AN INDEPENDENT INVESTIGATION AND ADVISORY ON THE ROLE OF WATER, SANITATION AND HYGIENE IN THE 2023 CHOLERA OUTBREAK IN HAMMANSKRAAL, SOUTH AFRICA

WORK PACKAGE 3: WATER, SANITATION AND HYGIENE (WASH) SERVICES MAPPING

Final Report to the
Water Research Commission

by

Norah Motha[1], Tshilidzi Mathedimosa[2]

[1] Cubic M Africa (Pty) Ltd.
[2] Liafhetha Projects (Pty) Ltd.

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Obtainable from
Water Research Commission
Bloukrans Building, Lynnwood Bridge Office Park
4 Daventry Street
Lynnwood Manor
PRETORIA

orders@wrc.orgza or download from www.wrc.org.za

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EXECUTIVE SUMMARY

BACKGROUND

Cholera is a contagious diarrhoeal disease that affects vulnerable communities. It is caused by the bacterium *Vibrio Cholerae* which is mainly transferred through the consumption of contaminated water and food, transmission from contaminated environmental point sources and contact with cholera cases. Improved access to clean water, sanitation and hygiene (WASH) is crucial in the prevention of cholera transmission. In response to the Cholera outbreak in Hammanskraal, the Water Research Commission initiated a technical investigation into the potential sources of contamination and pathways for transmission.

AIMS

The following were the aims of the project:

1. Document historical meteorological data and environmental conditions that existed in the Hammanskraal region during the assessment period..
2. Document sources of water in use and available sanitation and hygiene facilities in the region.
3. Undertake a risk mapping based on the water and sanitation services supply chain.

METHODOLOGY

The historical climate data for the Hammanskraal region was obtained from the South African Weather Services. The physicochemical and bacteriological data was sourced from the publicly available water quality compliance records kept by the Department of Water and Sanitation. The period under consideration was from November 2022 to the end of May 2023, which coincides with the emergence of the first cholera cases in the area. The historical data were analysed to gain insight into the potential links between meteorological factors and cholera outbreaks.

Field observations and surveys were relied upon to document the availability and functionality of the sanitation and hygiene facilities. By assessing the availability of these resources, potential areas of vulnerability were identified and the impact of inadequate WASH infrastructure has on cholera transmission understood. Information was gathered on the different water sources in use, including rivers, boreholes and community water supply systems through interviews with plant personnel with knowledge of the catchment, and secondary data such as planning documents and available literature.

Furthermore, the pathways through which contaminated water may enter the system and reach individuals were mapped out using the ISO 31000 Risk Management guidelines. This exercise helped to identify critical control points and develop targeted interventions to mitigate the risk of cholera transmission. This included assessing water sources, treatment processes, distribution networks, sanitation facilities and hygiene practices.

RESULTS AND DISCUSSION

The closer examination of the climate data over the assessment period, obtained from the Wonderboom Weather Station, revealed the occurrence of rainfall events in November, December, February and April with February experiencing almost threefold the monthly average over the same period. Both air and water temperature were mostly within the favourable range of 19°C to 28°C and 20°C to 45°C respectively, up to April, before dropping to below the favourable conditions in May.

The environmental conditions of the Apies River, from which Temba Water Treatment Works (WTW) abstracts, were documented based on the upstream Rooiwal Wastewater Treatment Works compliance data obtained from the Department of Water and Sanitation (DWS). The parameters that were analysed included pH, Electrical Conductivity (EC), Faecal Coliforms and the presence of host organisms such as Cyanobacteria and Water Hyacinth.

While pH was found to be within the favourable range of 6.5 to 9, EC concentrations were consistently below the 150 mS/m *V. cholerae* is known to thrive above this value. However, the bacteria have been previously discovered in freshwater resources with low EC values. Furthermore, there were elevated levels of microbiological contaminants in the Rooiwal WWTW effluent, with the plant consistently failing to meet the discharge limit for Faecal Coliforms. The inspection of both the Pienaars River, from which the Klipdrift WTW abstracts water and the Apies River-Leeukraal Dam system revealed excessive levels of blue-green algae and the presence of water Hyacinth in the case of Leeukraal Dam.

The primary water sources that were identified in the area include Temba WTW, Klipdrift WTW, Rand Water delivered through tankers, boreholes and hand-dug wells mostly concentrated in the Stinkwater area as well as the commercially available bottled water. Studies have shown that the water provided from boreholes and wells in the Stinkwater area is unsafe for consumption regarding microbial indicators.

The identified sanitation facilities encompass various types such as flush toilets, chemical toilets, septic tanks and pit latrines. A significant issue arises in some areas where the absence of a reliable water supply hinders the proper flushing of communal toilets. Consequently, the residents are forced to resort to alternative methods that pose greater risks. It is therefore imperative that the provision of sufficient water and sanitation services receives prioritisation in the areas affected by intermittent water supply. Additionally, the existence of illegal dumping sites and sewage manholes experiencing overflow raises considerable concern due to the potential exacerbation of public health challenges and environmental deterioration.

In the RDP (reconstruction and development programme) sections, most of the wash basins that were previously installed outside the toilets have regrettably collapsed. The absence of running water, hygiene facilities and soap within the toilet area implies that most individuals in the affected areas seldom wash their hands with soap after using the toilet, leaving the community vulnerable to the risk of cholera transmission.

CONCLUSIONS

While the historical meteorological data suggested that both the rainfall patterns and temperature were suitable for the growth and transmission of the *vibrio cholerae*, it Is important to consider other factors such as sanitation, access to clean water and hygiene practices in determining the risk and occurrence of cholera outbreaks.

The environmental conditions during the assessment period were mostly suitable for the survival of *V. cholerae* suggesting that if the bacteria were present in the area, particularly in the Apies River, its growth and transmission could have been promoted by the existing conditions.

The key risks that have been identified as potential pathways for cholera transmission include the high level of contamination in the rivers, the operational inefficiencies of the Temba WTW in treating the water to acceptable standards, inadequate sanitation infrastructure particularly in the informal and rural settlements, poor hygiene practices due to inadequate infrastructure and lack of community awareness.

RECOMMENDATIONS

In lieu of the above, it is recommended that the City of Tshwane adopt a risk-based approach as an effective mechanism to reduce the probability of future cholera outbreaks. The time series data for cholera and rainfall anomalies should be analysed further over longer periods to gain insight into any potential correlation between the two factors. These insights can help policymakers understand the potential impact of rainfall anomalies on the occurrence and spread of cholera outbreaks which can be valuable for them to develop targeted interventions, allocate resources effectively and craft preparedness strategies to prevent and respond to cholera outbreaks.

It is imperative for the health of the water resources in the area to be improved and protected to ensure sustainable provision of clean water to the community. Access to proper sanitation and hygiene infrastructure is indispensable as a mitigation measure to prevent further cholera transmission. Good hygiene practices should be promoted through community education and awareness to minimise their exposure to cholera.

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Name	Affiliation
Cholera Advisory Panel	Various Institutions
Dr Eunice Ubomba-Jaswa (Research Manager)	Water Research Commission
Mr Junior Setshedi	South African National Civic Organisation (Hammanskraal)
Mr Sipho Madlhabane	City of Tshwane
Mr Rodney Mathebula	Department of Water and Sanitation
Community Members	Hammanskraal

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ACRONYMS & ABBREVIATIONS

Abbreviation	Description
DWS	Department of Water and Sanitation
E. coli	*Escherichia coli*
EC	Electrical Conductivity
IRIS	Integrated Regulatory Information System
ISO	International Organization for Standardization
mg/l	Milligrams Per Liter
mS/m	Milli-Siemens Per Meter
NTU	Nephelometric Turbidity Units
pH	Potential of Hydrogen
RDP	Reconstruction Development Programme
SANS	South African National Standards
SAWS	South African Weather Services
TDS	Total Dissolved Solids
VIP	Ventilated Improved Pit Latrine
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WTW	Water Treatment Works
WWTW	Wastewater Treatment Works

GLOSSARY

No	Term	Meaning
1.	Cholera	An acute infectious bacterial disease of the small intestine caused by ingestion of food or water contaminated with the bacterium *Vibrio cholerae*.
2.	Dwelling	Any structure intended or used for human habitation.
3.	Hazard	A biological, chemical, physical and/or radiological agent that has the potential to cause harm.
4.	Hygiene	Practices people adopt to keep themselves or their environment clean to maintain health and prevent the spread of diseases.
5.	Lag	A period between one event and another.
6.	Risk	The likelihood of identified hazards causing harm in exposed populations in a specified time frame.
7.	Settlement	A place where a group of people live. This is classified according to the characteristics of a residential population in terms of urban and rural, degree of planned and unplanned and jurisdiction.
8.	*Vibrio cholerae*	A species of Gram-negative, facultative anaerobe bacteria, the bacteria can be infectious – disease-causing or non-infectious (does not cause a disease).

CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

Following the Cholera outbreak in Hammanskraal, north of Pretoria, which has claimed more than twenty lives, a technical investigation into the potential source of contamination and possible transmission pathways was initiated by the Water Research Commission in collaboration with the Department of Water and Sanitation. Given the large number of cholera cases in Hammanskraal, it has been imperative to investigate the factors contributing to the transmission of the disease to prevent or eliminate future epidemics.

Studies have shown that ingestion of *Vibrio Cholerae* occurs from the consumption of contaminated food and water, contact with cholera cases and transmission from contaminated environmental point sources (Zoua, Djaouda, Maïworé, Liang, & Nola, 2020) It has been proven that the prevention of cholera transmission can be achieved through access to clean water, availability of adequate sanitation and good hygiene practices. (D'Mello-Guyett, Gallandat, Van den Bergh, Taylor, Bulit, Legros, Dominique, Peter, Checchi, Francesco, Cumming & Oliver, 2020)

1.2 PROJECT AIMS

The following were the aims of the project:

1. Document historical meteorological data and environmental conditions that existed in the Hammanskraal region during the assessment period
2. Document sources of water in use and available sanitation and hygiene facilities in the region
3. Undertake a risk mapping based on the water and sanitation services supply chain

1.3 SCOPE AND LIMITATIONS

The focus of the study was on the Water, Sanitation and Hygiene (WASH) infrastructure as it relates to the domains of transmission, i.e. within households and community level. Due to a limited timeframe of less than a month, the ability to collect data from a larger sample size was limited. The lack of ethical oversight further posed a limitation on risk mapping as there may have been inadequate consideration of potential risks to the health and well-being of the community.

CHAPTER 2: METHODOLOGY

2.1 STUDY AREA

Hammanskraal is situated north of Pretoria in the Gauteng Province, South Africa as shown in Figure 1 below. The region has an estimated population of 21345 (2011) and is characterised by multiple settlement types namely: industrial, commercial, rural, social housing (RDP), township and small holdings. Geographically, the area is divided into three sections, namely, Hammanskraal East, West and Central. Hammanskraal Central, which includes areas such as Kanana, Temba, some informal settlements, and part of the RDP housing section, is the largest. The East section includes areas such as Marokolong, Refiloe, Kekana and Babelegi while the West section comprises New Eersterust, Stinkwater, Refentse and the rest of the RDP section.

The central part of Hammanskraal is supplied with drinking water from Temba Water Treatment Works (WTW). The plant abstracts raw water from the Leeukraal Dam which is fed by the Apies River. The contamination of the Apies River that can be attributed to the inadequately treated wastewater effluent from the upstream wastewater treatment works, in particular, Rooiwal Wastewater Treatment Works (WWTW), has been a subject of disputes over the years.

The eastern and western parts are supplied by the Klipdrift WTW belonging to Magalies Water, and Rand water pipelines respectively. Other water sources include water tankers from both Magalies and Rand water lines (fire hydrants), boreholes and commercially available bottled water from various suppliers.

In terms of wastewater treatment, the area is served by two main WWTW, Temba and Babelegi wastewater systems. Temba WWTW is located approximately 500 m downstream of the WTW abstraction point while Babelegi WWTW is located approximately 4 km further downstream. Consequently, the effluent discharge of these plants does not have a bearing on the water quality of the Temba WTW abstraction point. In contrast, the Rooiwal WWTW located a mere 15 km upstream of the Temba WTW has a negative impact on the quality of the water abstracted by the Temba WTW.

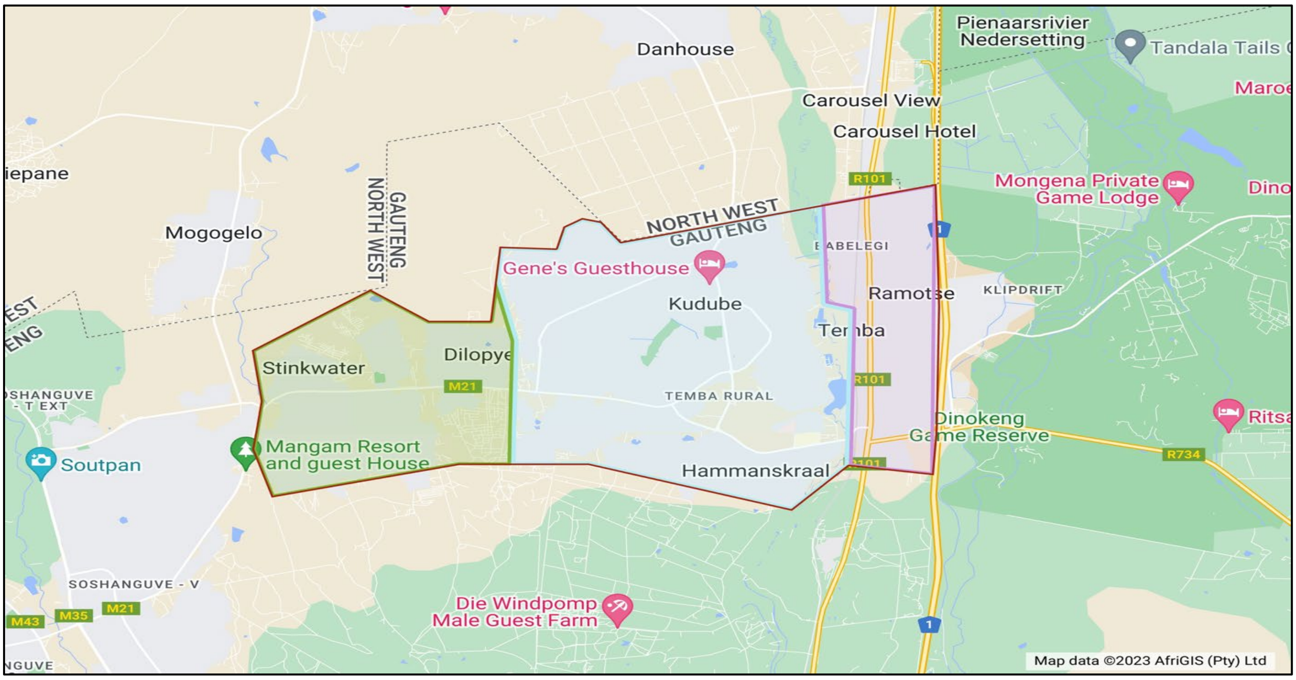

Figure 1: Location Map of Hammanskraal

2.2 DATA COLLECTION

2.2.1 Meteorological data and environmental conditions

The historical climate data for the region comprising of the temperature and rainfall pattern was obtained from the South African Weather Services.
The physicochemical and bacteriological data was sourced from the publicly available water quality compliance records kept by the Department of Water and Sanitation. The parameters that were analysed includes the following:

- pH of the water source
- Electrical Conductivity (EC) in mS/cm in the raw water
- Surface water temperature estimated from air temperature data
- Faecal Coliforms (CFU/100 mL) in the Final water

Once collected, the data was analysed and interpreted to identify patterns and trends related to cholera transmission over the assessment period, i.e. November 2022 to May 2023.

2.2.2 Identification of water sources, sanitation and hygiene facilities

Existing scientific literature on cholera transmission pathways was reviewed to establish a theoretical framework and inform the design of the questionnaire. This included studies on the role of contaminated water sources, poor sanitation and hygiene infrastructure in spreading the disease. As a next step, field observations and survey were carried out in the different sections of Hammanskraal to determine the source of drinking water, available sanitation and hygiene facilities in the area. The distribution, characteristics and uses of water sources were described. Data were collected to establish the practices of water collection, distribution, utilisation, handling and storage, as well as waste disposal, sanitation and hygiene. The eighteen participants were identified through referrals and selected according to their residential status. Furthermore, face-to-face interviews were conducted with the plant personnel with knowledge of the water supply and distribution in the area.

The structured questionnaire was used as an instrument to collect the following information:

- Water Practices/Services
  - Type of water source
  - Method used to fetch water from the source
  - Duration of water storage at home
  - Method used to clean water storage container
  - Treatment of stored water
  - Water use per source
- Sanitation Options and Personal Hygiene
  - Type of toilet used
  - Hand washing facilities

Water source coordinates were recorded using the GPS software.

2.2.3 Risk mapping

Jones, Bouzid, Few, Hunter & Lake (2020) developed a health impact pathway and causal process diagram (refer to **Appendix A** attached) that provides an explanation of how climate change dynamics (e.g. extreme weather conditions) may affect cholera risk in vulnerable communities through WASH. The risk factors pertaining to cholera transmission were mapped through the lens of the causal process diagram developed by Jones et al. (2020). Within the diagram, the relationship between WASH factors and cholera transmission is highlighted. The various components of the WASH supply chain were analysed to identify potential points of contamination and assess the risk of cholera transmission. The factors were categorised as water treatment, water source, sanitation, hand hygiene and water storage.

Each identified risk was subjected to a risk rating exercise based on the likelihood of occurrence and severity of impact as per ISO 31000 guidelines for risk management. The risk register provides guidance on areas for prioritisation as they relate to the implementation of control measures and focus areas for further investigation or research. A risk rating categorisation matrix to be used is presented in Table 1 below:

Table 1: Risk Categorisation Matrix

Risk rating categorisation			Impact/Severity of Consequence				
			Insignificant	Minor	Moderate	Major	Catastrophic
			1	2	3	4	5
Probability/ Likelihood	Almost certain	5	5	10	15	20	25
	Likely	4	4	8	12	16	20
	Moderately likely	3	3	6	9	12	15
	Unlikely	2	2	4	6	8	10
	Rare	1	1	2	3	4	5

Risk Rating	Range
Low	0-9
Medium	10 - 15
High	> 15

CHAPTER 3: RESULTS AND DISCUSSION

3.1. METEOROLOGICAL DATA AND ENVIRONMENTAL CONDITIONS

The correlation between climate conditions and the spread of cholera disease has also been studied by several researchers and studies found that Air temperature, rainfall and extreme weather conditions such as drought and floods all have an impact on the spread of the cholera disease (Constantin de Magny et al.,2008; Jutla et al., 2013); Rainfall events can contribute to cholera disease outbreaks as runoff may erode contaminated wastes into the fresh water resources, which may also lead to rapid transportation of nutrients into water resources. The presence of these nutrients could, in turn, cause an increase in host organisms such as algae and water Hyacinths in the water resources, thereby creating a suitable environment for the multiplication of the *V. cholerae* bacteria.

Extreme weather events such as floods and droughts also play a critical role in the spread of the bacteria, floods can lead to damage of the water and sanitation infrastructure and these are critical in the control of the disease. Therefore, damage to this infrastructure increases the chances of disease spread. On the other hand, drought results in low levels of water in the resources, thereby increasing conductivity or concentration of dissolved salts in the water and these conditions create a suitable environment for the survival of the bacteria. Moreover, the reduced availability of clean drinking water may lead to individuals seeking alternative sources of water and may result in the use of unsafe drinking water.

The rainfall and air temperature data presented below, was obtained from the Wonderboom weather monitoring station located approximately 18 km upstream of the Hammanskraal region.

3.1.1 Rainfall

Figure 2 below illustrates the rainfall patterns for the assessment period as recorded daily at the Wonderboom station. Most rainfall events occurred during the months of November, December, February and April, consistent with the summer season rainfall patterns in the Gauteng province over the same period. Over the assessment period, rainfall in the Hammanskraal region was estimated to have been less than 30 mm per event, with the 8th of February recording the highest total of 75.8 mm.

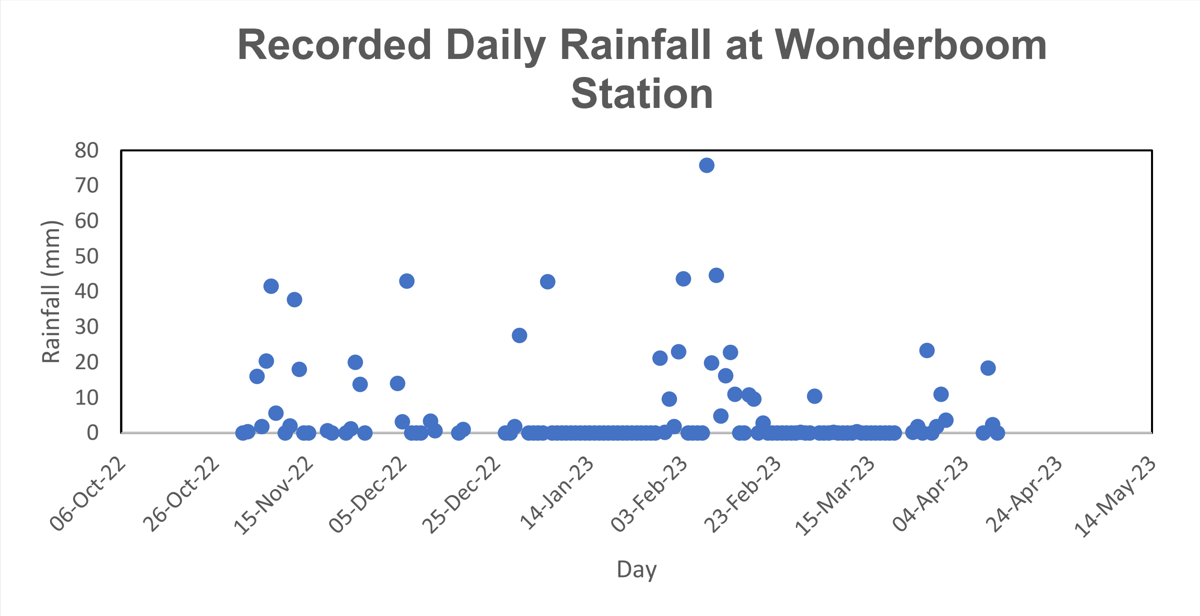

Figure 2: Daily Rainfall as recorded at Wonderboom Weather Monitoring Station

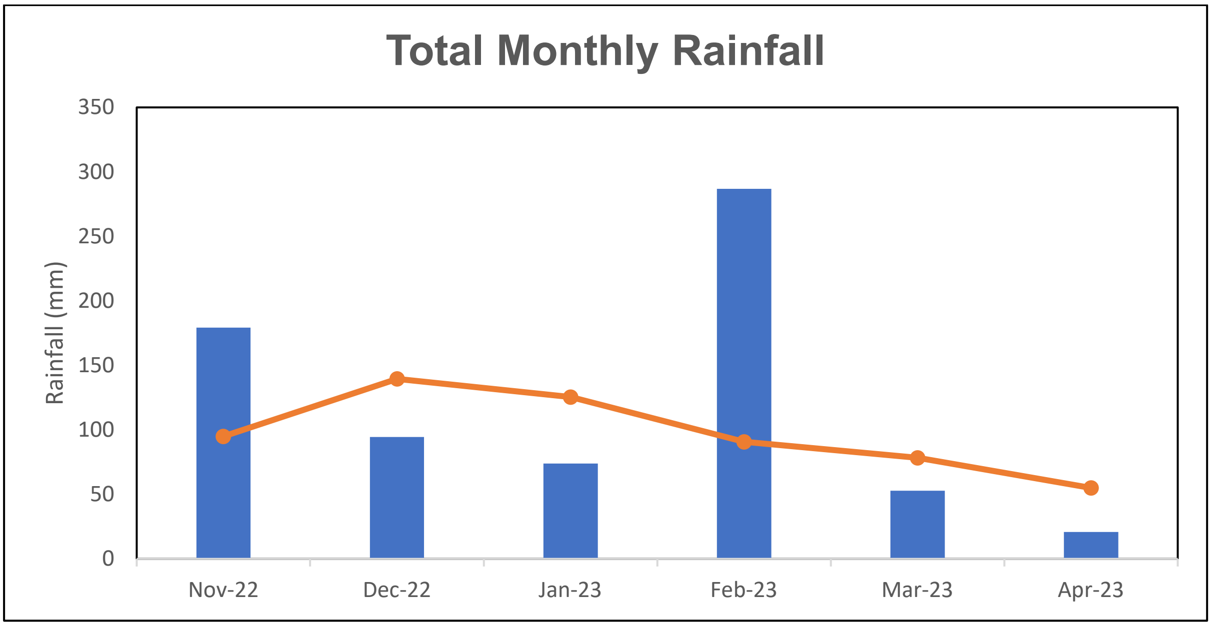

Figure 3: Total Monthly Rainfall as recorded at Wonderboom Weather Station

The area receives approximately 331 mm of rainfall on average, this is below the 464 mm average annual for South Africa and 1000 mm global average annual rainfall. However, for the period November 2022 to April 2023, the area received a total rainfall of 708 mm indicating above-average rainfall in the area.

In terms of total monthly rainfall, December, January, March and April 2023 received below-average rainfall per month as illustrated in Figure 3 above. Only November 2022 and February 2023 saw monthly totals that were above average, with February 2023 experiencing almost threefold the monthly average rainfall. This implies a lag of nearly three months between the peak rainfall in February and the first reported cholera cases in May 2023. This delay can be attributed to the incubation period of the bacteria, as well as the time it takes for affected individuals to come into contact with contaminated water and subsequently develop symptoms of cholera. Moreover, the possibility of initial cases of cholera going undetected or unreported for some time due to various factors such as lack of awareness among the affected community, cannot be ruled out. Considering the above, the relationship between time series for cholera and rainfall anomalies in the Hammanskraal region should be analysed to gain insight into any potential correlations. This information can be valuable for policymakers in designing appropriate interventions and preparedness strategies to mitigate the impact of cholera outbreaks.

While peak rainfall can provide favourable conditions for the spread of cholera, it Is important to consider other factors such as sanitation, access to clean water and hygiene practices in determining the risk and occurrence of cholera outbreaks.

3.1.2 Temperature

The air temperature range of 19°C to 28°C is optimal for the survival and proliferation of *Vibrio cholerae*, as indicated in section 3.1 above. During the assessment period, air temperature fell within this range 98% of the time.

It is worth noting that just four days in total (in the months of November 2022 and May 2023) recorded temperatures were below the ideal growth range. Although the presence of *vibrio cholerae* cannot be determined by temperature alone, the reported temperature throughout the assessment period suggests that if *Vibrio cholerae* was already present in the area, the air temperature was favourable for the bacteria's growth.

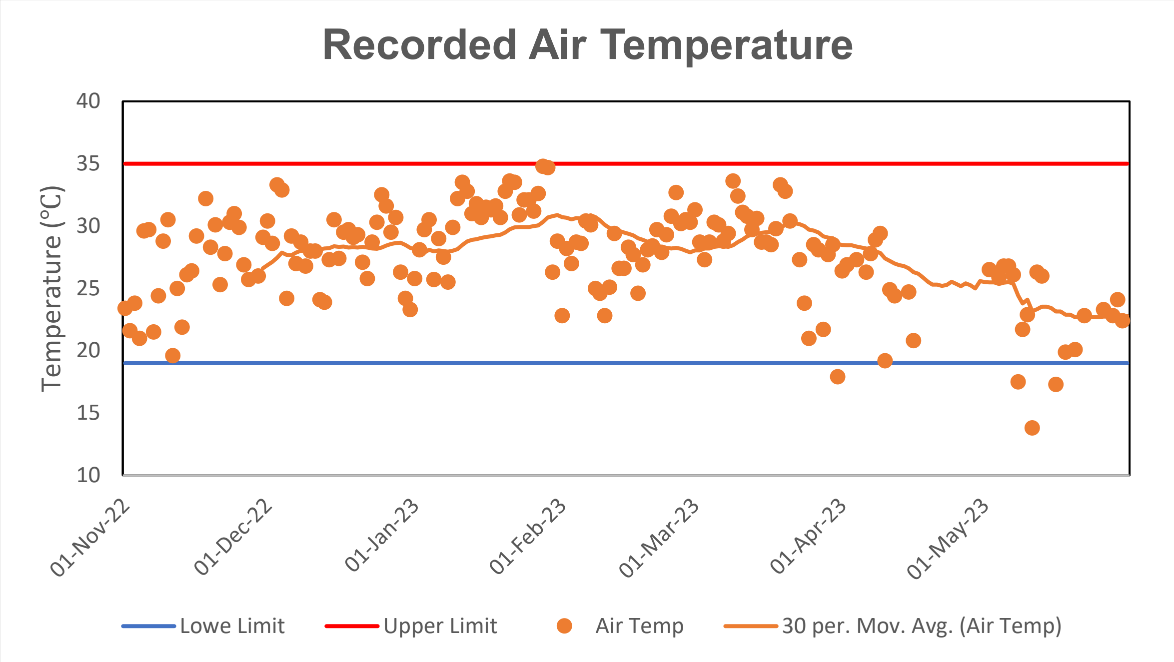

Figure 4: Recorded Air Temperatures

A surface water temperature range of 20°C to 45°C is conducive for vibrio cholerae to thrive. However, a paucity of information exists on the surface water temperatures in the Hammanskraal region. Such information is key to determine the existence of environmental conditions that could be conducive for the survival and growth of the *vibrio cholerae*.

There is a direct correlation between air and surface water temperatures. According to Morril et al., (2001), with every 1°C increase in air temperature, surface water temperature increases by between 0.6°C and 0.8°C. It is for this reason that surface water temperatures were estimated based on the 0.7°C temperature average for every 1°C increase in air temperature and the results are presented below.

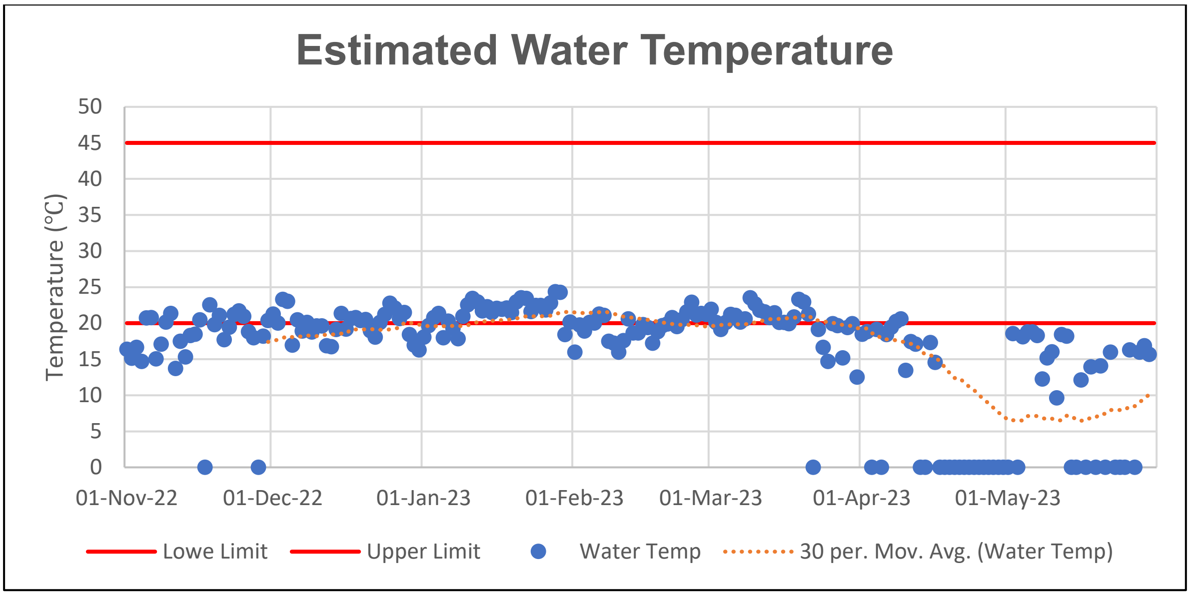

Figure 5: Estimated water temperature

The data, as presented in the Figure 5 above, indicates that if the relationship as posited by Morril (2001) holds true for this area, then the surface water temperature was mostly within the favourable temperature range. Apart from May, which dropped below the favourable range, the monthly averages from November 2022 to April 2023 were within the favourable temperature for *V. cholerae* to survive and thrive.

3.1.3 Environmental condition

3.1.3.1 Electrical conductivity

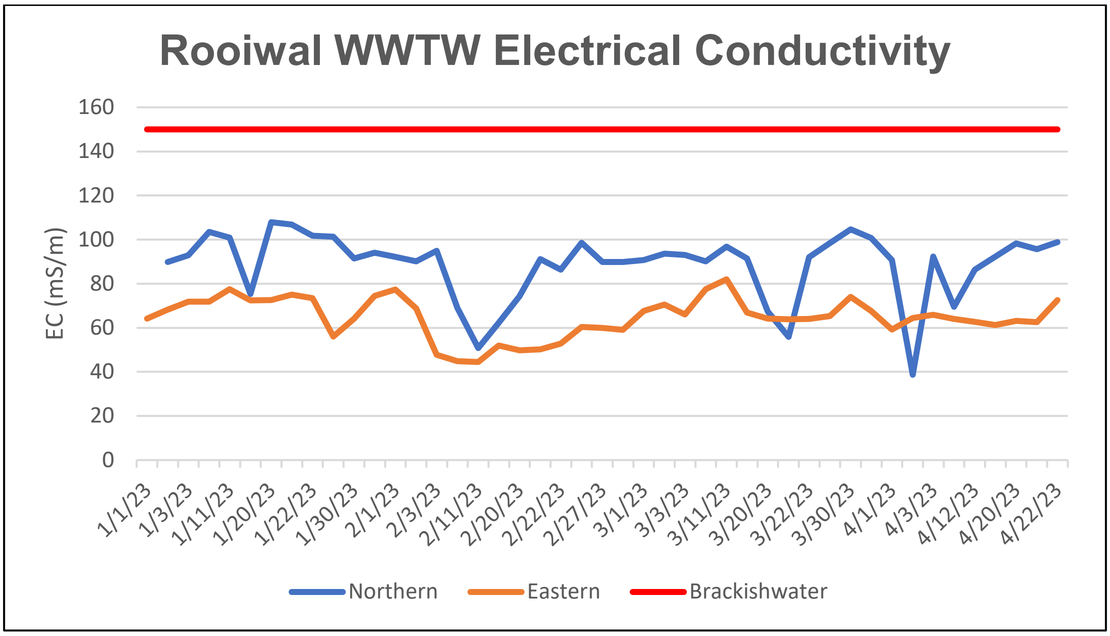

Figure 6: Electrical Conductivity Compliance for Rooiwal WWTW

The *vibrio cholerae* bacteria thrive in brackish water, which has EC values exceeding 150 mS/m. As depicted in Figure 6 above, electrical conductivity concentrations in the effluent from the Rooiwal WWTW were consistently below 150 mS/m, indicating that the water would not be suitable for the survival of the bacteria. It is important to note that the bacteria have been discovered in various freshwater resources before, including rivers and lakes, therefore a low EC value does not necessarily imply that the water is free of the vibrio cholerae bacteria.

3.1.3.2 pH

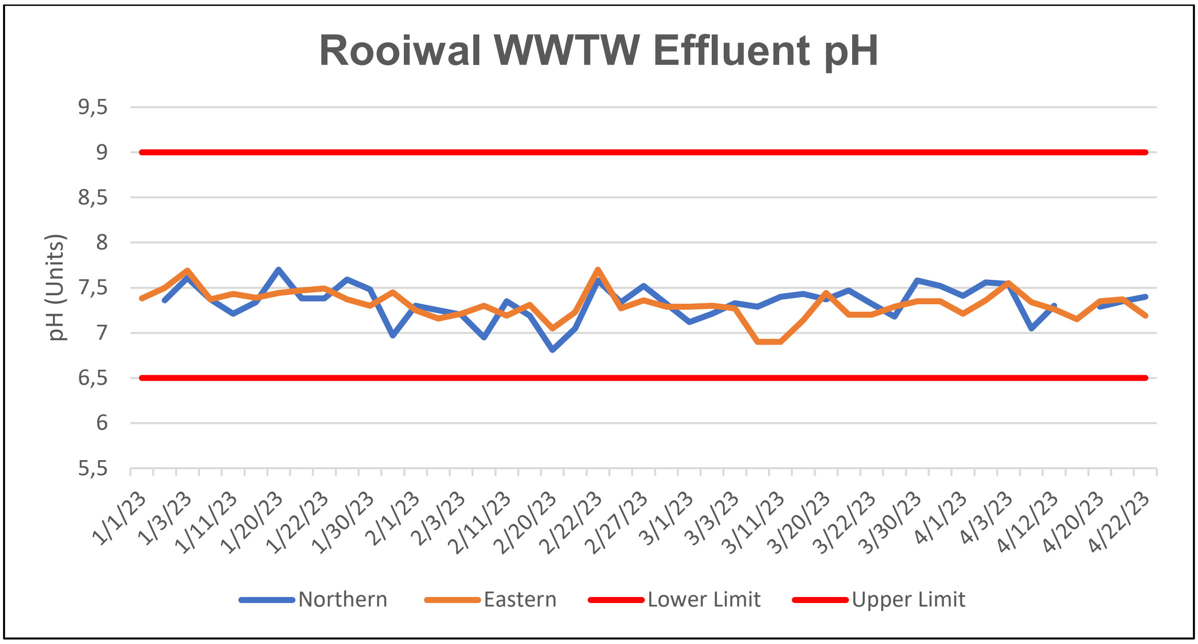

Figure 7: pH compliance of the Rooiwal WWTW Effluent

The results show that the effluent pH for both modules at Rooiwal WWTW was within the 6.5 to 9 range. Although the results complied with the DWS special limits for pH, these conditions also provide a conducive environment for growth of vibrio cholerae bacteria. Therefore, if the bacteria are present in the wastewater, pH of the effluent water would be suitable for the survival and growth of the bacteria.

3.1.3.3 Faecal Coliforms

The results obtained for the period January to April 2023 show that the Rooiwal WWTW has consistently failed to meet the discharge limit for microbiological parameters, achieving 0% compliance for all four months (Table 2 below). Although the indicator organism used at Rooiwal WWTW is faecal coliform, the continued non-compliance indicates inadequate disinfection at the plant. Hence, the plant discharged effluent which still contained high concentrations of microbiological contaminants.

Table 2: Faecal coliform compliance for the Rooiwal WWTW

ate	No of samples	No of complying samples	% Compliance achieved	% Compliance Required
Rooiwal Eastern				
Jan-23	12,00	0,00	0%	≥95%
Feb-23	12,00	0,00	0%	≥95%
Mar-23	12,00	0,00	0%	≥95%
Apr-23	9,00	0,00	0%	≥95%
Rooiwal Northern				
Jan-23	11,00	0,00	0%	≥95%
Feb-23	12,00	0,00	0%	≥95%
Mar-23	12,00	0,00	0%	≥95%
Apr-23	8,00	0,00	0%	≥95%
Summary	**88**	**0,00**	**0%**	**≥95%**

Vibrio cholerae is also a bacterium that is inactivated or killed using chlorine as a disinfectant in wastewater treatment. Therefore, the presence of other indicator microorganisms such as Faecal coliform may also indicate that if vibrio cholerae was present in the wastewater, the treatment process at Rooiwal WWTW would be inadequate to remove it. Elevated levels of microbiological contaminants present a serious health risk to the downstream users who rely on the surface water for recreational and agricultural uses.

3.1.3.4 Presence of algae and Hyacinths in raw water sources

The majority of Hammanskraal sections receive drinking water from Temba WTW while some areas receive drinking water from Magalies water Klipdrift WTW. Temba WTW and Klipdrift WTW abstract raw water from the Leeukraal dam in the Apies River and directly from the Pienaars river respectively. Blue-green algae (Cyanobacteria) and water hyacinths have been shown to be good carriers of *Vibrio cholerae* bacteria (Islam et al., 2004). As observed during the inspection of the raw water sources on the 7th of June 2023, the presence of excessive levels of blue-green algae in both the Pienaars river and the Leeukraal dam was evident (Figure 8).

Figure 8: Blue-Green Algae as observed at Pienaar River and Leeukraal Dam

Although the water hyacinth was not observed during the inspection of the Pienaar River, the Roodeplaat Dam which is upstream of the Klipdrift WTW is known to be characterised by excessive water hyacinths growth. It is therefore plausible for traces of hyacinth to find their way to the Klipdrift WTW abstraction point. The Leeukraal dam's inspection on the other hand, an abstraction point of the Temba WTW, revealed the presence of both water hyacinths growth and blue-green algae. As it has been demonstrated that the presence of cyanobacteria (i.e. blue-green algae) and water hyacinths correlates with the proliferation of vibrio cholerae, the two WTW should have the necessary technology in place to treat raw water effectively and, as a result, minimise the risk of cholera transmission through the consumption of drinking water from these WTW.

In lieu of the above, the environmental and climate conditions during the assessed period were mostly suitable for the survival of *Vibrio cholerae*, suggesting that if the bacteria were present in the area, particularly in the Apies River, its growth and transmission could have been promoted by the existing conditions.

3.1.4 Waste Management and sewer spillages

Poor sanitation facilities are commonly associated with the transmission of cholera within communities (Griffith, 2006). Intrinsically, it is crucial to promptly contain and address raw sewage spillages which can potentially contaminate nearby water sources, facilitating the introduction of bacteria into the water. Furthermore, individuals who come into contact with these contaminated water sources during recreational or traditional activities may be at higher risk of contracting the disease.

Illegal dumping sites, on the other hand, can serve as reservoirs for bacteria due to the presence of items such as soiled diapers and vegetable remnants. In the event of direct contact with these items, individuals may become infected with the bacteria if it is present in the waste. Furthermore, during periods of rainfall, the bacteria can be transported into rivers through runoff from illegal dumping sites, thereby increasing the risk of contamination. Recently, a physical examination was conducted in specific areas of Hammanskraal to evaluate the state of sewer spillages and waste management.

During the site visit, the team noted with great concern the prevalence of illegal dumping sites in the area, some near the river. Illegal dumping sites play a significant role in the transmission of cholera Illegal dumping sites as they often contain hazardous waste and pollutants that can leach into the surrounding environment, including the river. Additionally, flies and other vectors attracted to the dump sites can carry the bacteria from the contaminated waste to nearby food or water sources, further increasing the risk of cholera transmission (Fotedar, 2001). Therefore, addressing and preventing illegal dumping sites is crucial in reducing the spread of cholera and other waterborne diseases.

Figure 9: Illegal Dumping site in the Stinkwater Area

To minimise the risk of cholera transmission, a clean-up drive was embarked upon as shown in Figure 10 below. These initiatives, if carried out regularly with the involvement of the community are crucial in combating illegal dumping by fostering a sense of ownership and responsibility towards maintaining a clean and healthy environment.

Figure 10: Clean-up drive in the vicinity of Apies River

Sewage overflowing from manholes (Figure 11), as observed during the site visit, introduces a high concentration of pathogens, further increasing the risk of cholera transmission. The combination of illegal dumping sites and sewage creates an ideal breeding ground for disease-causing organisms and emphasizes the urgent need for effective measures to address and prevent contamination to protect public health.

Figure 11: Overflowing sewage manhole

In the long term, should the issue of illegal dumping sites and sewage be left unresolved, it can lead to a worsening public health crisis and environmental degradation. It is critical for the City of Tshwane to take swift action to prevent further contamination, implement proper waste management systems and educate the community about the importance of preserving the cleanliness and health of their environment.

3.2 WATER SOURCES, SANITATION AND HYGIENE (WASH) FACILITIES

Hammanskraal area falls under the jurisdiction of the city of Tshwane Metropolitan Municipality which has a water services authority status. As a Water Services Authority, City of Tshwane municipality has the executive authority and the right to administer water services as authorized in terms of Section 84(1)b and Section 84(1)d of the Municipal Structures Act (Act No. 117 of 1998). As such, the Municipality is therefore obliged to meet the requirements of Section 11(1) of the Water Services Act (Act No.108 of 1997) which emphasizes the duty to ensure efficient water and sanitation services.

Hammanskraal area consists of multiple types of settlements which receive varied levels of water and sanitation services. The types of settlement in the area include:

- **Informal settlements:** A significant portion of these settlements lack access to water and sanitation services. While small sections do have access to water infrastructure and flush toilets, the service is not reliable. Consequently, most of these areas depend on water delivered by tankers and stored in communal tanks. The community then collects water using polycan drums and buckets.

  This situation poses several challenges for the residents of these informal settlements:

  - The reliance on water sourced from tankers and communal storage tanks may lead to limited access to and availability of clean water. This can result in difficulties in meeting basic hygiene needs such as washing hands and maintaining cleanliness in households.

  - Moreover, the use of polycan drums and buckets as water collection methods may not be the most efficient or sanitary solution. These containers may not be properly cleaned or maintained, increasing the risk of contamination and the spread of waterborne diseases.

  To address these challenges, it is important to prioritise the provision of adequate water and sanitation services to these areas which can include ensuring regular and reliable water supply and improving sanitation facilities.

- **Rural settlements:** In most rural parts of Hammanskraal, there is a lack of provision for running water. Consequently, these areas rely upon the water tankers supplied by the City of Tshwane municipality as an alternative means of fulfilling their water requirements. However, it should be noted that a considerable proportion of households in these areas have taken an initiative to drill boreholes within their premises, which enables them to primarily depend on groundwater as a source of water supply.

It is crucial to assess the quality of groundwater before consuming it, as Baloyi (2019) highlights that its quality can vary greatly within a village, ranging from safe to highly detrimental. Therefore, it is not recommended to consume groundwater without first determining its quality, as emphasized by Conrad & Murray (2019). Regular testing and analysis are essential to ensure the safety of drinking water, especially in rural areas where groundwater is the main source of water supply. The community should be educated about the potential risks while safe consumption practices are promoted.

In terms of sanitation services, most households in these areas rely on pit latrines, although a small number have installed septic tanks with flush toilets. However, in the case of households with septic tanks, the wash basins are typically located inside the main house, which means there is no immediate access to the facilities after using the outdoor toilets. This lack of convenient access to hygiene facilities, can pose challenges for promoting hygiene practices. It is important to ensure that proper disposal of waste especially from the septic tanks is maintained to prevent contamination of groundwater and surface water sources.

- **RDP sections:** The social housing sections of Hammanskraal are a significant portion of the area. They currently receive water through standpipes from the Temba WTW. However, the water supply is not always adequate, so water tankers are used to supplement the supply. These tankers source water from the Rand Water pipeline and deliver it once a week to a communal tank. The community then collects water using polycan drums and buckets. While some residents use tap water for various purposes other than drinking, there are still members of the community who rely solely on tap water for all domestic applications including drinking. This highlights the importance of ensuring reliable and accessible water supply in these areas.

  Regarding sanitation and hygiene facilities, the RDP sections have outdoor flush toilets within the premise. These toilets are also fitted with wash basins mounted outside. However, many basins have become detached from the walls, leaving only the taps functioning. Additionally, many of the houses have additional rooms in the yards that are typically rented out and share the same toilets as the main households.

- **Township:** The township sections also receive water from the Temba WTW and have running water in their houses supplemented by the weekly deliveries from the water tankers, Like the RDP section, most residents use water from the Temba WTW for all household activities other than drinking and rely on water tankers and commercially available bottled water for drinking purposes. Others still rely on the water from the Temba WTW for all domestic purposes.

In the Township area of Hammanskraal, there are both indoor and outdoor flush toilets available. The indoor toilets are equipped with wash basins that are conveniently located for easy access to promote hand washing.

A summary of the water sources, sanitation technology and hygiene practices for the various settlements in the Hammanskraal area is presented in Table 3 below:

Table 3: Summary of the water sources, sanitation and hygiene facilities used in the study area

Type of settlement	Water source	Water storage	Sanitation Technology	Hygiene practices
Township	>Temba WTW. >Tankers from Rand Water pipeline >Bottled water from retail stores	Use directly from tap without storage Buckets & Polycan Drums 'JoJo' tanks for emergency	>Flush toilets inside the main house >Outside Flush toilets for outside rooms	Wash Basin in toilet room for the main dwelling
RDP	>Temba WTW. >Tankers from Rand Water pipeline >Bottled water from retail stores	Use directly from tap without storage Buckets & Polycan Drums 'JoJo' tanks for emergency	Flush toilets outside dwelling	>Wash Basin mounted outside toilet wall. *Most basins have become detached and no longer available*
Informal	>No running water (Mainly) >Klipdrift WTW >Tankers from Rand Water pipeline >Bottled water from retail stores	>Directly from the tap (Limited) >JoJo tanks >Buckets >Polycan Drums	Flush toilets outside dwelling (Limited) Pit latrine Chemical toilets (Snake Park area)	Wash Basin mounted outside toilet wall No hand washing facilities for most households
Rural	>Running water from Rand Water (Limited) >Groundwater through private boreholes >Tankers from Rand water pipeline	Directly from the tap (Limited) 'JoJo" tanks Buckets Polycan Drums	Pit latrine Flush toilets inside dwelling connected to septic tank (Limited)	No wash basins close to toilets Indoor Wash basins (limited)

The WASH facilities in the study area as observed during the site visit are visually presented below:

Water sources and storage facilities

Sanitation and Hygiene facilities

3.3 WATER SUPPLY CHAIN RISK MAPPING

Observations from the site visits including the water course inspections, interviews, and water quality data were used as primary information for conducting the risk identification process along the water supply value chain for the Hammanskraal area. The identified risks were allocated/grouped according to the risk factor (Water source, water treatment, water storage, sanitation and hygiene facilities) under which they belong, each risk was then evaluated and based on the likelihood of occurrence and impact, a risk rating was allocated for each risk. Control measures observed during site visits were also documented and the proposed additional measures are also provided. It is worth noting that the Temba WTW does not have a Water Safety Plan in place which serves as a guideline for addressing any potential risks that may result in poor-quality water. The findings from the risk assessment process are presented in the Table 4 below.

Table 4: Risk Assessment Findings

Risk Category	Risk No	Risk Identified	Hazard Root Cause	Likeli-hood	Consequence	Risk Rating	Existing control Measures	Additional Control Measures required
WATER SOURCE								
Bulk WTW	1	Presence of high concentrations of pathogens in the Apies River and Leeukraal Dam due to poor sewage effluent quality from Rooiwal WWTW	Operation & Maintenance	5. Once per day	5. Public Health Impact	25	Disinfection is in place at Rooiwal WWTW. However, it is inadequate as microbiological results have consistently exceeded the DWS limits.	❖ Improve Rooiwal WWTW treatment processes and strengthen sewage infrastructure ❖ Conduct regular monitoring and testing of both Rooiwal WWTW effluent and Apies River to identify contamination and take appropriate action.
Bulk WTW	2.	Eutrophic conditions in the Apies and Pienaars Rivers leading to the presence of algae and Hyacinth which act as carriers for vibrio cholerae	Poor effluent quality from upstream WWTW	5. Once per day	5. Public Health Impact	25	Temba and Klipdrift WTW designs include Ozone dosing & dissolved air floatation unit and pre-chlorination respectively for the removal of algae laden waters. However, lack of maintenance of *the* system (especially at Temba WTW) renders them less effective.	❖ Pre-treatment equipment maintenance should be prioritised. ❖ Adopt a risk-based approach by developing and implementing wastewater risk abatement plan (W_2RAP) that takes into consideration the findings and recommendations of risk management tools such as process audit, condition assessment report, etc.
Borehole/Wells	3	Risk of contamination of aquifers in the Stinkwater area from illegal dumping sites.	Management	3. Once per month	5. Public Health Impact	15	None.	City of Tshwane to implement bylaws that stipulates the minimum distance requirements between pit latrines and boreholes. Land use management should be prioritised.

Water tankers	4	Risk of contamination due to poor tanker management and inadequate monitoring protocols.	Management	5. Once per day	5. Public Health Impact	25	Ineffective Contract Performance management in place.	Implement contract performance management with tracking and regular inspection.
Water tankers	5	Risk of water contamination due to lack of quality monitoring of the water in tankers.	Management	5. Once per day	5. Public Health Impact	25	Infrequent water quality monitoring is undertaken	Develop and implement monitoring programmes for tankers.
Bottled Water	6	Risk of bottled water contamination due to lack of regular quality monitoring	Management	2. Once per year	5. Public Health Impact	10	None.	Municipal bylaws to include requirements for regular water quality testing for bottling companies.
		Risk of contamination of water resources due to sewer spillages runoff to the river	Maintenance	4. Once per week	4. Regulatory impact	16	Maintenance team is available to attend to reported spillages. However long turnaround times result in spillages continuing for an extended period.	City of Tshwane to improve their response times and ensure that sewer spillages are attended to and resolved within 24 hours from the time of reporting.

WATER TREATMENT								
WTW	7	Lack of pre-treatment due to the unavailability of the ozone dosing equipment	Maintenance	5. Once per day	2. Compliance Impact	10	None at Temba WTW - ozone dosing not functional. Pre-chlorination is achieved at Klipdrift WTW	Refurbish the ozone system at Temba WTW.
WTW	8	Risk of inadequate chlorination due to poor chemical treatment	Design/Planning	5. Once per day	5. Public Health Impact		None at Temba WTW. Water safety plan in place at Klipdrift WTW.	Develop and implement Water Safety Plan
WTW	9	Risk of inadequate disinfection in the final water due to long supply chain processes	Poor management	3. Once per month	5. Public Health Impact	15	Term contracts for the supply of chemicals in place	None required
Household Treatment	10	Failure of residents to boil water of adverse quality due to frequency of load shedding.	Ignorance and lack of awareness	5. Once per day	5. Public Health Impact	25	Boil water notices are issued regularly to the members of the public.	Conduct awareness campaigns about the importance of boiling water especially during an outbreak

WATER STORAGE								
Communal Tank	11	Risk of contamination and cholera transmission due to lack of communal tank regular maintenance	Management	3. Once per month	5. Public Health Impact	15	Communal tanks are kept closed to reduce risk of contamination	Develop and implement a cleaning program for each communal tank
Household Tank	12	Risk of contamination and cholera transmission due to extended storage of municipal water in the domestic storage tank	Intermittent bulk water supply	3. Once per month	5. Public Health Impact	15	None in place	Educate the community about the risks of long water storage periods. Ensure continued supply of potable water to reduce reliance on household tanks
Small Household Container	13	Increased risk of contamination and cholera transmission due to the use of wide-mouthed containers	Lack of awareness	4. Once per week	5. Public Health Impact	20	None in place	Educate community on the risks of using wide-mouthed containers and the benefits of using narrow mouthed containers

SANITATION								
Flushing toilets	14	Risk of cholera transmission due to inadequate shared flushing toilet maintenance	Lack of household maintenance	3. Once per month	5. Public Health Impact	15	Cleaning of the toilets is undertaken	Educate community on the importance of regular toilet cleaning, especially if shared between families.
Pit Latrines	15	Risk of bacteriological ground water contamination due to proximity of pit latrines/septic tanks to aquifers.	Lack of awareness	2. Once per year	5. Public Health Impact	10	Residents are required to register their private Boreholes with the local authority.	City of Tshwane should implement bylaws that stipulates the minimum distance requirements between pit latrines and boreholes
HYGIENE								
Wash Basins	16	Risk of less frequent handwashing due to the absence of wash basins and soap	Poor construction	4. Once per week	5. Public Health Impact	20	Wash basins available in some households	Provide sanitisers for use in areas where access to wash basins is limited. Educate community on the importance of regular hand washing.
Treated Water	17	Risk of not washing hands frequently due to reduced treated water availability	Lack of running water	2. Once per year	5. Public Health Impact	10	Clean water provided through tankers to augment supply	Increase frequency of tanker deliveries and promote alternative hygiene methods such as hand sanitiser.

CHAPTER 4: CONCLUSIONS & RECOMMENDATIONS

4.1 CONCLUSIONS

The main objective of this study is to document the historical meteorological data and environmental conditions in the Hammanskraal area; identify water sources in use and determine the adequacy of sanitation and hygiene facilities in the region while investigating potential environmental reservoirs of *Vibrio cholerae*, and factors that contribute to its persistence.

The climate and environmental conditions that existed during the November 2022 to May 2023 assessment period can be interpreted as follows:

- Air and water temperature were mostly within the conducive ranges for growth of vibrio cholerae
- Higher than normal rainfall in December 2022 and February 2023 may have contributed to the transportation of the bacteria to water resources. However, there was a lag of approximately three months between the peak rainfall in February and the first reported cases in May 2023 which can be attributed to the incubation period of the bacteria, as well as the time it takes for affected individuals to come into contact with contaminated water and subsequently develop symptoms of cholera.
- With the exception of EC, all the other WWTW effluent quality results assessed support a suitable environment for growth of the bacteria.

While peak rainfall can provide favourable conditions for the spread of cholera, it Is important to consider other factors such as sanitation, access to clean water and hygiene practices in determining the risk and occurrence of cholera outbreaks.

Due to the paucity of information on the surface water quality data, the wastewater treatment effluent data of plants upstream of WTW abstraction points were relied upon to provide an indication of the river health. In the case of the Temba WTW, the environmental conditions were found to be conducive for the survival and proliferation of *V. cholerae* in all parameters except electrical conductivity (EC). The presence of cyanobacteria and hyacinth in both the Apies and Pienaar rivers, considered to be good carriers of *V. cholerae*, further validates the potential persistence of the bacteria in the water source.

The primary water sources that were identified in the area include Temba WTW, Klipdrift WTW, Rand Water delivered through tankers, boreholes and hand-dug wells mostly concentrated in the Stinkwater area as well as the commercially available bottled water. The water provided from boreholes and wells was previously reported to be unsafe for consumption regarding microbial indicators.

The sanitation facilities that were identified include flush toilets, chemical toilets and pit latrines. It was noted that in some areas there was no running water to flush the shared toilet facilities due to the prevalence of intermittent water supply, pushing the affected residents to riskier alternatives. The provision of adequate water and sanitation services to these areas should be prioritised. The presence of illegal dumping sites and overflowing sewage manholes was noted as a cause for concern as it can lead to a worsening public health crisis and environmental degradation.

In the RDP houses, most of the wash basins that were previously installed outside the toilets have regrettably detached from the walls. The absence of running water, hygiene facilities and soap within the toilet area implies that most individuals in the affected areas seldom wash their hands with soap after using the toilet, leaving the community vulnerable to the risk of cholera transmission.

4.2 RECOMMENDATIONS

It is recommended that any potential correlations between time series for cholera and rainfall anomalies in the Hammanskraal region be analysed further over a longer period as it can be valuable for policymakers in designing appropriate interventions and preparedness strategies to mitigate the impact of cholera outbreaks.

It is of critical importance to conduct regular monitoring and testing of surface and groundwater to identify potential contamination and take appropriate action. Improvement of the Rooiwal WWTW treatment processes and sewage infrastructure should be prioritised to improve the health of the Apies River and Leeukraal Dam.

The City of Tshwane municipality should adopt a risk-based approach for both wastewater and water treatment systems to minimise the risk of outbreaks associated with waterborne diseases. Water source protection measures, which include regulating land use and water use should be fortified to safeguard the wellbeing of residents and the environment. It is critical for the municipality to implement proper waste management systems and educate the community about the importance of preserving the cleanliness and health of their environment.

The provision of adequate water and sanitation services to informal and rural settlements, which can include ensuring regular and reliable water supply and improving sanitation facilities should be strengthened. Similarly, convenient access to hygiene facilities and good hygiene practices should be promoted through community education and awareness to minimise their exposure to cholera.

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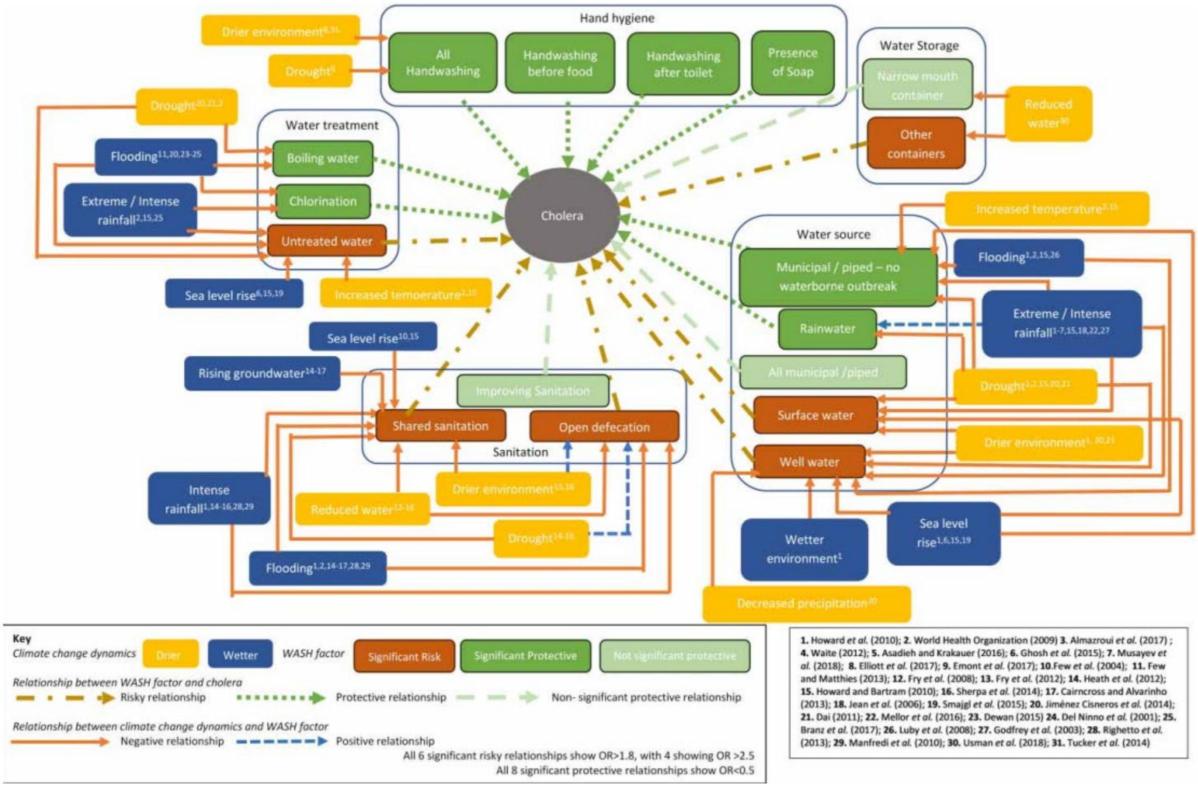
APPENDIX A: CAUSAL PROCESS DIAGRAM



APPENDIX B: SURVEY RESULTS

Risk Category	Characteristics	Stinkwater 1	Stinkwater 2	Kudube 1	Kudube 2	Kudube 3
Water Source	Rain	No	No	No	No	No
	Indoor tap	Yes	No	Yes	No	No
	River	No	No	No	No	No
	Private Borehole	Yes	No	No	No	No
	Communal tap (including tankers)	No	No	Yes	Yes	Yes
	Yard Tap	Yes	Yes	Yes	Yes	Yes
Water Treatment	Untreated	Yes	No	No	No	No
	Treated	No	Yes	Ye	Yes	Yes
	Boiling	No	No	No	Not always	Not always
Water use practices	What do you use the water for?	Drinking and all household uses	Drinking and all household uses	Drinking and all household uses	Drinking and all household uses	Drinking and all household uses
Water Storage	JoJo Tank	Yes	No	Yes	Yes	Yes
	Canister	No	No	No	No	No
	Bucket	No	Yes	Yes	Yes	Yes
	Other containers……………………	No	No	No	No	No
	How long do you store water before consumption?	Directly from the tank	7 days maximum	<3 days	<5 days	<5 days

Risk Category	Characteristics	Stinkwater 1	Stinkwater 2	Kudube 1	Kudube 2	Kudube 3
Sanitation Facilities	Pit Latrine	Yes	Yes	No	No	No
	Flushing toilet	No	No	Inside house	Inside yard	Inside yard
	Septic Tank	No	No	No	No	No
	Do you share a toilet with other households?	No	No	No	No	No
Hygiene Facilities	Wash basin	None	None	Inside bathroom	Outside the toilet	Outside the toilet
	Where do you keep your soap?	In the house	In the house	bathroom	In the house	In the house
	Distance of the wash basin from the toilet?	No wash basin	No wash basin	<1 m	<1 m	<1 m

Risk Category	Characteristics	Marokolong	Snake Park	Kanana 1	Kanana 2	Kanana 3
Water Source	Rain	No	No	No	No	No
	Indoor tap	No	No	No	No	No
	River	No	No	No	No	No
	Private Borehole	No	No	No	No	No
	Yard tap	Yes	No	No	No	No
	Communal tap (including tankers)	No	Yes	Yes	Yes	Yes
Water Treatment	Untreated	No	No	No	No	No
	Treated	Yes	No	Yes	Yes	Yes
	Boiling	No	No	No	No	No

Risk Category	Characteristics	Marokolong	Snake Park	Kanana 1	Kanana 2	Kanana 3
Water use practices	What do you use the water for?	Drinking and household uses	Drinking and household uses	Drinking and household uses	Drinking and household uses	Drinking and household uses
Water Storage	JoJo Tank	No	No	No	Yes	No
	Canister	No	No	No	No	No
	Bucket	Yes	Yes	Yes	Yes	Yes
	Other containers……………………	No	No	No	No	No
	How long do you store water before consumption?	<3 days	<7 days	<5 days	<5 days	<5 days
Sanitation Facilities	Pit Latrine	Yes	Chemical toilet	No	No	No
	Flushing toilet	No	No	Outside yard	Outside yard	Outside yard
	Septic Tank	No	No	No	No	No
	Do you share a toilet with other households?	No	Yes	No	No	No
Hygiene Facilities	Wash basin	None	None	Outside toilet	Damaged	Damaged
	Where do you keep your soap?	Kitchen	House	In the house	In the house	In the house
	Distance of the wash basin from the toilet?	>10 m	No wash basin	<1 m	<1 m	<1 m

Risk Category	Characteristics	Kanana 4	Ramotse 1	Ramotse 2	Sekampaneng	Dilopye
Water Source	Rain	No	No	No	No	No
	Indoor tap	Yes	Yes	No	No	No
	River	No	No	No	No	No
	Private Borehole	No	No	No	No	No
	Communal tap (including tankers)	Yes	No	No	No	Yes
	Yard tap	Yes	Yes	Yes	Yes	Yes
Water Treatment	Untreated	No	No	No	No	No
	Treated	Yes	Yes	Yes	Yes	Yes
	Boiling	Yes	No	No	Sometimes	No
Water use practices	What do you use the water for?	Drinking and household uses	All household uses	All household uses	Tankers- Drinking Tap: Household	All household uses
Water Storage	JoJo Tank	No	No	No	Yes	No
	Canister	No	No	No	No	No
	Bucket	Yes	No	No	Yes	Yes
	Other containers……………………	No	Direct from tap	Direct from tap	No	No
	How long do you store water before consumption?	<5 days	Immediately	Immediately	<5 days	<5 days
Sanitation Facilities	Pit Latrine	No	Yes	Yes	Yes	Yes
	Flushing toilet	Outside yard	Yes	Yes	No	No
	Septic Tank	No	Yes	Yes	No	No

Risk Category	Characteristics	Kanana 4	Ramotse 1	Ramotse 2	Sekampaneng	Dilopye
	Do you share a toilet with other households?	No	No	No	No	No
Hygiene Facilities	Wash basin	Damaged	In bathroom	In bathroom	None	None
	Where do you keep your soap?	In the house	bathroom	bathroom	In the house	In the house
	Distance of the wash basin from the toilet?	<1 m	<1 m	<1 m	N/A	N/A

Risk Category	Characteristics	Kanana informal	Kanana informal 2	Snakepark
Water Source	Rain	No	No	No
	Indoor tap	No	No	No
	River	No	No	No
	Private Borehole	No	No	No
	Yard tap	Yes	Yes	No
	Communal tap (including tankers)	Yes	Yes	Yes
Water Treatment	Untreated	No	No	No
	Treated	Yes	Yes	No
	Boiling	No	No	No
Water use practices	What do you use the water for?	All household uses	All household uses	Drinking and household uses
Water Storage	JoJo Tank	No	No	No
	Canister	No	No	No
	Bucket	Yes	No	Yes

Risk Category	Characteristics	Kanana informal	Kanana informal 2	Snakepark
	Other containers……………………	No	No	No
	How long do you store water before consumption?	<5 days	<5 days	<7 days
Sanitation Facilities	Pit Latrine	Yes	No	Chemical toilet
	Flushing toilet	Yes	Outside the house	No
	Septic Tank	No	No	No
	Do you share a toilet with other households?	Yes	Yes	Yes
Hygiene Facilities	Wash basin	Outside toilet	Outside toilet	No
	Where do you keep your soap?	In the house	N/A	House
	Distance of the wash basin from the toilet?	<1 m	<1 m	No wash basin