-load-shedding periods. The data sets fitted the negative binomial distribution, which required the Modern Applied Statistics with S (MASS) package.

Results and Discussion

Results

The generalised linear model indicated that there were no significant differences between pH (t = 0.17, p = 0.87), electrical conductivity (t = 0.07, p = 0.95), and turbidity (t = 0.59, p = 0.55) during periods of load shedding and periods of no-load shedding. Similarly, the volumes of water treated and distributed to end users during load shedding were similar (t = 1.41, p = 0.16) to the volumes treated and distributed when there was no load shedding. In contrast, the analysis revealed a significant difference (t = -2.06, p = 0.04) between chlorine concentrations at times with and without load shedding. During load shedding, the levels of chlorine were higher than during periods of no-load shedding (Figure 5).

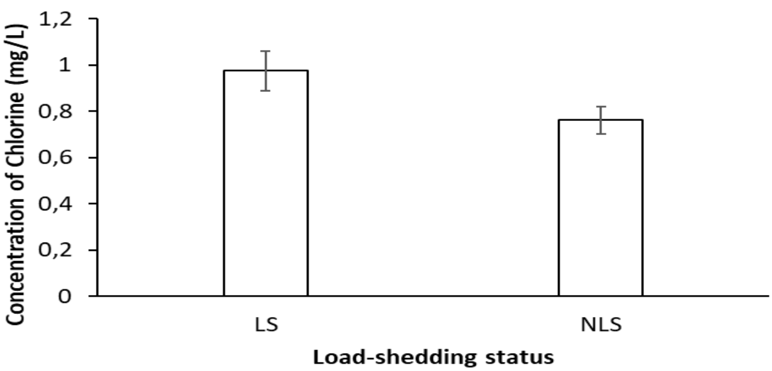

Figure 5: Chlorine concentrations during periods of load shedding (LS) and no-load shedding (NLS) in the ORTDM

Discussion

Water Quality Processing

Despite the interruptions caused by load shedding, water pH levels remained consistent. A few factors could account for the absence of significant differences in water pH, as follows:

1. Experience of Process Controllers

During the study, it was found that most personnel working in the water treatment plants of various local municipalities had been employed at these plants for at least 10 years. Therefore, they were experienced enough to perform manual operations such as adjusting the pH of water before distribution. Their expertise helped to maintain consistent pH levels during times of load shedding. Huttinger et al. (2015) also found that in Rwanda, water treatment facilities often resort to manual operations in the absence of electricity. The findings contrast with those of Moore (2022), who discovered that in some facilities in Northwest Province, employees treat load shedding periods as extended lunch breaks, maintaining that they can do little in the absence of electricity.

2. Buffering Capacity

Water's natural ability to buffer maintains its pH levels. Even when there are pressure changes caused by the absence of electricity, the buffering effect prevents drastic pH fluctuations (Grochowska, 2020; Middelburg et al., 2020). As a result, the pH levels in the ORTDM water treatment facilities remained relatively stable.

3. Short Duration of Load Shedding

Load shedding usually occurs in cycles, lasting for relatively short periods. The study revealed that in the Oliver Reginald Tambo District Municipality (ORTDM), the maximum duration is between two and four hours, depending on the stage of load shedding determined by the national energy provider, Eskom. These short interruptions are unlikely to have a significant impact on the overall pH of water. Karrim (2019) noted that in Cape Town and Durban, most regions do not face major water outages unless the load shedding exceeds Stage 4. These results contrast with those of Machimana et al. (2024), who found that in

Mohlaba, Tzaneen, load shedding happens more frequently, and even after power is restored, it takes time for water to return to taps.

Turbidity

Turbidity refers to the cloudiness or murkiness of water resulting from the presence of suspended particles, such as silt, algae, and organic matter (Water Science School, 2018). When water pressure decreases because of load shedding, the flow of water through pipes can slow down. This reduced flow can lead to the accumulation of silt and other particles in the pipes, which can increase turbidity (Water Science School, 2018). However, the effect of load shedding on turbidity is influenced by several factors, including the structure of the water distribution system, the length of the load shedding period, and the location of the water treatment plant (Gelderblom, 2023). The study's findings reveal no significant differences in water turbidity between periods with and without load shedding. Some potential explanations for this minimal difference include the following:

1. Water Treatment Processes and Distribution System Design

The water treatment facilities in Oliver Reginald Tambo District Municipality (ORTDM) have efficient processes in place that effectively eliminate or decrease turbidity before the water is delivered to consumers, even during load shedding. The district's distribution systems are strategically designed to minimise the effects of load shedding on water quality during these outages. This contrasts with the findings of a study conducted in Kenya by Ogutu and Otieno (2003), which revealed that Moi University's drinking water treatment plant had numerous faults, including cracks and mud balls in its filter units, resulting in reduced efficiency and lower filtration rates.

2. Monitoring and Maintenance

Consistent monitoring and maintenance of water infrastructure are crucial for preventing sediment accumulation in water treatment plants and ensuring that water turbidity remains stable, even during periods of load shedding. This appears to be the case in the ORTDM. In West Sumatra Province in Indonesia, community development initiatives have been implemented that aim at enhancing the water infrastructure, thereby improving both water supply and quality (Vitri and Herman, 2019). Kang

(2019) on the other hand, noted that deteriorating and poorly monitored urban water infrastructure in Korea, including ageing reservoirs and broken water supply systems, has led to a situation where 21.3% of the population feels unsafe to drink municipal water.

Electrical Conductivity

According to Klaassen (2020), electrical conductivity is a material's ability to transport an electric current. In the case of water, this property relies on the presence of charged particles, or ions, in the water. When salts and other inorganic compounds dissolve in water, they break down into ions, which enhance conductivity. As a result, saltwater, with its higher salt content, has significantly greater conductivity than normal drinking water.

During load shedding, water distribution systems experience reduced pressure. However, the electrical conductivity of the water remains stable because this aspect depends on the presence of dissolved ions, which are unaffected by power outages. Therefore, even if the water supply is disrupted during load shedding, the conductivity of the water does not change. In this case, it is the inherent nature of electrical conductivity that explains the consistency in electrical conductivity during load-shedding and non-load-shedding periods.

Chlorine

The findings of the study indicate a notable variation in chlorine concentrations in the water during load shedding and non-load shedding periods. The following factors may explain this difference:

1. Stability of Water Treatment Processes and Chlorine Residuals

Chlorine is widely used as a disinfectant in water treatment processes, primarily to maintain a certain level of residual chlorine in the treated water for microbial safety (Collivignarelli et al., 2017). The differences in chlorine concentrations between load shedding and non-load shedding periods may be attributed to the fact that monitoring and dosing of chlorination are performed manually during load shedding. The results of this study align with those of Winter (2011), who found that without an electrically operated dosing system, dosing halts unless the water treatment facility has backup power. In the absence of such backup, chlorine levels vary considerably. The finding is also supported by

Gelderblom (2023), who states that during load shedding, municipalities struggle to produce clean drinking water. In contrast, Huttinger et al. (2015) found that rural healthcare facilities in Rwanda utilised hydraulically powered chlorine systems, enabling effective water treatment without the need for electricity. With these systems, water chlorination is unaffected by power outages. High levels of chlorine in water can lead to the formation of hazardous disinfection by-products, posing significant health risks such as cancer and reproductive issues, while also affecting water quality (Kalita et al., 2024).

Water Quality and Blue Drop Report

The Department of Water Affairs (DWA) has launched a comprehensive Water Services Regulation Strategy aimed at the water sector. This regulation outlines the responsibilities and expectations of water service institutions, ensuring consumer protection against services that may be unsafe or unsustainable (Hamza & Schneider, 2014). According to Department of Water and Sanitation (2023), the Blue Drop process assesses how well water service authorities and providers perform, giving rewards or penalties to municipalities based on specific minimum standards and criteria. Each evaluated water supply system receives a Blue Drop score, which is then combined to create an overall Blue Drop percentage score for the municipality. The Blue Drop National (BDN) Report (2023) indicates that the Oliver Reginald Tambo District Municipality achieved a Blue Drop score of 56.7% in 2023, indicating average performance and highlighting critical risks related to operational capacity, infrastructure maintenance, and compliance. At first glance, these results may seem inconsistent with this study's findings, which showed that water treatment facilities maintained stable water quality (pH, turbidity, and electrical conductivity) and quantity during load shedding.

It is important to emphasise that the two assessments focus on different levels of performance. This study specifically analysed the short-term impact of load shedding on operational efficiency, and the results demonstrate that the district's water treatment facilities are relatively resilient in coping with temporary power outages. By contrast, the Blue Drop assessment evaluates long-term, systemic issues across broader dimensions of governance, technical capacity, and infrastructure sustainability. The findings should therefore be seen as complementary: while facilities are able to manage short-term disruptions effectively, wider institutional and structural weaknesses continue to pose risks to safe and reliable water supply in the district.

The Blue Drop scores for district municipalities, including Oliver Reginald Tambo District Municipality (ORTDM), are shown in Figure 6. The data indicates that Oliver Reginald Tambo District Municipality's score improved between 2014 and 2023; however, it remains at an average performance level, with a score of 95% or higher required for optimal performance. Furthermore, the Blue Drop National Report (2024) highlights that ORTDM, the water service authority (WSA) in the region, faces significant risks with regard to operational capacity, design capacity utilisation, water quality compliance, technical capacity, and water safety plans, all of which are in the 'critical' category.

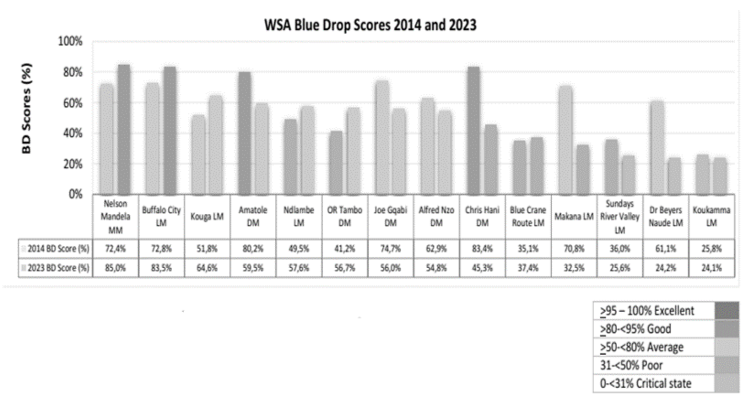

Figure 6: The Blue Drop Performance Barometer presenting the individual WSA Blue Drop Scores.
Source: Blue Drop National Report (2023)

Table 1: % BDRR/BDRR max scores and WSSs in critical and high-risk space

WSA Name	2023 Average %BDRR/BDRR max	WSSs in critical and high-risk spaces	
		Critical risk (90–100%)	**High risk (70–<90%)**
Alfred Nzo DM	35.6%	Kinira	
Amatole DM	53.5%		Xhora
Dr Beyers Naude LM	47.6%	Waterford	Jansenville
Koukamma LM	62.8%	Clarkson, Joubetina, Krakeel, Misgund, Storms River	Louterwater
Makana LM	55.5%		Alicedale
OR Tambo DM	46.5%		Mhlanga, Mzimvubu

Sundays River Valley LM	64.3%		Kirkwood
Totals		**7 of 154 (5%)**	**7 of 154 (5%)**

Table 1 shows the Blue Drop Risk Rating (% BDRR/BDRR max) scores for the district municipalities and local municipalities in the Eastern Cape, along with the status of the water supply system for each.

The volume of water processed

The null hypothesis, which states that there is no significant difference between the average volumes of water supplied by ORTDM water treatment works during times of load shedding and times without load shedding, is accepted. Consequently, the alternative hypothesis, which proposes a significant difference in water supply during these two conditions, is rejected. This result may be explained by various factors, as follows:

1. Storage Reservoirs

Water treatment facilities in the Oliver Reginald Tambo District Municipality typically feature storage reservoirs that contain a certain amount of treated water. During load shedding, while water treatment processes may be affected, the stored water in these reservoirs continues to be supplied to consumers. This stored supply ensures reliable distribution even in the midst of load shedding. These observations align with findings that show the water stored in reservoirs can sustain supply for approximately 24 hours during power outages (Kotulla et al, 2022). In addition, research conducted in Caledon indicates that there are restrictions on reservoir outlets at night in order to increase storage capacity for use during outage periods (Ruiters, 2022).

2. Alternative Energy Solutions

The study revealed that some water treatment facilities in the district use alternative energy sources (such as backup generators) to ensure electricity supply during load shedding. A study conducted by the Water Research Commission (2019) found that other municipalities, such as Tshwane, also utilise backup power to ensure their water treatment facilities continue to operate during load shedding hours. These findings are in line with those of Kotulla et al. (2022), who discovered that in the Czech Republic, diesel generators are used as a backup power supply for water treatment facilities.

Summary

This research examined the impact of load shedding on the quality and quantity of water treated by facilities in the Oliver Reginald Tambo District Municipality during load shedding periods, compared to times without load shedding. The findings suggest that although load shedding affects the operational efficiency of these facilities, there is no notable difference in the volume of water released or in the quality of the water (as measured by pH, electrical conductivity, and turbidity). However, there were significant fluctuations in chlorine levels between periods of load shedding and non-load shedding. These findings indicate that Oliver Reginald Tambo District Municipality water treatment facilities maintain consistent standards regardless of the presence or absence of power. While load shedding affects water treatment facilities, multiple factors help to ensure a continuous water supply. Backup systems, storage reservoirs, and energy-saving measures all contribute to closing the gap during load shedding.

Conclusions

This study found that Oliver Reginald Tambo District Municipality's water treatment facilities are generally resilient to short-term power outages caused by load shedding. Water quality parameters, such as pH, turbidity, and electrical conductivity, remained stable, and the water volumes supplied to communities were not significantly affected. However, chlorine levels exhibited notable fluctuations, highlighting the vulnerability of manual dosing processes during power outages.

Although these findings are positive in terms of immediate operational resilience, they should be interpreted in conjunction with broader assessments, such as the Blue Drop Report, which highlights systemic risks in the municipality's overall water service delivery. In this sense, the results are not contradictory but rather complementary: facilities are coping with short-term load shedding events, yet long-term sustainability is undermined by infrastructure, compliance, and governance challenges.

Future research should prioritise the Oliver Reginald Tambo District Municipality as a whole, rather than concentrating only on the facilities selected for this study. This broader focus would enable a more thorough investigation of aspects within the district that were not included in this research, resulting in more well-rounded findings. Similarly, future studies could benefit from conducting water quality sampling at water treatment facilities rather than relying on easily accessible data, thereby enhancing the reliability and accuracy of the quantitative data obtained.

References

Adom, R. K., Simatele, M. D., & Reid, M. (2022). The Threats of Climate Change on Water and Food Security in South Africa. *American Journal of Environment and Climate*, *1*(2), 6-10. https://doi.org/10.54536/ajec.v1i2.568

Banderker, S. I. (2022). The Perceived Psychosocial and Economic Impact of Load-Shedding on Employees in Selected Small Micro Medium Enterprises. https://internationalbusinessconference.com/wp-content/uploads/2024/10/CP102-Naidoo_Chetty-impact-of-loadshedding-final-corrected.pdf

Botha, T. (2019). The Impact Of'load-Shedding'within the Nelson Mandela Bay Restaurant Industry The IIE]. https://iiespace.iie.ac.za/server/api/core/bitstreams/8078dc0d-e898-4996-b7e5-9e536174d23c/content

Chitonge, H. (2020). Urbanisation and the Water Challenge in Africa: Mapping out Orders of Water Scarcity. *African Studies*, *79*(2), 192-211. https://doi.org/10.1080/00020184.2020.1793662

Collivignarelli, M. C., Abbà, A., Benigna, I., Sorlini, S., & Torretta, V. (2017). Overview of the Main Disinfection Processes for Wastewater and Drinking Water Treatment Plants. *Sustainability*, *10*(1), 86. https://doi.org/10.3390/su10010086

Connor, R. (2015). The United Nations World Water Development Report 2015: Water for a Sustainable World (Vol. 1). UNESCO publishing. https://doi.org/https://doi.org/10.18356/7cb7d6bd-en

Department of Water and Sanitation. (2023). Blue Drop Report National *2023*. Retrieved from https://ws.dws.gov.za/iris/releases/BDN_2023_Report.pdf

du Plessis, A. (2023). Water Resources from a Global Perspective. In *South Africa's Water Predicament: Freshwater's Unceasing Decline* (pp. 1-25). Springer. https://doi.org/https://doi.org/10.1007/978-3-031-24019-5_1

Eales, K. (2011). Water Services in South Africa 1994–2009. *Transforming water management in South Africa: Designing and implementing a new policy framework*, 33-71.

Economic and Social Commission for Asia and the Pacific. (2016). Sustainable Development Goal 6: Ensure Availability and Sustainable

Management of Water and Sanitation for All. https://doi.org/10.18356/29661a20-en

Gelderblom, C. (2023). Compromised Water Availability and Quality Is the Hidden Cost of Loadshedding. Retrieved 16 May 2024 from https://www.wwf.org.za/?43942/Compromised-water-availability-and-quality-is-the-hidden-cost-of-loadshedding#:~:text=In%20addition%20to%20the%20challenges,for%20sand%20filters%20to%20operate.

Grochowska, J. (2020). Assessment of Water Buffer Capacity of Two Morphometrically Different, Degraded, Urban Lakes. *Water*, *12*(5), 1512. https://doi.org/10.3390/w12051512

Gulati, M., Jacobs, I., Jooste, A., Naidoo, D., & Fakir, S. (2013). The Water–Energy–Food Security Nexus: Challenges and Opportunities for Food Security in South Africa. *Aquatic Procedia*, *1*, 150-164. https://doi.org/10.1016/j.aqpro.2013.07.013

Hamza, P., & Schneider, J. (2014). Drinking Water in the Amathole District, Republic of South Africa. https://www.researchgate.net/publication/271962962_Drinking_Water_in_the_Amathole_District_Republic_of_South_Africa

Kalita, I., Kamilaris, A., Havinga, P., & Reva, I. (2024). Assessing the Health Impact of Disinfection Byproducts in Drinking Water. *Acs Es&T Water*, *4*(4), 1564-1578. https://doi.org/10.1021/acsestwater.3c00664

Kang, H. (2019). Challenges for Water Infrastructure Asset Management in South Korea. *Water Policy*, *21*(5), 934-944. https://doi.org/10.2166/wp.2019.005

Karrim, A. (2019). Load Shedding: Minor Effect on Water Treatment and Supply, Unless It Goes Beyond Stage 4. Retrieved 15 August 2024 from https://www.news24.com/news24/load-shedding-minor-effect-on-water-treatment-and-supply-unless-it-goes-beyond-stage-4-20191212

Klaassen, P. (2020). Electrical Conductivity, Why It Matters. Retrieved 16 May 2024 from https://www.canna.co.za/articles/electrical-conductivity-why-it-matters

Kotulla, M., Goňo, M., Goňo, R., Vrzala, M., Leonowicz, Z., Kłosok-Bazan, I., & Boguniewicz-Zabłocka, J. (2022). Renewable Energy Sources as Backup for a Water Treatment Plant. *Energies*, *15*(17), 6288. https://doi.org/10.3390/en15176288

Machimana, L. I., Gumbo, A. D., Moyo, H., & Mugari, E. (2024). The Impact of Load-Shedding on Scheduled Water Delivery Services for Mohlaba-Cross Village, Greater Tzaneen, South Africa. *Water*, *16*(14), 2033. https://doi.org/10.3390/w16142033

Middelburg, J. J., Soetaert, K., & Hagens, M. (2020). Ocean Alkalinity, Buffering and Biogeochemical Processes. *Reviews of Geophysics*, *58*(3), e2019RG000681. https://doi.org/10.1029/2019rg000681

Nel, A., Shaw, D., Mlilo, S., & Dube, V. (2022). Mthatha Bulk Regional Water Supply Scheme Takes Shape. *Civil Engineering= Siviele Ingenieurswese*, *30*(5), 14-19. https://journals.co.za/doi/full/10.10520/ejc-civeng_v30_n5_a6

O.R. Tambo District Municipality. (2022/2027). O.R. Tambo District Municipality Idp. Retrieved from https://ortambodm.gov.za/wp-admin/admin-ajax.php?juwpfisadmin=false&action=wpfd&task=file.download&wpfd_category_id=110&wpfd_file_id=17481&token=&preview=1

Ogutu, C., & Otieno, F. (2003). Assessing the Performance of Drinking Water Treatment Plant Using Turbidity as the Main Parameter (Case Study: Moi Universtity-Kenya). *Department of Civil Engineering, Faculty of Engineering, Tshwane University of Technology: Pretoria, South Africa*. https://wisa.org.za/wp-content/uploads/2018/12/WISA2006-P124.pdf

Paraschiv, S., Paraschiv, L. S., & Serban, A. (2023). An Overview of Energy Intensity of Drinking Water Production and Wastewater Treatment. *Energy Reports*, *9*, 118-123. https://doi.org/10.1016/j.egyr.2023.08.074

Potgieter, J. C., Herold, C., Van Dijk, M., & Bhagwan, J. (2019). Economic Benefit of Ensuring Uninterrupted Water Supply during Prolonged Electricity Disruptions–City of Tshwane Case Study. *Journal of the South African Institution of Civil Engineering*, *61*(4), 19-28. https://doi.org/10.17159/2309-8775/2019/v61n4a2

Ruiters, T. L. (2022). Load Shedding Creates Water Crises in Caledon. Retrieved 17 July 2023 from https://www.proquest.com/newspapers/load-shedding-creates-water-crises-caledon/docview/2722786055/se-2

Smith, K., & Liu, S. (2017). Energy for Conventional Water Supply and Wastewater Treatment in Urban China: A Review. *Global Challenges*, *1*(5), 1600016. https://doi.org/10.1002/gch2.201600016

South African Local Government Association. (2022). The Impact of Load Shedding in the Provision of Health Care Services to Communities: Virtual Ministerial Briefing. Retrieved 07 April 2023 from: www.salga.org

van der Merwe-Botha, M., & Quilling, G. (2024). Development of Regulations to Entrench Water Efficient Sanitation Solutions in Bulk Services. https://www.wrc.org.za/wp-content/uploads/mdocs/3173%20final.pdf

Vitri, G., & Herman, H. (2019). Infrastructure Maintenance System for Community Development Projects to Improve the Quality of Infrastructure Services in West Sumatra Province. IOP Conference Series: Materials Science and Engineering,

Water Reasearch Commission. (2019). Mitigating the Impact of Electricity Disruption on Water Supply – Case Study of the City of Tshwane. Retrieved 15 May 2024 from https://www.wrc.org.za/wp-content/uploads/mdocs/2591_final.pdf

Water Science School. (2018). Turbidity and Water. Retrieved 16 May 2024 from https://www.usgs.gov/special-topics/water-science-school/science/turbidity-and-water

Winter, D. (2011). Power Outages and Their Impact on South Africa's Water and Wastewater Sectors. Water Research Commission Pretoria. https://www.wrc.org.za/wp-content/uploads/mdocs/KV%20267-111.pd