A WATER QUALITY-BASED PREDICTIVE TOOL FOR DISASTER MANAGEMENT OF WATERBORNE INFECTIONS DURING DROUGHT EVENTS

WORK PACKAGE 3: BACTERIOLOGICAL ASSESSMENT OF WATER SOURCES AND RETROSPECTIVE ANALYSIS OF DIARRHEAL PREVALENCE IN NELSON MANDELA BAY

Final Report to the
Water Research Commission

by

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- Overview of work packages (WRC report no. 3229/1/25)
- Work package 1: Integrated ecological assessment of vegetation, physico-chemical properties and schistosomiasis intermediate host snail distribution in freshwater bodies (WRC report no. 3229/2/25)
- Work package 2: Prevalence, associated risk factors and diagnostic biomarkers of schistosomiasis among school going children in Nelson Mandela Bay Municipality (WRC report no. 3229/3/25)
- Work package 4: Pre- and post-intervention assessment of an educational program on hygiene knowledge and practices among municipal waste and sanitation workers in Nelson Mandela Bay (WRC report no. 3229/5/25)

EXECUTIVE SUMMARY

BACKGROUND

A few studies have linked water quality and the prevalence of diarrhoeal cases in developing countries. It is estimated that 94% of the diarrhoeal burden of disease is attributed to the environment and is associated with risk factors such as unsafe drinking water and poor sanitation and hygiene. Globally, the highest burden of diarrheal disease occurs in sub-Saharan Africa, with particularly high burdens of childhood diarrhoea. Despite this, there are few studies that have examined the links between environmental factors and diarrheal diseases in sub-Saharan Africa. Water that is microbiologically contaminated may result in the transmission of pathogens, resulting in an increased health risk of diarrhoeal diseases. The bacterial pathogens Vibrio cholerae, *Salmonella* and *Shigella* are amongst those microorganisms that cause severe waterborne disease in developing regions. *Vibrio cholerae*, *Salmonella* and *Shigella* bacteria have been isolated from the final effluent of South African wastewater treatment facilities and their receiving water bodies.

AIMS

The aim of the project – work package 3 (WP3):

1. Assess the bacteriological quality of water sources as well as the retrospective prevalence of diarrhoea in the study area.

METHODOLOGY

Kariega, formerly known as Uitenhage, is a town in South Africa's Eastern Cape Province (-33.7479; 25.4124), situated 30 km northwest of Gqeberha, within the Nelson Mandela Bay Municipality alongside Despatch, Kwa Nobuhle, and neighbouring areas. This study focused on environmental water bodies in Kariega, including the Swartkops River (-33.768223; 25.381220), Willow Dam (-33.750817; 25.412898), and Strelitzia Dam (-33.753229; 25.426892). From June 2023 to April 2024, 52 water samples (40 from municipal supplies, 12 from environmental sources) were collected across seasons to assess dry and wet periods. Samples were analysed at the CSIR Water Centre (Pretoria) for total coliforms, *E. coli*, *Salmonella*, *Shigella*, *Vibrio cholerae*, and physicochemical parameters (pH, conductivity, total dissolved solids) using methods such as Colilert™-18 MPN for coliforms/*E. coli* and PCR assays targeting specific genes (*invA* for *Salmonella*, *ipaH* for *Shigella*, *ompW* and *ctxAB* for *V. cholerae*). Diarrheal prevalence data (pending from NICD/DHIS) and municipal water quality records will be correlated with microbial findings. Non-parametric statistical analyses (Spearman's correlation, Welch tests, ANOVA) were applied due to non-normal data distribution, aiming to link water quality variations to public health trends in the study period

RESULTS AND DISCUSSION

The water quality assessment in Kariega, which involved sampling 13 places (including taps, clinics, recreational areas, and riverine sites) spanning four seasons, indicated substantial contamination. 18% of tap water and 100% of environmental samples above Total Coliform standards, whilst 5% of tap water and all environmental samples surpassed *E. coli* thresholds, signifying faecal contamination due to deteriorating infrastructure, sewage, and agricultural runoff. While tap water exhibited no presence of *Salmonella*, ambient water revealed the presence of *Shigella* (8%) and *Vibrio cholerae* (33%), underscoring dangers for people relying on untreated sources. The physicochemical parameters of tap water (pH, conductivity, TDS) conformed to norms; nevertheless, environmental samples displayed heightened alkalinity, excessive conductivity (up to 1283 mS/m), and TDS (6305 mg/L), indicating contamination from industrial, agricultural, or geological origins. Health data linked these findings to recurrent cholera outbreaks (over 1,200 cases in 2023), elevated diarrhoeal disease mortality in children, and endemic Bilharzia (4 million annual cases), highlighting public health risks associated with insufficient sanitation, contaminated water access, and climate-related challenges, thereby necessitating urgent enhancements in infrastructure and treatment in accordance with WHO guidelines.

GENERAL

An understanding of health outcomes and their links to environmental exposure may lead to improvements in environmental and disease surveillance that will help to address public health problems.

CONCLUSIONS

The research reveals substantial deficiencies in health surveillance and water quality management in Kariega, South Africa. Although tap water adheres to safety regulations, ambient water sources are tainted with pathogens such as Shigella and V. cholerae, presenting risks of waterborne diseases. Elevated levels of electrical conductivity (EC) and total dissolved solids (TDS) in environmental water signify pollution resulting from anthropogenic activity. Essential recommendations encompass enhancing cleanliness, focused monitoring, community education, infrastructure improvements, and interdisciplinary research. Resolving these concerns is essential for public health resilience and is consistent with Sustainable Development Goals (SDG 6: Clean Water; SDG 3: Health Equity). The paper highlights the interconnected issues of health inequities, infrastructure deficiencies, and environmental degradation, advocating for WHO-aligned initiatives to reduce risks and attain sustainable development objectives.

RECOMMENDATIONS

By decentralising health reporting to district/municipal levels and providing clinicians with diagnostic instruments (e.g., cholera rapid-test kits) and training, it is imperative to address water quality and public health challenges. Enhancing surveillance systems is essential. Installation of water treatment infrastructure at communal and recreational locations, as well as remediation of high-risk sites (e.g., Swartkops River downstream), should be prioritised in targeted interventions. Longitudinal studies that establish a connection between Kariega-specific health data and water quality, as well as interdisciplinary investigations into under-reported diseases such as mercury toxicity, must be the emphasis of research. Policy initiatives should promote the inclusion of climate resilience in water security strategies and the allocation of funding to enhance laboratory capacity. The identification of pollution regions must be rigorous, and enhanced monitoring should be expanded to include seasonal pollutant trends and heavy metals. In order to implement public health measures, it is necessary to educate the community about water hazards, establish warning signs in high-risk recreational areas, and conduct awareness campaigns that advocate for safe water practices, such as boiling and filtration. The collective objective of these actions is to construct climate-resilient water systems, enhance health outcomes, and reduce contamination.

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ACRONYMS & ABBREVIATIONS

CSIR	Council for Scientific and Industrial Research
ctxAB	Cholera Toxin subunits A and B (gene markers for toxigenic *V. cholerae*
DHIS	District Health Information System
EIEC	Enteroinvasive *Escherichia coli*
MPN	Most Probable Number (microbiological method)
NHLS	National Health Laboratory Service
NICD	National Institute for Communicable Diseases
NMC	Notifiable Medical Conditions
ompW:	Outer Membrane Protein W (gene marker for *Vibrio cholerae*)
PCR	Polymerase Chain Reaction
Stats SA	Statistics South Africa
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization

CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

Diarrhoea can be caused by infections of bacterial, viral, and parasitic organisms, most of which are spread by faeces-contaminated water (WHO, 2017). The leading cause of death among children under five years of age in developing countries is diarrhoea (Kotloff et al., 2013). It is estimated that 1.7 billion cases of childhood diarrhoea occur annually, and diarrhoea is the leading cause of malnutrition in children under 5 years of age (WHO, 2017). Furthermore, as much as 60% of diarrhoea in low- and middle-income countries in 2016 may be the result of inadequate water, sanitation, and hygiene (WASH) (Prüss-Üstün et al., 2019). The percentage of children under the age of five in the Eastern Cape province of South Africa that died from diarrhoea and gastroenteritis (of presumed infectious origin) ranged from 19.7% in 2006, 21.7% in 2007, 24% in 2008 to 18.7% in 2009 (Stats SA, 2012). The Eastern Cape had the highest number of diarrhoeal deaths in 2017/2018, as well as the highest child diarrhoea case fatality rate in those aged under five (District Health Barometer, 2019).

Kariega (originally known as Uitenhage) is a town located in the Eastern Cape Province, which falls within the Nelson Mandela Bay Municipality. According to the 2011 General Household Survey, the population density of Uitenhage (Kariega) was 1376 persons/km^2 and 78.5% had access to piped water inside their dwelling (STATS SA, 2011). In February 2022, the Nelson Mandela Bay Municipality issued a warning as follows: “The Nelson Mandela Bay Municipality would like to inform residents that the latest tests have shown a deterioration in our water quality. The current drought facing the city, with the resultant low dam levels and fluctuating reservoir levels, is one of the major contributing factors”. Residents were advised to boil their tap water before drinking it. The contaminated drinking water was found to originate from the Grassridge temporary treatment works, which was one of the measures put in place to allow the city to receive water from sources other than dams due to the prolonged drought in the area (Ellis, 2022). There is significant evidence that climate change may alter the incidence of waterborne diseases and the incidence of diarrhoea (Levy et al., 2018). As this can cause a substantial effect on population health and the incidence of waterborne disease, the relationship between environmental factors and diarrheal disease should be examined.

1.2 PROJECT AIMS

The aim of the project:

1. To assess the bacteriological quality of water sources as well as the retrospective prevalence of diarrhoea in the study area.

1.3 SCOPE AND LIMITATIONS

A small number of studies conducted in South Africa have shown a link between the consumption of unsafe drinking water and diarrhoeal diseases (Oyekale, 2017; Edokpayi et al., 2018; Kapwata et al., 2018; Moropeng et al., 2018). However, little is known of the health problems associated with water use within the Kariega area. This study aims to address this knowledge gap by looking at the water quality of drinking water (and their raw water sources) and investigating potential links between water quality and diarrhoeal prevalence in the neglected study area of Kariega.

CHAPTER 2: METHODOLOGY

2.1 STUDY AREA

Kariega, formally known as Uitenhage, is a town in the Eastern Cape Province of South Africa. It is located at -33.7479; 25.4124 and is situated 30 km northwest of 3 Gqeberha. The town forms the Nelson Mandela Bay Municipality along with the neighbouring towns of Despatch and Kwa Nobuhle, the city of Gqeberha, and other nearby areas. Environmental water bodies (in the Kariega study area) that may be included in this study are: The Swartkops River (Cuyler St), located at -33.768223; 25.381220; Willow Dam (Graaff Reinet Rd), located at -33.750817; 25.412898, and Strelitzia Dam (Nemesia Rd), located at -33.753229; 25.426892.

2.2 SAMPLING

Water samples were collected and assessed over the various seasons (summer, autumn, winter, and spring) within the study area to cover dry and wet seasons. The goal was to collect 13 water samples per season: 10 from municipal water supply points and three from environmental water resources. This resulted in the sampling and analysis of 52 water samples in total. The samples were collected from June 2023 to April 2024 and analysed for various indicator organisms and enteric pathogens: total coliform bacteria, Escherichia coli, Salmonella sp., Shigella sp., and Vibrio cholerae. The samples were aseptically collected and transported on ice to the CSIR laboratory by means of a courier (DHL).

2.3 SAMPLE SIZE

In total, 52 water samples were collected and tested. Forty samples from treated water outlets (n=40) and twelve from environmental raw water sources (n=12).

2.4 ANALYSIS OF WATER SAMPLES

The water samples were analysed at the CSIR Water Centre's Microbiology Laboratory in Pretoria.

2.4.1 Total coliform bacteria and E. coli

Detection and quantification of total coliform bacteria and *E. coli* were done using the Colilert™ most probable number (MPN) method (IDEXX, USA). For this method, Colilert™-18 capsules (containing the defined proprietary substrate, IDEXXTM) were used to obtain results within 18 to 24 hours, and the results were enumerated using the Quanti-tray™ 2000 option. The trays were incubated at 35°C (for 18 - 24 hours) 4 and total coliform counts were read under visible light (yellow cells), while *E. coli* was read under UV light (fluorescent cells). Readings were converted to most probable number results using the IDEXX MPN Generator application.

2.4.2 Detection of Salmonella species and Shigella species

One hundred millilitres of water was filtered through 0.22 µm polycarbonate membrane filters. The filter membrane was incubated overnight in 100 ml buffered peptone water at 35°C. One millilitre of broth was collected from the overnight incubations and centrifuged at 13000 rpm for 2 minutes to pellet the cells. The

The supernatant was discarded, and the DNA was extracted from the concentrated cells using InstaGene™ Matrix (Biorad Technologies, USA). *Salmonella sp*. was detected using a real-time polymerase chain reaction (PCR) assay that targets the invA gene (Malorny et al., 2003). *Shigella* (virulent types) and/*or E. coli* EIEC were detected by real-time PCR targeting the ipaH (invasion plasmid antigen) gene (Theron et al., 2001).

2.4.3 Detection of Vibrio cholerae

One hundred millilitres of water was filtered through 0.22 µm polycarbonate membrane filters. The filter membrane was incubated overnight in 100 ml alkaline peptone water (adjusted to a pH of 8.4) at a temperature of 35°C. One millilitre of broth was collected from the overnight incubations and centrifuged at 13000 rpm for two minutes to pellet the cells. The supernatant was discarded, and the DNA extracted from the cells using InstaGene™ Matrix (Biorad Technologies, USA) following the manufacturer's protocol. For the detection of *Vibrio cholerae* (toxigenic and environmental strains), the gene coding for the Outer Membrane Protein (ompW) was targeted using real-time PCR (le Roux & van Blerk, 2011; Nandi et al., 2000). For toxigenic strains, the ctxAB genes were targeted in a real-time PCR amplifying a section of the cholera toxin A and B subunit (Goel et al., 2005; le Roux and van Blerk, 2011).

2.4.4 Physico-chemical parameters

The following physico-chemical parameters were measured in each sample: Electrical conductivity, total dissolved solids, and pH. Measurements were taken by the fieldworkers with a portable meter that utilises calibrated field probes. Analysis was performed (on an aliquot of each sample) within 24 hours of sample collection.

2.5 DATA COLLECTION

Diarrhoeal prevalence data Diarrhoeal case data (prevalence statistics) is still to be obtained from the National Institute for Communicable Diseases (NICD), which is the custodian of NHLS data, and the District Health Information System (DHIS). The dataset will only include information applicable to the study area (Kariega) and cover the same time period as planned for the water quality component (June 2023 to April 2024). Water quality data will also be useful, and the availability thereof from the local municipality will be investigated. 9.6

2.6 DATA ANALYSIS

The data was not normally distributed and therefore required a non-parametric statistical approach. Tests that were utilized include Spearman's rank correlation, Welch tests and one-way ANOVA analysis.

CHAPTER 3: RESULTS AND DISCUSSION

3.1 WATER QUALITY SAMPLING:

Water samples were collected from 13 locations in Kariega, encompassing community taps (Doornhoek), healthcare institutions (Middle Street Clinic, Park Centre Clinic), recreational areas (Jubilee Park Dam), and riverine settings (Swartkops River Upstream/Downstream). A total of 52 samples were analysed for pathogens and physicochemical qualities over the four seasons: Winter, Spring, Summer, and Autumn.

3.1.1

The data suggests that Kariega's water systems are contaminated with microbial organisms at alarming levels. Specifically, 18% of tap water samples and 100% of environmental water samples exceed the acceptable limits for Total Coliforms, while 5% of tap water and 100% of environmental water samples exceed the limits for *E. coli.* The Total Coliforms and *E. coli* detected in both environmental and potable water samples are presented in **Table 3.1.**

3.1.1.1 Total Coliforms

The general efficacy of water treatment is indicated by the total number of Coliforms. Intermittent breaches in treatment (e.g., pipe leakage, inadequate chlorination) or biofilm formation in distribution systems are suggested by the 18% non-compliance in potable water. The WHO recommends that the total coliforms in potable water be 0 CFU/100 mL. Potential entry points for microorganisms are indicated by their presence (WHO, 2017). South African National Standard (SANS 241:2015) is consistent with the World Health Organisation (WHO) in its requirement for the absence of Total Coliforms in treated water. The systemic challenges in ageing infrastructure or maintenance gaps, particularly in rural or informal settlements, are underscored by the 18% exceedance. In comparison to the environmental water, which exceeds the limits by 100%. Untreated sewage, agricultural runoff, and informal settlements lacking sanitation are all sources of pervasive faecal pollution that are reflected in universal contamination.

3.1.1.2 E. coli

A definitive indicator of faecal contamination is *E. coli*. If the tap water exceeds 5%, it is indicative of recent faecal ingress into the supply, which poses a direct health risk. The WHO guidelines mandate that the concentration of *E. coli* in potable water be 0 CFU/100 mL. Its presence is associated with diarrhoeal diseases (WHO, 2017). Although the 5% non-compliance is lower than Total Coliforms in the context of South Africa, it is critically important. This issue is similar to those that were observed in municipalities such as Hammanskraal in 2023, where cholera outbreaks were precipitated by E. coli contamination (DOH SA, 2023). Universal E. coli contamination underscores chronic faecal pollution in rivers, dams, and groundwater, with a result of exceeding limits by 100% in the environmental water. Pit latrine overflows in informal areas and insufficient wastewater treatment facilities (60 percent of which are dysfunctional in South Africa) exacerbate this issue (Green Drop Report, 2022).

Table 3.1: Total Coliforms and E. coli detected in both environmental and tap water samples.

		Too high in TAP	Too high in ENV
Four seasons	Total Coliforms	18%	100%

E. coli	5%	100% (75%)

3.1.2 Detection of other pathogens in water samples

Table 3.2 presents data on the detection *of Salmonella, Shigella*, and *Vibrio cholerae* (cholera) in tap water and environmental water samples.

3.1.2.1 Salmonella

We did not detect *Salmonella* in either potable water (n=40) or environmental water (n=12). Tap water is devoid of *Salmonella*, which is consistent with the elimination of enteric pathogens by effective municipal treatment procedures (e.g., chlorination, filtration) (WHO, 2017). In environmental water, the absence of detection may be indicative of low faecal contamination levels at sampling sites, seasonal fluctuations (e.g., reduced survivability in colder temperatures), or competition with another microbiota (Bain et al., 2014).

3.1.2.2 Shigella

Shigella was identified in environmental water at an 8% prevalence (n=12), but it was not present in potable water. The presence of *Shigella* in environmental water indicates that faecal contamination is likely the result of inadequate sanitation, sewage overflow, or agricultural discharge (Kotloff et al., 2018). The effectiveness of treatment systems in eliminating bacterial pathogens is underscored by the absence of these pathogens in potable water. Nevertheless, the 8% environmental prevalence poses a risk to communities that rely on untreated water for consumption or recreation.

3.1.2.3 Cholera (Vibrio cholerae)

V. cholerae was detected in environmental water at a 33% prevalence (n=12), but it was not present in potable water. The high detection rate of *V. cholerae* in environmental water is a cause for concern, as it is known to flourish in brackish or warm waters that contain organic nutrients (Ali et al., 2015). This is consistent with the downstream contamination of the Swartkops River, as indicated by previous data. The effectiveness of treatment in preventing waterborne outbreaks is further substantiated by the absence of cholera in tap water. Environmental reservoirs, however, continue to pose a public health hazard, particularly in areas with inadequate access to purified water (Lessler et al., 2018).

Table 3.2: Pathogens detected in water samples

	Salmonella	***Shigella***	**Cholera *(V. Cholerae)***
Tap Water (n=40)	-	-	-
Environmental Water (n=12)	-	**8%**	**33%**

3.1.3 Physicochemical properties

The data compares pH, electrical conductivity (EC), and total dissolved solids (TDS) between tap water and environmental water samples collected during winter (Wi) and spring (Sp) sampling rounds. **Table 3.3** shows the measured physicochemical properties.

3.1.3.1 pH

pH for tap water ranged from 6.67–7.77, within the acceptable WHO range (5–9.7) for drinking water. This neutral to slightly alkaline pH reflects effective municipal treatment, which often includes corrosion control to prevent pipe degradation (WHO, 2017). pH for environmental water showed higher alkalinity (7.67–9.15), still within the acceptable range but suggests natural or anthropogenic influences such as weathering of carbonate-rich geological formations (e.g., limestone) common in South Africa's Eastern Cape (DWS, 2020). Alkaline industrial effluents (e.g., textile or mining discharges) or nutrient runoff from agriculture, which can stimulate algal growth and elevate pH through photosynthesis (Oberholster et al., 2019).

Electrical Conductivity (EC)

EC values for tap water (17.3–65.6 mS/m) were well below the WHO threshold (≤170 mS/m), indicating low ion content due to treatment processes like reverse osmosis (WHO, 2017). EC for environmental water varied widely (34.5–1283 mS/m), with some samples exceeding the guideline (≤170 mS/m). High EC indicates natural sources such as geological weathering (e.g., salt deposits) or seawater intrusion in coastal areas like Kariega (DWA, 2018), or anthropogenic sources such as agricultural runoff (fertilizers), industrial effluents, or wastewater discharge. The extreme upper value (1283 mS/m) suggests severe contamination, likely from localized pollution hotspots (e.g., Swartkops River downstream near industrial zones) (Venter et al., 2020).

3.1.3.2 Total Dissolved Solids (TDS)

TDS for tap water (85–321 mg/L) were far below the limit (≤1200 mg/L), consistent with safe drinking water standards. TDS for environmental water ranged from 168–6305 mg/L, with the upper value (~6305 mg/L) drastically exceeding the guideline. High TDS correlates with elevated EC and implies that there are high concentrations of dissolved ions (e.g., salts, nitrates, heavy metals), potential contamination from urban runoff, mining activities, or untreated sewage. The extreme value (6305 mg/L) likely stems from mining tailings, untreated wastewater, or concentrated agricultural runoff (Okedeyi et al., 2014). Such levels pose risks to aquatic ecosystems and render water unfit for irrigation or domestic use without treatment (DWAF, 1996).

Table 3.3: Measured physicochemical properties.

Wi + Sp Rounds	pH (5 - 9.7)	Electrical Conductivity (≤170 mS/m)	Total Dissolved Solids (≤1200 mg/L)
Tap Water	6.67 - 7.77	17.3 – 65.6 mS/m	85 – 321 mg/L
Environmental Water	7,67 - 9.15	34.5 – 1283 mS/m	168 – 6305 mg/L

3.2 HEALTH DATA ANALYSIS

The critical public health challenges associated with environmental, occupational, and socio-economic factors in South Africa are reflected in the enumerated NMCs. The following information was emphasised as a result of the collection of monthly Notifiable Medical Conditions (NMC) Reports from February 2021 to January 2024. See figures **3.1-3.2.**

3.2.1 Cholera

Recurrent epidemics, such as the 2023 surge (1,200+ cases), are associated with inadequate sanitation and contaminated water sources (NICD, 2023). Health implications include elevated mortality rates in regions that are underserved and lack access to pure water. Oral rehydration therapy, sanitation, and potable water are prioritised in the WHO Guidelines (WHO, 2023). Contamination is further exacerbated by climate-driven inundation and inadequate wastewater treatment infrastructure (DWS, 2022).

3.2.2 Waterborne Illnesses (e.g., Typhoid, Cryptosporidiosis)

In South Africa, diarrhoeal diseases are responsible for approximately 10% of fatalities among children under the age of five (Stats SA, 2021). Implications for Public Health: Associated with the prevalence of faecal contamination in water, which is a problem in informal settlements. The World Health Organisation (WHO) recommends that universal access to adequately managed drinking water be encouraged (WHO, 2017). Nevertheless, only 83% of households in NMBM have access to essential waste collection services (NMBM-IWMP, 2016).

3.2.3 Bilharzia (Schistosomiasis)

This disease has a high prevalence rate, as evidenced by both national and provincial data. Bilharzia is endemic in the Eastern Cape, KwaZulu-Natal, and Limpopo, with an estimated 4 million cases annually (SA Health, 2020). Organ injury is a consequence of chronic infection, which is linked to exposure to freshwater. Snail habitat control and mass drug administration (praziquantel) (WHO, 2022). One of the challenges associated with bilharzia is the limited healthcare access in rural areas and the reliance on untreated surface water.

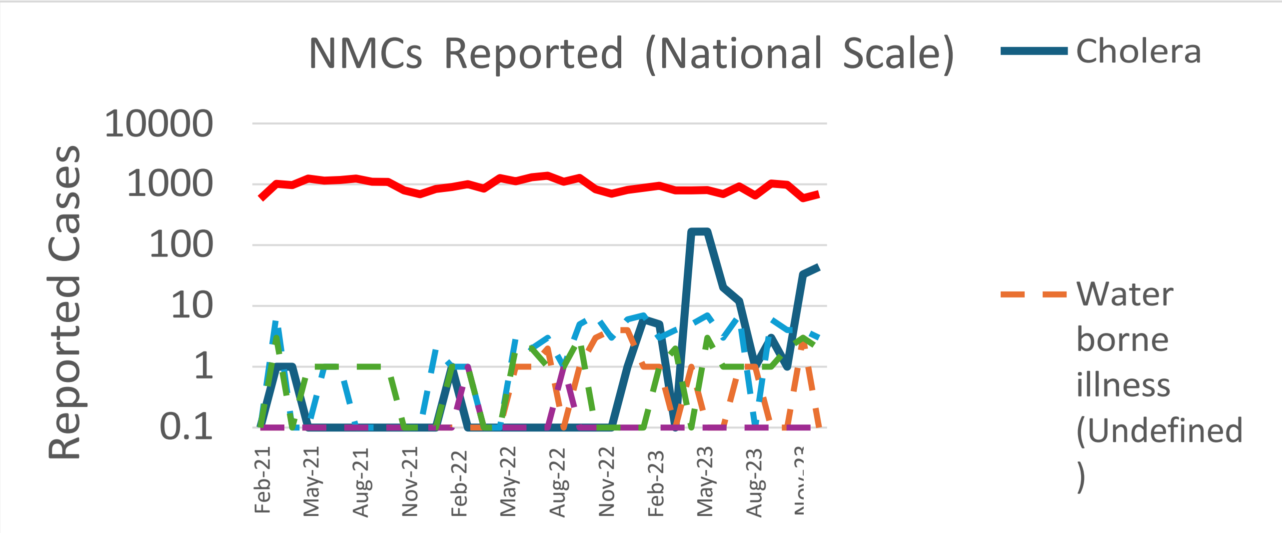

Figure 3.1: NMCs reported in South Africa (2021-2023)

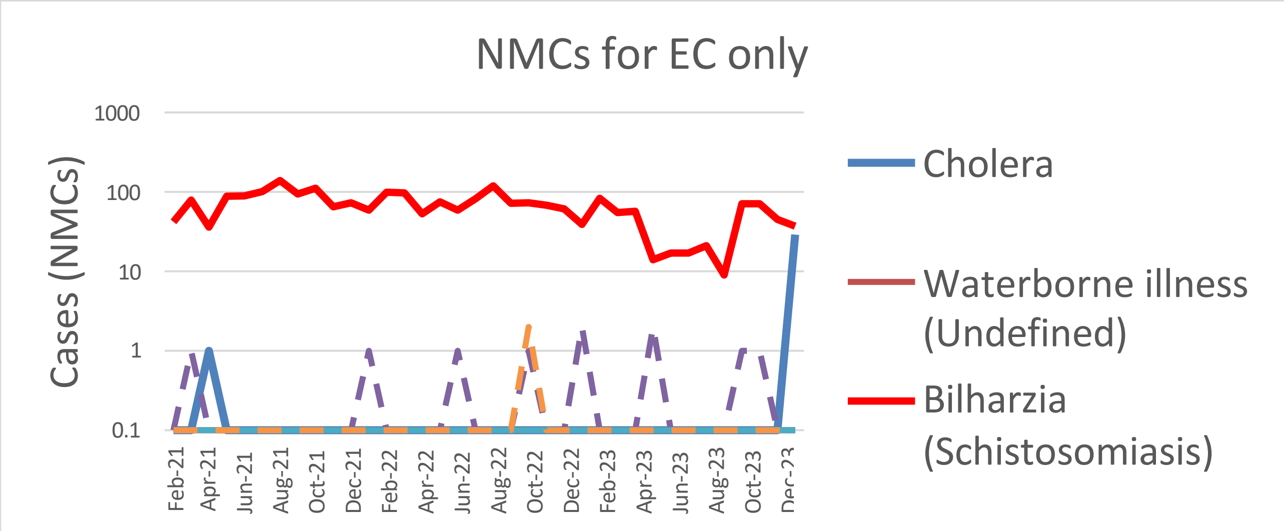

Figure 3.2: NMCs in Eastern Cape only

CONCLUSIONS & RECOMMENDATIONS

3.3 CONCLUSIONS

The study highlights the critical deficiencies in health surveillance and water quality management in Kariega. The urgent need for enhanced sanitation, targeted monitoring, and community education to mitigate waterborne disease risks is underscored by the detection of *Shigella* and *V. cholerae* in environmental water in Kariega, despite the fact that tap water remains safe. The resolution of these deficiencies is essential for the resilience of public health and is consistent with Sustainable Development Goal 6 (Clean Water and Sanitation). Although the safety standards for potable water in Kariega are met, the environmental water quality is compromised by the variable and frequently extreme EC/TDS levels, which are indicative of a substantial anthropogenic influence. Improved monitoring, community engagement, and targeted pollution management are necessary to address these issues in order to protect both public health and ecosystems. It is imperative to mitigate water-related health risks by implementing targeted infrastructure, interdisciplinary research, and enhanced data granularity. Additionally, the intersection of health inequities, infrastructure deficits, and environmental degradation is emphasised in South Africa's NMC profile. In order to alleviate the burden of these conditions and achieve Sustainable Development Goal 3 (Good Health and Well-being), it is imperative to prioritise WHO-aligned interventions in water quality, sanitation, and disease surveillance.

3.4 RECOMMENDATIONS

- **Improve Surveillance Systems**:
  - Encourage the implementation of health reporting at the district or municipal level to facilitate the development of localised analyses.
  - Provide diagnostic instruments (e.g., cholera rapid-test kits) and educate clinicians on NMC reporting protocols.
- **Targeted Interventions**:
  - In an effort to mitigate pathogen exposure, prioritise remediation of high-risk sites (e.g., the Swartkops River downstream).
  - Install water treatment infrastructure at communal faucets and recreational sites.
- **Research Priorities**:
  - Conduct longitudinal studies that establish a connection between water quality metrics and health data specific to Kariega.
  - Conduct interdisciplinary collaborations to investigate diseases that are not fully reported, such as mercury toxicity.
- **Policy and Capacity Building**:
  - Advocate for the allocation of funding to enhance the laboratory's capacity for pathogen detection.

    - Implement the integration of climate resilience planning into water security strategies, as suggested in postgraduate projects.

- **Pollution Source Identification**: Investigate hotspots (such as the Swartkops River downstream) to identify instances of illicit dumping or industrial discharges.

- **Enhanced Monitoring**:

    - Increase the scope of sampling to encompass heavy metals and specific ions (e.g., nitrates, chlorides) in order to identify the sources of contamination.

    - To evaluate pollutant dynamics, monitor seasonal trends (e.g., dry versus rainy seasons).

- **Public Health Measures**:

    - Provide information to communities that depend on environmental water regarding the hazards and treatment methods (e.g., filtration, boiling).

    - Ensure that warning signs are installed at recreational sites that pose a high risk, such as Jubilee Park Dam.

    - Create public awareness campaigns that emphasise the importance of safe water practices and the prevention of waterborne diseases.

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